

Proceedings of  
ISPS 2013



# Proceedings of the International Symposium on Performance Science 2013

Edited by

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## Preface and acknowledgments

ISPS 2013 marked the fourth International Symposium on Performance Science. The conference theme, *Performing Together*, encouraged submissions of original research examining collaborative performing activities of all types and between various constituents, and the 144 articles published in this volume show the full range and extent to which the international community of performance scientists responded to the call. The *Proceedings of ISPS 2013*, however, can only hint at the engaging interdisciplinary discussions and debates which took place during the symposium at the University of Music and Performing Arts Vienna, a clear sign of the health and vibrancy of this rapidly growing field.

We should like to thank several people without whose help and support ISPS 2013 could not have happened. First among them are the conference delegates and the authors who contributed their work to this volume. We would also like to acknowledge the generous support of our institutions, the University of Music and Performing Arts Vienna and the Royal College of Music. We thank the members of the Scientific Committee for their advice and guidance throughout the planning stages of the conference. Finally, we wish to acknowledge Lisa Aufegger, Eulalie Charland, Michaela Korte, Rosie Perkins, and George Waddell for their tireless work in editing and revising the proceedings manuscript, as well as our conference assistants who were integral to the preparation and delivery of a very full and dynamic program.

Aaron Williamon  
Werner Goebel



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# Scientific committee

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Wednesday  
28 August 2013



Keynote paper



# Dancers: Fit bodies?

**Emma Redding**

Department of Dance Science, Trinity Laban Conservatoire of Music and Dance, UK

Dancers view themselves as artists not athletes, and for this reason, the physiological development of the dancer's body is addressed to a lesser extent than the dancer's creative and artistic abilities. Dance training can no longer be as reflective of the physiological demands of the dance profession as it was decades ago because the norm for today's dancer is to work within more than one style for more than one choreographer. Although there has been a shift in recent years toward the physiological aspects of the dancer's body through the development of Somatics and Release-based techniques, research shows that dance training (e.g. class and rehearsal) is carried out at a lower intensity than performance—dance is highly skill oriented and requires much time in training for learning and reflection. Lastly, dance is an art form and certain body types appear to be more preferable than others from an aesthetic point of view, even though they may not be as durable from a physiological perspective. For these reasons, the question as to whether dancers are *fit for purpose* is both important and challenging. This article discusses the discrepancies between the changing physiological demands of dance and the current training and education of dancers. The historical developments of the body in dance training and performance are explored, as well as the research around dancers' fitness.

*Keywords:* dance; fitness; injury prevention; physiology; training

The demands placed on today's dancers are becoming greater and more diverse than ever before, and in order to respond to the diverse range of choreographic styles of dance, the twenty-first century dance artist is required to be a self-referencing, independent, versatile, collaborative, and creative individual (Bales and Nettle-Fiol 2008).

The historic location (in statutory education in England) of dance as a curriculum subject has been within Physical Education. However, dance

teachers in schools, and the National Dance Teachers Association have developed arguments for dance in the curriculum as artistic and creative engagement, rather than as physical activity per se. Since the 1990s, the reduction in hours dedicated to dance in the curriculum and other general curriculum-related issues have led to a strengthening of the arguments for curriculum dance experience to focus on the creative and imaginative development of the child. Gill Clarke supported this view at the Dance UK conference in 2008:

They are not machines, nor athletes—although extraordinary virtuosity might be one of their means of expression. They are imaginative artists. What we see in performance is not their physical bodies, but their “selves”—their imaginations and intentions and wills and desires in disciplined motion (Clarke 2008).

Historically, dancers trained in a technique to prepare for choreography that utilized that particular technique (e.g. Graham technique prepared dancers for Martha Graham choreography). Indeed, Foster (1997) claims that not only was the dancer trained exclusively for that technique but each choreographic work was designed exclusive of others. The cardiovascular requirements of choreographic work were met during the technical training and subsequent rehearsals of that work: the technique itself and the subsequent rehearsals prepared the dancer for the physiological energy demands of the performance. Today’s dancer cannot be so confident of the relationship between training and performance because dancers of today are required to work with a diverse variety of choreographic styles. The range of choreographic demands made upon contemporary dance artists (and indeed classical ballet dancers) makes it necessary to address dancers’ *fitness for purpose*. No longer does one dance technique serve one choreographer or choreographic genre. Therefore, there is a need to consider the general physiological development of the dancer who is likely to operate within a portfolio career profile, where s/he will work with many choreographers.

Foster (1997) reflects this in her concept of the “The hired body,” arguing that dancers hone their technical skills not for one particular choreographer but rather for any dance maker who chooses to work with them. In other words, “the body available for hire,” must have a range of technical skills and a capacity to respond to differing choreographic demands. “Dancers spend between two to six hours per day, six to seven days per week for eight to ten years creating the ‘dancing body’” (Foster 1997).

Possible negative connotations of Foster’s concept of the body for hire are far outweighed by the enhancing qualities embraced within the interrogation

of the physiological body that became the focus of the somatic approaches to dance training that emerged through the 1990s and onwards. Ownership and understanding of one's dancing body from within is what characterizes many of the artistic and technical developments in contemporary dance during this period.

From the 1990s onwards, then, the focus on the kinesthetic takes another direction in the development of release based-techniques which adopt a somatic approach to learning: these have emerged out of a concern for understanding the physiology of the body and its sensorimotor integration system, and the desire to learn how to learn from within the self.

Dance is a high skill based activity where tremendous demands are placed upon the dancer's body in terms of joint range of motion, coordination, and balance. Dancers' bodies are exposed to prolonged, complex, and cognitively-demanding movement tasks and required to jump, perform fast explosive movements, balance, and turn, at the same time giving due attention to flow, suspension, and many other qualities. Dancers are expected to be expressive through their bodies and, above all, communicate with an audience. In preparation for performance, dancers must be able to recall series' of intricate, complicated, and coordinated movement vocabulary and phrases. It is to be expected, then, that a significant part of dance training will be devoted to technical training. However, the specific focus within technical training is on skill acquisition rather than general physiological development even though an exercise physiologist commented in 1990 that: "Dancers are, in fact, among the supreme all-round athletes in our society, and as such are well worth a look at physiologically" (Sharp 1990).

As the exercise intensity of dance increases, one's ability to perform highly skill-based complex movement tasks decreases, and for this reason, a good level of fitness seems vital for dance advocating a greater emphasis on the physiological.

While the argument for dance as an art form appears to have been won, there is no denying the research over the last two decades which has examined the dancers' physiological body and the subsequent development of dance practice created out of that focus. The physical fitness status of professional and student dancers has been explored over the last two decades, for example with findings suggesting that dancers are not as fit as they should be (Chatfield *et al.* 1990, Cohen *et al.* 1982, Dahlstrom *et al.* 1996, Rimmer *et al.* 1994).

In order to consider whether dancers' bodies are really *fit for purpose*, however, it is obligatory to define the component of fitness. If by the term fitness, we mean flexibility, dancers bodies are indeed fit (Kadel *et al.* 2005).

However, if we take the view that dance calls upon the other components of physical fitness such as muscular strength and cardiorespiratory fitness, the outlook is possibly less bright. Dancers appear to be similar to non-endurance athletes at least in terms of their cardiorespiratory fitness (Chatfield *et al.* 1990; Cohen *et al.* 1982, Dahlstrom *et al.* 1996, Rimmer *et al.* 1994). Furthermore, there appears to be a discrepancy in the intensity level of class, rehearsal and performance, at least in classical ballet and modern dance, which partly explains dancers' lack of fitness—the training cannot meet the demands of the choreography (Wyon and Redding 2005). Muscular strength is another component of fitness which warrants consideration. While the demands of classical ballet involve the lower extremities, other dance genres such as contemporary and modern dance require good levels of upper body strength to perform floor work and complicated partner lifts (Ambegaonkar *et al.* 2012). It appears that dancers' upper body strength training is only now catching up with the new demands of modern dance choreography. This is a shift from the dance training of years ago which was developed out of the choreography itself.

The prevalence of injury is high compared with many other athletic populations (Laws 2005), and one of the biggest perceived causes of injury is *fatigue* followed by *difficult choreography*. Dancers should not only build rest into their training regimens but also undertake supplementary training as recommended by a number of studies (e.g. Brown *et al.* 2007, Angioi *et al.* 2012); however, it is often the case that new methods of training take a while to become the accepted norm. While it is unclear whether fitter dancers are better dancers, several strong attempts have been made to substantiate this link (Twitchett *et al.* 2011, Angioi *et al.* 2012). Evidence of such a link would certainly support grounds for supplementary fitness training for dancers. Regardless of whether a link exists, however, the onset of fatigue and subsequent detriments to performance are likely to be delayed among fitter dancers.

Dance is an art form and therefore certain body types appear to be more preferable than others from an aesthetic point of view even though they may not be as durable from a physiological perspective. Preliminary research has indicated that body types could be predictors of dance talent. In a survey conducted around teachers' perceptions of their students' career potential, students with longer legs measured through anthropometric tests were considered more likely to succeed (Redding *et al.* 2011). This generates debate around form versus function, particularly given that long legs are considered to be less dexterous for certain physical activities.



While one's skeletal structure such as limb length is mostly predetermined, one's fitness is influenced not only by genetics and gender but experience and training. Fitness is, therefore, a dynamic and trainable entity and dance educators face the challenge of providing an environment for training that facilitates optimal fitness development.

Dancers view themselves as artists, not athletes, even though the highly trained physical skills and movement vocabulary through which they communicate their ideas in choreographic work share much in common with those of athletes. There is a mismatch between what dance science knows and what dance does and the question as to whether dancers' bodies will ever be fully *fit for purpose* for the demands of a constantly changing profession is one which remains an unanswered and exciting enquiry.

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Symposium:  
Control of sequential movements  
in musical performance



# Neuronal mechanisms underlying early acquisition and action-monitoring of piano sequences

**María Herrojo Ruiz and Andrea A. Kühn**

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This paper focuses on the neuronal mechanisms underlying the acquisition and monitoring of piano sequences during learning and skilled performance. A brief introduction describes approaches for the analysis of cortical and subcortical neurophysiological signals in parallel with the evaluation of performance data. In addition, the results from two studies are presented. In the first, we have demonstrated in 20 healthy pianists and 6 pianists with musician's dystonia the cortical electrophysiological (EEG) mechanisms associated with error-monitoring during overlearned piano performance. In the second, we investigated the role of the human basal ganglia (BG) in the acquisition of novel piano sequences. Here, we used intracranial recordings in the internal globus pallidus, the main motor output structure of the BG, in 10 patients undergoing deep brain stimulation for dystonia while they practiced novel sequences of finger movements on a digital piano. The main outcomes were that the modulation of pallidal oscillatory activity reflected encoding of sequence boundaries, and this effect emerged with training corresponding with improvements in performance. The implications of our findings to understanding the pathophysiology of movement disorders and to music pedagogy and performance are discussed.

*Keywords:* sequence learning; movement disorders; neurophysiology; basal ganglia; error monitoring

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# Hand motor control in skilled and impaired piano playing

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This paper begins by introducing basic methods to record and analyze finger movements and muscular activity in musical performance and then focuses on the two primary issues in hand motor control: independent movement control and coarticulation (i.e. modulation of muscular activity depending on preceding and subsequent motor actions). Time-varying joint angles at fingers and finger muscular activities were recorded by using a data-glove and surface electromyography, respectively, in expert pianists, amateur pianists, and pianists with focal dystonia. The individuated finger movements were maintained across different tempi for healthy pianists but not for pianists with focal dystonia, indicating loss of independent control of fingers in the patients. Finger muscular activity of healthy pianists displayed modulation in response to the upcoming and following key press, indicating forward and backward coarticulation. A prominent difference between the experts and amateurs was evident in the duration of muscular burst, which was narrower for more skilled pianists. In sum, individuated finger movements and coarticulation play roles in accurate and efficient piano performance. Modulation of these motor skills by learning and focal dystonia not only provides information on optimal piano technique and pedagogy but also enables accurate diagnosis of movement disorders caused by piano practice.

*Keywords:* fine motor control; focal dystonia; electromyography; multivariate analysis; synergy

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# Using motion capture analysis to characterize skilled cello bowing

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Stringed instrument bowing is a complex skill in which precise movement of the bow is achieved by specific coordination of the degrees of freedom of the right arm. We introduce and apply 3D motion capture methods to analyze two aspects of skilled cello bowing: (1) How are important task variables stabilized during movements? (2) How do expert cellists achieve fast and precise bow reversals? Ten expert cellists and age-matched novices performed repeated continuous (legato) bowing movements. Performance measures included mean and variability of task variables (e.g. bowing angle), range of motion and correlation patterns of joint angles, and velocity and acceleration profiles of bow and arms. During bow movements experts showed more accurate control of task variables and a more distributed coordination, whereas novices mainly used proximal joints. Additionally, experts exhibited more pronounced acceleration patterns at bow reversals, which were characterized by a proximal-distal gradient with earlier and lower-amplitude acceleration peaks at more proximal joints. Expert cellists' performance is based on flexible use and coordination of degrees of freedom. The particular coordination pattern at bow reversals may allow generating high accelerations at the end effector while reducing the required joint torques at the proximal joints.

*Keywords:* stringed instrument bowing; motion capture; movement coordination; timing; degrees of freedom

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Thematic session:  
Performance education I



# Theory and practice: A case study of how Schenkerian analysis shaped the learning of Chopin's *Barcarolle*

**Roger Chaffin<sup>1</sup>, Cristina Caparelli Gerling<sup>2</sup>,  
Alexander Demos<sup>1</sup>, and Andrea Melms<sup>1</sup>**

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When confronted by a problem, experts in many fields begin by looking at the “big picture”. Experienced musicians do the same when learning a new piece, first forming a “musical image” of the whole piece. What happens when the composer has cleverly obscured the big picture? To find out, we recorded the practice of an experienced pianist and music theorist as she learned Chopin's *Barcarolle* for the first time and then gave ten public performances. Initially, the pianist felt that her practice did not progress and she discontinued work at the piano to undertake a detailed Schenkerian analysis before continuing. Places that the pianist identified as important in the Schenkerian structure she also used as starting places during practice. The effect was present in the initial practice sessions, before the analysis, and later during preparation for public performance. The effect was not present immediately after the analysis while the pianist learned and memorized the piece, when starting places were mainly determined by fingering issues. The big picture shaped practice during the pianist's initial efforts to understand the piece and again during her preparation for performance.

*Keywords:* performance; performance cues; Schenkerian analysis; practice

Experienced concert soloists use the musical structure of a piece to organize both their practice and their memory. Knowing that memory failure is always a possibility in live performance, they prepare a safety net: a mental map based on the musical structure that allows them to keep track of where they are and provides landmarks reminding them of what to do next. These *per-*

*formance cues* (PCs) are prepared during practice so that they come to mind automatically, ensuring that the performance unfolds as planned.

The development of PCs has been observed in a small number of longitudinal case studies involving pieces in which the musical structure was relatively clear-cut by J. S. Bach, Debussy, and Stravinsky (Chaffin 2007, Chaffin *et al.* 2002, Chaffin *et al.* 2010, Ginsborg and Chaffin 2011). Here, we describe the development of a pianist's mental map for a piece whose musical structure was much more challenging to identify even for the pianist involved (the second author), who is a theorist as well as a performer. Chopin's *Barcarolle Op. 60* is a masterpiece of structural resourcefulness that constantly surprises the listener with its beguiling harmonic and melodic patterns. How does a performer approach a piece whose complexity requires meticulous probing and exploration, in which structural landmarks are disguised or obscured?

The pianist kept a record of her practice and performances over a four-year period as she learned the Barcarolle for the first time and gave ten public performances. She recorded approximately 20 hours of practice at the beginning and end of this time-period. We transcribed the practice and compared the locations that the pianist used as starting places with the locations of the PCs that she reported using in her performances. We expected that, as in the previous longitudinal studies of PC development, the pianist's starting places would reflect her understanding of the musical structure and show how she established the PCs that she reported.

We were interested to see how the unusual structural complexity of the Barcarolle affected this process. In previous longitudinal studies the musical structure was relatively transparent to the highly trained musicians involved. From the start, they used the structure to organize their practice, starting and stopping at section boundaries. How would the pianist organize her practice of a piece whose musical structure was harder to discern?

## METHOD

### Participants

The pianist, the second author of this paper, was trained in classical piano and in music theory in Brazil and the USA. She is Professor of Music at the Federal University of Rio Grande do Sul, in Brazil where she performs regularly both as a soloist and as a chamber musician.

## Materials

The pianist selected Frédéric Chopin's *Barcarolle Op. 60* for the study because she saw it as an opportunity to learn a staple of the piano repertoire that she had never played before. The piece is one of Chopin's last and greatest works, capturing the essence of his pianism, profound knowledge of counterpoint, and reflecting his admiration of J. S. Bach. In this work, his treatment of dissonance achieved new heights of sophistication and expressive power. The *Barcarolle* was one of the works that Chopin chose for his last recital in Paris in 1848, shortly before his death. Notated in 116 bars in 12:8 time, the *Barcarolle* takes approximately 8.5 minutes to perform.

## Procedure

The pianist learned the *Barcarolle* and gave ten public performances over a four-year period, recording more than 20 hours of her practice during three periods (see Table 1). During periods when she did not record her practice she kept a log of her activities. The first practice period consisted of 3.5 hours of practice in four sessions in March 2008, after which the pianist interrupted her work at the piano to develop her own Schenkerian analysis. When she resumed practice eight months later in February 2009, she made much better progress and scheduled the first public performance for the following year. She recorded a third period of practice as she prepared for a series of performances in the laboratory in September to November 2012. We transcribed the practice by recording the location of each start and stop.

Table 1. Time-course of activities and PC reports showing duration of practice recorded.

<i>Time period</i>	<i>Activity</i>	<i>PC reports</i>	<i>Dates</i>	<i>Duration recorded practice</i>
1	Practice sessions 1-4	-	2008 March	3:31:00
2	Schenkerian analysis	-	2008 June-Aug.	-
3	Practice sessions 5-18	-	2009 Feb.	13:49:00
4	Practice sessions 19-43	1-4	2010 Jan.-Feb.	-
5	Public performances 1-6	5	2010 Feb. – 2011 Feb.	-
6	Practice sessions 44-49	-	2012 Sept.-Nov.	3:00:00
7	Lab performances	6-7	2012 Jan.-May	-
8	Public performances 8-10	8	2012 April-Aug.	-

The pianist reported the PCs she used during performance on eight occasions, marking them on copies of the score shortly after performances to indicate features of the music she had paid attention to as she played. She made the first four reports after practice performances during the six weeks before the first public performance, the fifth report after the first public performance, and the last report after the final (tenth) public performance more than 2.5 years later. During the final months of the study she also provided a *standard* report of the PCs that she generally attended to and a report of the *Schenkerian structure* in which she located musical transitions and rated them on a 1-4 scale with 1 representing the most important. Other PC reports also identified transitions in the same Schenkerian structure but were not classified in terms of level of importance.

The pianist labeled each feature that she marked to indicate the aspect of the music involved, using varying numbers of labels in different reports (range=2-8; mode=6). The labels were: section, subsection, Schenker, Schenker-level 1-4, switch, dynamics, heightening, tempo change, and fingering.

We examined the relationship between PC reports and starts using stepwise multiple regression analyses. We performed separate analyses for each time period (2008, 2009, and 2012). The dependent variable in each case was the number of starts per bar. The predictor variables were the various types of PC identified in the eight reports with presence and absence of PCs in each bar dummy coded as 0 or 1. The same predictors were used in each analysis.

## RESULTS

The pianist's initial work on the piece took place during four long practice sessions in 2008, totaling 3.5 hours. During these sessions she started most frequently in bars where she later reported PCs based on her Schenkerian analysis (see Table 2). She also started more frequently in bars where she later reported PCs for fingering.

After undertaking the Schenkerian analysis, which took two months, the pianist set the piece aside for six months. When she resumed work she learned and memorized the piece in 13 sessions, each averaging approximately an hour in length. During this second practice period the effects of fingering PCs on practice seen in the first period continued, i.e. the pianist continued to start in bars containing fingering PCs. The effects of Schenkerian structure, on the other hand, disappeared. The analysis appeared to have resolved the issues that had previously motivated her starts at structural turning points, leaving her free to focus more on technical and pianistic issues.



Table 2. Summary of significant effects of PCs for expression and technique on frequency of starts during practice during three time periods.

<i>PC type and Report no.</i>	<i>Practice period</i>		
	<i>2008</i>	<i>2009</i>	<i>2012</i>
<i>Expression</i>			
Schenkerian (6)	89.07**	-	-
Schenker level 4 (7)	18.81*	-	-
Harmonic descent (4)	-	-	24.79*
<i>Basic Technique</i>			
Fingering (3)	-	85.70***	-
Fingering (4)	37.28*	86.61***	-
Fingering & misc. (5)	36.31*	44.10*	-

Note. \*p<0.05, \*\*p<0.01, \*\*\*p<0.001

Three years later, when the pianist next recorded her practice, the effect of the Schenkerian structure reappeared. The pianist labeled these PCs “harmonic descent,” referring to the series of harmonic descents that bring the piece back to the F# tonic in measure 113. At this point the pianist had already given six public performances. She was secure in her technique and no longer needed to start at PCs for fingering. Instead, she was thinking in terms of the tonal and harmonic trajectory of the music, working to do justice to the complexity and subtlety of Chopin’s design.

## DISCUSSION

The pianist solved the problem of learning a structurally opaque piece by interrupting practice to complete a Schenkerian analysis. Trained as a music theorist, this was her solution when she found that working at the keyboard did not produce the kind of progress to which she was accustomed. Like experts in other fields she approached the problem of learning the *Barcarolle* by first developing a clear idea of the “big picture” (Chaffin *et al.* 2002, Glaser and Chi 1988) and developing a “musical image” of the piece (Neuhaus 1973, p. 17). When she was unable to do this at the keyboard, analysis provided another route.

The pianist tried to understand the big picture from the beginning. This is why she used transitions in the Schenkerian structure as starting places in the initial practice sessions, even before beginning the analysis. Interestingly, once the analysis was completed, the effect disappeared while she learned and memorized the piece. The effects of Schenkerian structure on practice did not reappear until the final practice period, as she prepared for performance.

The strategy of looking first at the big picture is characteristic of expert problem-solving in many fields, from mathematics to chess to radiology. When experts are unable to see the big picture immediately they take time to explore the problem before trying to solve it. Novices, in contrast, plunge into the details without a clear idea of where they are going (Glaser and Chi 1988). As a result, their understanding of the problem is more superficial and their problem-solving efforts less effective. In our study, the pianist intuitively followed the strategy used by experts, although she was not, at the time, aware of these parallels between music practice and expert problem-solving.

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# Error tolerance and error prevention in music performance: Risk- versus error management

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Dealing with errors is a key aspect of music practice, teaching, and performance. Musicians at all levels develop strategies for avoiding errors. Research in pedagogy, psychology, and neuroscience shows that errors can provide useful information for the learning process. But many music teachers aim for errorless learning, focusing on unilateral error control rather than learning through errors. The pursuit of obsessive perfection can block learning processes and development of performance skills. We see a deficit in systematic teaching and learning strategies for dealing with errors when performing and practicing music. Research in instrumental pedagogy has also neglected error issues. We need a “culture of errors” that balances error tolerance (while learning) against error prevention (while performing), and distinguishes risk management (prior to the error) from error management (during and after the error). We advocate approaching performance errors in constructive, creative, differentiated ways. A new theoretical framework could provide orientation for music education at all levels. In an interdisciplinary approach, ideas, data, and practical strategies from other disciplines, such as aviation, have been applied to the training of musicians.

*Keywords:* errors; performance; learning; expertise development; instrumental pedagogy

Musicians at all levels of proficiency and across the whole lifespan must deal with errors and develop strategies for avoiding them. Live music performances are rarely perfect, and imperfections often cause considerable chagrin. Beginners’ errors tend to be obvious and easily detected; as skill levels increase, the errors become less frequent and more subtle, and mostly go unnoticed by the audience (e.g. Flossmann *et al.* 2011).

Research in general pedagogy (Oser and Spychiger 2005) shows that the productive and creative potential of errors is underused. In educational contexts, errors may be accepted as unavoidable incidents, but generally they are not considered to be helpful and so are not even categorized in educational discourse (Weingardt 2004). In learning situations, where errors are supposed to be informative and positive learning opportunities, students merely avoid errors. This can also be observed in instrumental education. Musicians still have a generally negative attitude towards errors (Kruse-Weber 2012).

### **MAIN CONTRIBUTION: APPLYING CONCEPTS OF ERROR AND RISK MANAGEMENT IN INSTRUMENTAL MUSIC EDUCATION**

Higher-risk disciplines, such as aviation and medicine, have developed risk and error management training that aims to prevent errors and minimize their consequences when they occur. In an interdisciplinary approach, ideas, empirical data, and practical strategies from these disciplines have been applied to the training of musicians. Finally, recent studies in psychology and neuroscience have shown that error management training and learning situations, in which students are free to make errors, ultimately lead to better performances than more conventional approaches in which errors are simply avoided (Badke-Schaub *et al.* 2008, Keith and Frese 2005, Kornell *et al.* 2009, Spitzer 2008, Zapf *et al.* 1999). In this paper, we argue for error-friendly learning and teaching to raise awareness for error tolerance in musical practice.

### **Theoretical background**

In pedagogy, a paradigm shift has taken place from a behaviorist approach in teaching and learning processes to a more reflective didactic. This shift is reflected in attitudes towards errors (Kruse-Weber 2012). When appraising performance, errors are negative and should be avoided; they suggest that something is missing. But in a constructivist perspective, errors are useful and positive sources of information for further learning (Spychiger 2006). A constructive approach to errors incorporates informative feedback and error correction during the learning progress (Ericsson *et al.* 1993). This paradigm shift is not defined clearly in instrumental pedagogy. Here, errors are mostly still equated with failure, shame, and fear. Learning and performing situations during a lesson are not distinguished sufficiently; support and evaluation are not created transparently enough. There is a tendency to focus on unilateral error control rather than learning from errors (Kruse-Weber 2012).

Novices and experts approach errors differently. Novices may ignore errors and keep playing. Instead, experts tend to creatively set goals, exploring and experimenting with musical parameters and techniques. They extend the range of solutions beyond normal limits. They monitor their progress and lapses in concentration and motivation in a self-supportive way, and develop a positive and relaxed attitude to errors. Research (Zapf *et al.* 1999, Flossmann *et al.* 2011) confirms that expertise does not generally lead to a reduction of errors; instead, errors are managed and corrected faster and more easily.

Table 1 presents a model of stages of expertise in dealing with errors. According to this model, we have three stages which are error-friendly. Only procedural learning is primarily oriented toward error avoidance. In the declarative learning process, errors play an important role; teachers should give orientation and informative feedback. The creative stage is characterized by exploring new ideas, balances, tempos, sounds, and so on.

The role of errors in music performance is—in specific points—comparable with the role of errors in higher-risk disciplines such as aviation and medicine. Both cases refer to dynamic complex systems in which large amounts of data are quickly processed. Both involve psychological distress in response to errors or the threat of errors. Like errors in aviation or medicine, errors in musical performances or competitions can have specific, irreversible consequences.

The terms “risk management” and “error management” are used in industrial and organizational psychology. Risk management occurs prior to a potential error, and involves anticipating errors and associated disruptions. Error management occurs during and after an error; it includes risk management and is promoted by flexibility and an emotionally relaxed attitude toward errors. The main aim is not to avoid the error, but to avoid its negative consequences, and to resolve errors easily, quickly, and without stress (Zapf *et al.* 1999).

*Table 1.* Stages to expertise in terms of handling errors; modified after Mornell (2009).

<i>Stage of practice</i>	<i>Dealing with errors</i>
Exploration/deliberate play	No immediate correction of errors. Errors tolerated.
Declarative learning	Errors give information. Errors tolerated.
Procedural learning	Acquisition of error management. Errors avoided.
Creative practice	Inventions and innovations. Errors tolerated.

### *Error management*

Error management involves error tolerance, which in turn involves being prepared for disruptive events and adverse developments. It includes dealing with disturbances in a differentiated manner, so the initial goals are not significantly compromised (Weingardt 2004). In computer studies by Keith and Frese (2005), participants received instructions that emphasized the positive function of errors, and were encouraged to make errors and learn from them. The authors demonstrated that error management training (EMT) encourages self-regulation, emotion control, and metacognition. In EMT students reflect on the causes of errors and develop an emotionally relaxed attitude towards them, which improves learning. The positive effect of EMT is enhanced by additional metacognitive instructions which lead to a better adaptive transfer. Keith and Frese distinguished two major verbal categories: metacognitive (e.g. “if I do this here, I should be able to do that there”) and task-oriented statements (e.g. “now I do this, then this...that’s because I did this...;” Keith and Frese 2005, pp. 681-682).

### *Risk management*

A pilot who has experienced critical situations in a flight simulator and therefore is familiar with consequences of errors, such as poor decisions or incorrect responses, has trained and internalized reactions to errors that may happen in a future emergency (e.g. Oser *et al.* 1999). If trained only under ideal circumstances, such as flying in good weather (or a pianist playing on a brilliant instrument), there is a risk of the “Rumpelstilzchen Effekt:” potential problems or errors are not taken seriously or are overlooked. The musician is surprised about disturbances during a performance (e.g. Fuchs 2008).

## **IMPLICATIONS**

By only focusing on achieving the most precise interpretation of the score, instead of additionally exploring sounds and colors, a performance might lose individual expression. An exaggerated focus on avoiding errors may lead to the “true-false syndrome” (Mantel 2003, p. 56): if an error occurs that lies beyond the performer’s experience and expectations, there is a risk that the musician will not know how to react (see Figure 1, left). The integration of systematic error management into deliberate practice can be a useful complementary strategy to prevent errors (see Figure 1, right). The error lies within the anticipated range of possibilities. An extended number of solutions allows for musicians to manage and amend errors faster and more easily. By

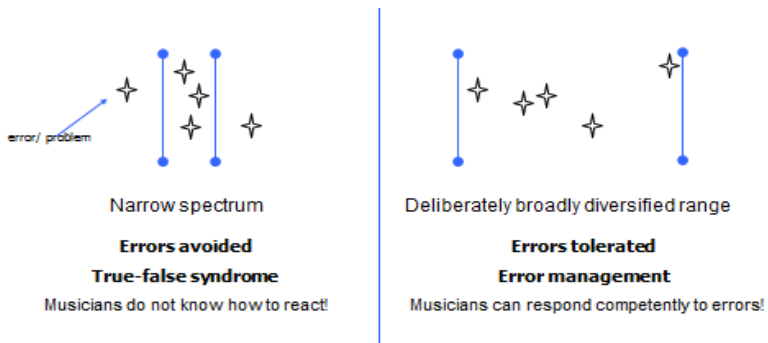


Figure 1. Extension of the range of solutions (Kruse-Weber 2012). (See full color version at [www.performancescience.org](http://www.performancescience.org).)

promoting an anxiety-free approach to error analysis, a positive error climate is created.

This theoretical study has demonstrated a need to revise responses to errors in instrumental pedagogy. We need a shift of focus—away from the familiar negative connotation of errors and strict avoidance of errors, and toward exploration and positive experiences of error in an error-friendly teaching and learning environment.

Research in other disciplines demonstrates that exploration of positive experiences with errors in error-friendly working conditions can promote successful learning and performing. An error-positive climate is created not by accepting errors, but by shifting the emphasis to error correction. In risk management, errors are anticipated and responses to them are trained; realistic expectations about errors tend to prevent errors from occurring. In EMT, challenging tasks are achieved by developing metacognitive skills to promote self-regulation and adaptive transfer.

Strategies in higher-risk disciplines show that risk and error management training can help to develop the ability to react appropriately and sensitively to errors. Training of this kind improves attention and awareness of performance traps and explicit knowledge of sensitive, performance-related factors. Developing a repertoire of diverse strategies for dealing constructively with errors should be an important objective for any music practitioner.

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# Feedback on elements of piano performance: Two case studies in higher education studio

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Feedback is a crucial component in the change and potential in individual performance. Feedback is both intrapersonal, which happens inside the individual, and interpersonal, such as when it is provided by a teacher or by an additional technology. Types of teacher feedback which are commonly reported in the instrumental learning and teaching literature are verbal and non-verbal. Technology-based feedback can also be accessed, such as by using a metronome, audio- or video-recording, both in real-time and after the event. Elements of piano performance that have been addressed in research include comments of an expert pianist during the learning process for a new piece, piano performance assessment, and analysis of expert piano performances. Two case studies in different higher education level piano lessons were undertaken. Two student pianists and one piano teacher participated in the study. Two approaches were used for the data collection: video observation and a questionnaire. An analysis involved relating the most observed elements of piano performance to the type of teacher feedback. This was then compared with the students' individual perspectives and the teacher's views on the same student, relating to the most difficult elements of piano performance learning and teaching.

*Keywords:* feedback; piano; learning; teaching; performance

Feedback, whether intrapersonal or interpersonal, is a crucial component in the change and potential in individual performance. In this sense, feedback can enable learning, such as for music learning (Welch 1985), and for piano performance learning. Feedback is both intrapersonal, which happens inside the individual, and interpersonal, such as when it is provided by a teacher or additional technology. The types of teacher feedback which are commonly reported in instrumental learning and teaching literature are verbal and non-

verbal. Several studies have reported types of teacher verbal feedback in instrumental and vocal learning and teaching by: (1) giving directions, (2) asking questions, (3) providing information, (4) giving verbal feedback (positive, negative, or neutral), (5) writing on the score, and (6) off-task comments (e.g. Benson and Fung 2005, Burwell 2010, Siebenaler 1997, Speer 1994, Welch *et al.* 2005). The same studies have also addressed teacher non-verbal feedback by: (1) playing alongside the student, (2) modeling (playing, or singing), (3) imitating student's performance, (4) making hand gestures, (5) giving non-verbal feedback (smiling, laughing, nodding, shaking, facial expression), and (6) conducting or tapping the pulse. Technology-based feedback can also be accessed, such as by using a metronome, audio- or video-recording, both in real-time and after the event.

In piano learning, teacher feedback is customarily provided in order to inform students about what can be improved in their playing (whether in technique or interpretation). Elements of piano performance that have been addressed in research include: comments of an expert pianist during the learning process for a new piece (Chaffin and Imreh 2002), piano performance assessment by adjudicators (Thompson *et al.* 1998, Thompson and Williamon 2003), and analysis of expert piano performance by using technology (Bresin and Battel 2000, Keithley 2004, Palmer 1988, Repp 1996). From this literature, a list of 15 elements of piano performance emerged: fingering, phrasing, dynamics, timing, pedaling, interpretation, emotional expression, rubato, melodic accuracy, rhythm accuracy, articulation, tone quality, musical structure, style, and overall flow.

Although several studies have investigated teacher feedback in piano studios, there is not much research on elements of piano performance which are related to them in higher education settings. The intention of this study is to compare and contrast the nature of feedback from one piano teacher working with two individual students, to investigate the most observed elements of piano performance during the lesson, and to capture the teacher's and students' views on the most difficult elements of piano learning through a post-hoc questionnaire. The focus is on understanding the match between the teacher's and student's perceptions and the observed data.

## METHOD

### Participants

Two higher education level principal study pianists and their piano teacher participated in this study.

## Materials

The materials for this study consisted of a digital movie camera, SANYO Xacti Model VPC-CA 65 EX, and a pilot ranking questionnaire (7-point scale).

## Procedure

Two approaches were used for the data collection: video observation of the lessons and a post-hoc questionnaire. Teacher and students' types of feedback during the lessons were captured by a digital camera. Students' views and teacher's perspectives on the same student for the most difficult elements of piano performance were gathered on a 7-point scale ranking questionnaire after each lesson finished. The observed piano lessons happened one week before the students' exams. Student A (Year 2 of study) performed two movements of a Romantic concerto while student B (Year 1 of study) played four solo piano pieces. The video recordings were transcribed and coded by using Nvivo10. A micro analysis of teacher feedback involved the coding elements of piano performance for both verbal and non-verbal feedback, and the elements of piano performance related to them.

## RESULTS

Teacher feedback in higher education level piano learning and teaching is both verbal and non-verbal and coincides with the literature on feedback in instrumental and vocal learning and teaching. Observed time for actual piano playing was greater in Lesson A (53%) than in Lesson B (38%), which might be related to each student's repertoire. Teacher verbal feedback was predominantly by providing information (14-16%) and by giving directions (12-14%), rather than by asking questions (5-10%) and giving feedback (5-10%) on piano performance timing, musical structure, interpretation, technique, dynamics, and rubato (see Table 1). Teacher non-verbal feedback was delivered by conducting, singing along with student's performance, modeling (singing, playing, or making a rhythmic sound), making the "sh" sound, and tapping the pulse or snapping the fingers, and appeared to be related to piano performance phrasing, rhythmic accuracy, dynamics, and timing. Technology-based feedback was also observed in Lesson A by using a metronome (6.70%). Feedback was delivered mostly on the following elements of piano performance: timing (26.16%), musical structure (16.08%), dynamics (8.05%), and technique (5.29%) for Lesson A, and musical structure (23.58%), timing (23.27%), interpretation (7.91%), technique (7.54%), and

*Table 1.* Feedback on elements of piano performance and their respective type of teacher verbal feedback for Lessons A and B.

<i>Elements of piano performance</i>	<i>Teacher verbal feedback</i>	<i>Examples for Lessons A and B</i>
Musical structure	Asking questions	How are we going to get a relationship between this and that? (B)
Timing	Asking questions	Could you tell me where the discrepancies are with the tempo? (B)
Timing	Providing information	We need to look at the tempo of that agrees with this. (A)
Interpretation	Providing information	It might take longer before they (the listeners) feel that they know what you want to do with this piece. (B)
Technique	Giving directions	Do that beautifully three times...then this, and then this. You do that every time you practice, and then within a few days you'll wonder what the problem was. (A) I'd say the faster you can do it tidily, the better. (B)
Dynamics	Giving directions	"Warmer", "louder", "pianissimo." (A)
Dynamics	Providing information	I think in Debussy, if you can be utterly precise with your dynamic marks, it really makes a difference, maybe more with Debussy than with any other composer. (B)

dynamics (5.11%) for Lesson B. Although technique was not included in the ranking questionnaire, it was highly observed in both lessons.

The data from the ranking questionnaire of piano learning difficulty priority suggested that the students' and the teacher's perspectives on the most difficult elements in piano performance did not appear to coincide (see Table 2). Although the most difficult elements of piano learning did not seem to be worked in each lesson, in Lesson A most of them were observed (timing, musical structure, and dynamics), apart from articulation and fingering. On the other hand, in Lesson B, there was not only a discrepancy between student's and teacher's perspectives on the most difficult elements, but also none of them was worked in the lesson, apart from dynamics.

*Table 2.* Student's individual perspectives *versus* teacher's views on the same student on the most difficult elements of piano performance, using a ranking questionnaire with 15 elements of piano performance. The ranked scores are demonstrated in parentheses, where 7 is the most difficult element of piano performance.

<i>Individual perspective</i>	<i>Teacher's view</i>
<i>Student A</i>	<i>On student A</i>
Dynamics (5)	Timing (5)
	Articulation (5)
	Fingering (5)
	Musical Structure (5)
<i>Student B</i>	<i>On student B</i>
Fingering (7)	Phrasing (5)
Pedaling (6)	Rubato (5)
Dynamics (5)	
Tone quality (5)	
Style (5)	

## DISCUSSION

Types of teacher feedback in these two higher education level piano lessons were mostly on piano performance timing, musical structure, dynamics, and technique. This finding might be related to the timing of the observed lessons (close to exams) or to a teaching pattern. There seems to have been a dissonance between: (1) teacher's and students' perceptions on their learning priorities and (2) the perceived purposes by teacher and student and the observed data by the researcher. Findings of this study are not generalizable as they are limited to only two case studies. However, they raise useful questions for subsequent research. The intention is to undertake more case study research in order to (1) clarify which elements are likely to present the greatest learning difficulty for a particular higher education piano student and (2) explore how technology might be used to (i) provide greater support for learning and (ii) reduce any differences in perceptions of learning need between students and teachers.

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**Thematic session:  
Perspectives on performance**





# Managing social interactions: Psychological skills of excellent dancers

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This study analyzed the psychological skills and processes of excellent dancers in managing social interactions and the emotional demands of performing together. Four contemporary dancers, aged 23-42 years, were nominated by a panel of experts for revealing excellence and agreed to participate in semi-structured interviews. An interview guide was created to explore the personal and social factors in the pathway to excellence. For the purpose of this study, psychological strategies and skills were analyzed, especially those related to performing together. Text coding and analysis was assisted by the computer software MAXQDA. Results demonstrated the importance of setting common goals and the ability to adapt to challenges and cope with others' behaviors and emotions to ensure balanced teamwork. Participants described several strategies to cope with the social and emotional demands of performing dance, including anticipating situations, task focus, self-control, positive self-talk, confidence, and imagery. Results suggested the importance of psychological skills to performing together. Further research is needed to develop new insights into the specific strategies dancers use to manage social interactions and cope with the emotional intensity of performing dance.

*Keywords:* dance; excellence; peers; coping; emotions

Performing artists are distinguished by their use of interpretive skills, act in a social context, and are usually members of a team. Thus, they are dependent on others to obtain a successful performance (Kogan 2002). Individuals are required to demonstrate effective psychological skills in order to achieve high levels of performance and manage emotional and social demands during the creative process of performing (Macnamara 2011). Research on performing

artists has focused mainly on the study of the individual factors regarding performance, talent identification, and development (Krasnow and Kabanni 1999, Walker *et al.* 2010). Personality characteristics of dancers and psychological factors associated with physical and physiological factors in dance have been investigated (e.g. Solomon *et al.* 2001) but little is known concerning the strategies dancers use to manage social interactions in performing together. Dancers are also studied as an “artistic object”, and several studies focus on the physical condition of the body and the implications of training, injuries, and eating disorders on the body and dance practice (e.g. Koutedakis and Jamurtas 2004, Noh *et al.* 2007). As for interpersonal factors, research demonstrates the role of parents, competitive peers, and masters in sustaining persistence and focus, as well as the impact of a motivational climate on dancers’ perceptions of competence (Walker *et al.* 2010, Queded and Duda 2009). Interpersonal factors play an important role in achieving high level performance, but research on dance has seldom explored the personal and interpersonal requirements to performing together. In addition, studies on the psychological qualities of excellent dancers are needed to gain a deeper knowledge of the psychological skills for performing excellence. Therefore, the aim of this study was to investigate the insider’s perspective on excellence in dance. In particular, psychological skills and strategies were analyzed, such as the coping strategies dancers use to manage the social interactions and emotional demands of performing together.

## METHOD

### Participants

Four outstanding contemporary dancers (two male, two female, aged 23-42 years) were nominated by a panel of experts for revealing excellence and agreed to participate in semi-structured interviews. They worked at dance companies and in national, international, and independent projects.

### Materials

An interview guide was created after reviewing guides previously used in studies with exceptional individuals, allowing us to identify the main topics that would allow an in-depth exploration of the process of developing and acquiring excellence (Sosniak 2006). Personal and social factors in the pathway to excellence were explored, such as the participants’ educational and professional paths, personal characteristics, and social interactions and net-

works. For the purpose of this study, psychological strategies and skills in performing were analyzed, especially when performing with others.

### **Procedure**

Participants were selected for displaying excellence in performance and being actively engaged in their professional area through a nomination strategy by a panel of experts. Additional quantitative criteria were considered, including awards, participation in international/European dance companies/projects, and professional certification. After expression of interest, interviews were scheduled according to the participants' convenience. Interviews were recorded and transcribed verbatim and then sent to participants for verification. Text coding and analysis was assisted by MAXQDA computer software. In order to explore the meanings and experiences of the participants in-depth an inductive content analysis strategy was employed allowing categories to emerge from the data (Kvale 1996). Validity procedures were used to increase legitimation (Onwuegbuzie and Leech 2007).

## **RESULTS**

Participants described several individual and social factors on their paths to excellence, such as their psychological skills and strategies for performing excellence, as well as the specifics of working within a team. For the purpose of this study, data were grouped into two main dimensions associated to performing together: (1) social skills to manage teamwork and interactions and (2) emotional regulation and coping skills.

### **Social skills**

Working together was a dimension that emerged from data analysis and refers to awareness of the importance of teamwork, as well as to the skills participants use in performing with others. For example, a dancer (Dancer 4) said: "It is a huge responsibility to be on stage. Success depends on me but also on so many others. It is a team work. The others need you but you also need others." Results demonstrated the importance of setting and sharing common goals and the ability to adapt to challenges the choreographer proposes, as well as those that arise through team creative processes. As Dancer 1 explained:

Sometimes I understand the proposal of the choreographer before the others and I have to wait that we [the team] all attain the same level of

understanding. I have to give others the time and space they need to understand the aims of the choreographer, but meanwhile I also have to adapt myself to others' rhythm.

Thus, participants highlighted the ability to be flexible and adapt to the different demands of performing together, as well as to the different learning and performing rhythms of each other. They also affirmed the importance of open communication with colleagues and choreographers, asking questions, and exchanging ideas that ensure that working goals are shared. Even if each dancer had his or her own interpretation of a movement as a creative member in the choreographic process, it seemed crucial to coordinate with others' meanings and actions or reconstruct their own meanings to adapt to the proposal. As Dancer 3 stated: "Even if I don't agree, I can't detract the creative process. I have to work my energy to suit to that project." In sum, communication skills and interpersonal skills are highly relevant to ensure balanced teamwork.

### **Coping skills**

Aware of the social and emotional demands of performing dance, participants described several coping strategies. Coping strategies refer to the mechanisms participants display to manage specific external and internal demands related to performing, such as audience behavior, anxiety, and performing with others (Lazarus and Folkman 1984). These psychological strategies gave participants perception of control and efficacy before, during, and after performing, and were vital to achieving successful outcomes. Participants described various strategies, such as anticipating situations, imagery, attentional control, task focusing, positive self-talk, and maintaining confidence and optimism. For example, Dancer 4 stated the importance of concentration and being totally focused on the task: "I am very concentrated before going on stage, as well as when I'm on stage. It is very important to be concentrated; it helps to better enjoy what you are doing." Another dancer (Dancer 2) explained how he uses confidence and positive self-talk in performing: "You have to be very confident on stage. Ok, look, now, there is nothing else to do, I'll blow it all. I like to get confident." Some participants also mentioned that they use group positive self-talk (e.g. "we are the best") as a strategy to reduce anxiety and improve confidence within the team.

Additionally, participants experienced several emotions, such as fright, anger, happiness, hope, relief, and shame. For example, Dancer 3 described the performing moment as a "bomb of energy wherein a person puts very

much intensity.” Another dancer (Dancer 2) described an experience of performing with shame and how important it was to switch his focus on that emotion to suit the demands of the performance and to guarantee a successful performance. Attentional control is also important in coordinating with others, as well as in anticipating others’ actions when performing on the stage. Dancer 1 described a situation where she associated attentional control, as well as cognitive and proprioceptive control, with performing successfully: “This was one of my best performances. I felt completely at ease as I was controlling everything - the audience, myself, the space, and my colleagues - everything.” In sum, coping skills are used to manage the demands of performing together, including dealing with colleagues, the audience, and each other’s emotional intensity.

## DISCUSSION

Psychological skills are of utmost importance to performing excellence (e.g. Collins *et al.* 2011, Gould *et al.* 2002). Creative processes and performing in dance involve coping with others when working together, as well as coping with one’s own emotional intensity and commitment to each task. This study revealed the awareness dancers have of the demands of performing together, as well as some strategies they use to cope with the emotional and social challenges of performing excellence. However, these results need to be further investigated in future studies specifically designed to explore the demands of performing together. Further research is required in order to develop new insights into the specific strategies dancers use to manage social interactions and cope with the emotional intensity of performing dance.

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# The multiple realities of actors in rehearsal

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In the context of reviewing research on role creation, this paper applies and extends the multiple realities framework. Many independent activities take place in the *actor sphere*: the self-as-actor intentionally carrying out expected activities such as memorizing and script analysis. Other realities include imagined worlds as actors “see” their characters and memory worlds as people once observed are mimicked or past emotional experiences recreated. The collaborative period is crucial. In scene rehearsals a new reality, the *drama world*, emerges. Here, the play’s structure and text are taken for granted, yet actors let go of prior intentions and spontaneously interact as characters, sometimes leading to actors’ surprise at what they did. Various interruptions, such as felt awkwardness or forgotten lines, dissolve the drama world and reveal actor sphere problems to reflect on. The various worlds interact. Actor sphere and drama world sometimes appear unbidden during everyday tasks and in dreams. The drama world is informed by prior work without being determined by it. Prior work may differentiate and prime actor intentions and character thoughts and feelings, making them available to self-as-character. This framework can be applied to other collaborative arts, promising arenas for its further development.

*Keywords:* acting; collaboration; creative process; spontaneity; theory

Psychologists have described acting as “living truthfully in imagined circumstances” (Noice and Noice 2006, p. 14) and as involving the ability to “enter readily into pretend worlds” (Goldstein and Winner 2009, p.123). This paper explores the implied phenomenological framework more explicitly with respect to the experience of preparing a role.

The idea that experience is qualitatively different in different worlds first appeared in psychology in the work of William James (1918) and was developed by Schuetz (1945) and Werner (1948). They distinguished the everyday

world from other worlds such as those of dreams, of pretend play, of art, and of science. Schuetz called them multiple realities and proposed that they differ in typical experience of self, type of sociality, and epoche (taken-for-granted assumptions). Werner pointed out that the everyday world differentiates into different spheres. For example, a child's everyday world may differentiate into a home sphere and a school sphere.

Acting is a fruitful arena for applying and extending the multiple realities framework. Prior qualitative studies, actors' written narratives, and interviews recently conducted by the author provide first-hand accounts of the experience of role creation. The following section reviews the activities they document and considers them in the light of the multiple realities framework.

### MAIN CONTRIBUTION

This paper introduces the concepts of *actor sphere* and *drama world* to capture the experiences of actors. The *actor sphere* is a differentiated part of the everyday world; the actor's self-experience is that of a professional actor intentionally carrying out tasks necessary to playing a role. In rehearsal, actors have the possibility of collectively creating another reality, the *drama world*. This is the world imagined by the playwright; here actors interact as their characters, with the character's intentions rather than those of the actor sphere of the everyday world, while taking for granted the structure, the lines, and the action of the play. The rules of the drama world need not follow those of the everyday world, and the time dimensions are typically different. The paper also introduces the concept of the *memory world*: vivid experiences of the past in the present.

Much of the research on role creation has dealt with the work actors do independently, both prior to the collaborative period and privately on rehearsal days. Many typical activities take place in the actor sphere as actors intentionally carry out the professional work of preparing a role, reading the play multiple times prior to and throughout the rehearsal period and memorizing lines (Noice and Noice 1997, Doyle 2013). As part of analyzing the play, some actors divide scenes into units (beats) and note their characters' feelings, emotions, and objectives in each (Noice and Noice 1997, Nemiro 1997). Many reflect on the character's overall personality and motivation (Olivier 1986, Noice and Noice 1997, Nemiro 1997), do research (Bandelj 2003), select costumes and props to bring to rehearsal (Nemiro 1997, Bandelj 2003), and reflect on and try out voices, intonations, and movements (Olivier 1986, Nemiro 1997, Bandelj 2003). Other activities may engage worlds of imagination: visual worlds as the appearances of characters come to actors (Olivier



1986, Sher 1985) or fiction worlds as the prior history of the character is created by activities such as writing the character's autobiography or diary (Bandelj 2003).

Actors put themselves in a memory world in two different ways. Past observations of others may be mimicked and re-created in the body (Olivier 1986, Goldstein and Winner 2010) or the actor's past emotional experiences may be recreated in sensuous detail (Nemiro 1997, Bandelj 2003).

Actors distinguish between two kinds of techniques: working outside-in (beginning with how the character appears to an outside observer) or inside-out (finding the character by identifying the character's psycho-emotional qualities in oneself). Visualizing the character and recreating past observations by mimicry are examples of outside-in techniques. Imagining as the character and recreating events from the actor's own past are inside-out techniques. The training of English actors tends to emphasize outside-in techniques, whereas American training emphasizes inside-out methods (Goldstein and Winner 2010). Actors' narratives about preparing for specific productions show that, though the techniques of one tradition may be emphasized, actors from each tradition report using some techniques of the other (Olivier 1986, Doyle 2013). Furthermore, neuropsychological work suggests that both techniques are steps to "living in" the drama world with the feelings of the character. Keyser and Gazzola (2009) have shown that when people observe someone else intending, acting, and feeling, their brain patterns are similar to those triggered when they themselves intend, feel, and act in those ways. And Laird (2007) has shown, as James (1918) once suggested, that creating the body of an emotion gives some of its feeling.

Whatever the prior independent work, most actors reported that their portrayals changed radically as a result of the collaborative process (e.g. Sher 1985). Some even reported ambivalence about memorizing early, since the very act of memorizing involved stressing lines one way or another, threatening to freeze interpretation prematurely (Doyle 2013).

Rehearsing with other actors under the guidance of the director was experienced intermittently as a social situation in which actors were aware of being judged, an actor-sphere work situation in which they were intentionally focused on how to do the play, and an emerging drama world. Actors told of possible tensions between their visions and that of the director (Nemiro 1997, Doyle 2013). Since actors recognized directors' authority, they had to adapt, often through additional independent work. Actors occasionally reported times in which they were unable to do so and felt that the production suffered (Olivier 1986, Doyle 2013). More typical outcomes were either an internaliza-

tion of the director's vision or integration between the two views (e.g. Sher 1985).

The fruits of independent work were starting points for rehearsals. Nevertheless, rehearsals centered on actors listening and reacting to one another, allowing as Olivier (1986) wrote of Othello rehearsals, "the play becoming less of a play and more of a reality" (p. 101). At these times, actors reported they were no longer aware of intentions from prior independent work and instead allowed scenes to unfold freely.

"You must be able to stand there not thinking of that line. You take off the other actor's face. Otherwise, for your next line, you're not listening and not free to respond naturally, to act spontaneously," wrote Caine (1990, p. 28-29).

Noice and Noice (2006) called this "active experiencing" rather than "trying;" actors spoke of "being present" in contrast to "indicating" or "acting" (Noice and Noice 2006, Nemiro 1997). The author proposes that what actors are experiencing—are present to—is the drama world. The events of the play, its memorized lines, and agreed-on movements are taken for granted and become the foundation for spontaneity. Actors reported that these were times when acting was effortless, spontaneous, unintended, and surprising; a time of unexpected discovery (Bandelj 2003, Doyle 2013).

Intermittently, the drama world dissolved as actors experienced awkwardness, forgotten lines, mishaps, etc. The interruptions revealed actor sphere problems to reflect on collaboratively and/or independently. Runthroughs, which require knitting together scenes previously rehearsed separately, typically revealed problems making continuous residence in the drama world unlikely (Doyle 2013).

Between rehearsals and times set aside to work on the play, actors live in the everyday world. They reported, though, that once they were in a production the shape of everyday life changed, and both actor sphere and drama world often appeared unbidden during everyday tasks. Actors also told of anxieties about upcoming productions appearing in dreams—being in the wrong play, forgetting lines, appearing naked on stage (Sher 1985, Doyle 2013). Here, everyday concerns about self and possible failure penetrated the world of dreams.

Thus the various worlds of the actor in rehearsal affect one another without announcement. The most wonderful and mysterious example is the way the drama world is informed by prior work without being determined by it. One actor, speaking of unexpected discoveries in the drama world, put it this way: "[t]hat happening 'in the doing' is the best thing.... It seems like it comes from nowhere and it does. It also comes from all the thinking, learning, understanding, being present, being with another, knowing the story.... Again,

you don't know 'till you are both there and let yourself go." Such moments, the actor said, are "the joy of acting" (Doyle 2013). Here the tensions inherent in role creation—individual work versus collaboration, structure versus spontaneity, intending versus allowing—are transcended in the drama world. The process is not fully understood. The play's structure, the individual work, and the rehearsal discoveries may serve to differentiate and prime the character's thoughts, feelings, and objectives, making them likely to become integrated into the spontaneous interactions of the actor-characters in the drama world.

### IMPLICATIONS

Three challenges emerge from this inquiry. Firstly, public acclaim for acting generally goes to individual actors, and much of the research on acting has focused on actors' independent work. The challenge now is to inquire further into the collaborative aspects which actors themselves tell us are crucial; the drama world has to be co-created.

Secondly, the multiple realities framework clarifies and illuminates actors' work and may be useful for gaining insight into other performing arts. Composer Roger Sessions (1952) wrote that a composer lives "in a world of sounds" (p. 38). This suggests differentiating the experience of music professionals into a *musician sphere* and a *sound world*. Some tensions are similar for musical groups: individual work-collaboration, structure-spontaneity, and intending-allowing.

Finally, the theoretical challenge is to advance our understanding of how various realities interact. Under what conditions does one reality intrude into another? When and how does one become the basis for doing and experiencing in another? And what is the structure of experience in worlds outside everyday reality? Merleau-Ponty (1962) suggested that each world may have another as an indeterminate horizon and that there can be sudden reversals, making the other the center of experience. The experiences of actors in rehearsal (and performance) provide intriguing material for exploring these issues.

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# Reading and understanding performers through critics, or vice versa

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Elite piano performances selectively reflect technical and expressive solutions to interpretative problems. These solutions are often credited as features of distinctive “artistry” and biographical “musicianship.” A young, skilled, conservatory-trained musician, however, is not an experienced performer, and perhaps the former does not inform the latter, or the latter does not necessarily supersede, or inherit, the former. Recorded evidence, among other things, can reveal that the work of a great performer is not marked by a wholly uniform interpretative style. Therefore, interpretative variety (e.g. renewed performances of the same work) can be assumed by the same performer through a personal filter of interpretative choices and, perhaps, a metaphor of age shift. We believe that we can learn more from prominent performers when highlighting the merits of their performances as tokens of authorial contextual practice, in contrast, perhaps, to the notion of the uniqueness of performers. The aim of this article is to put into question mainstream conceptions concerning performers as individual artists. Three influential artists (Gould, Pollini, Uchida) are examined through biographical impressions, selective recordings, and published interviews.

*Keywords:* artistry; musicianship; critics; pianists; biography

In a piano masterclass by Malcolm Bilson, on Beethoven’s Sonata No. 31, Op. 110, Kramer (2011, pp. 50-51) witnessed a student “struggling to give the strangely archaic second theme of the first movement an elevated expressiveness that kept sounding overwrought,” to which Bilson replied: “play this theme as if you had never heard of Beethoven.” If the “strangely archaic” theme was executed in a somehow mannered style, as Bilson’s ironic remark

suggests, one can ask, regardless of the efficacy of Bilson's solution, is it possible to play Beethoven as if we had "never heard of him?"

Clarke (2002) argues that performances are heard against a backdrop of previous performances and recordings, some of which are regarded as objects of study. The abundance of concurrent performances and the interpretative diversity available to the contemporary listener and performer means that, unless we are living isolated in an alien world or have an autistic engagement with performance, Bilson's "positivist" solution is very unlikely. The same can be said about musical works: even in Beethoven's time an informed performer would immediately compare a work such as the *Diabelli Variations* with the previous *Goldberg Variations* (Butt 2004). The existence of public performances and the circulation of recordings in these circumstances strongly attach professional music criticism with everyday performing practice; both performers and critics are witnesses and form part of the same imaginary community. The critic's thought usually goes into the writing; an idealized sense of the performer's style, artistry, and musicianship eventually emerges, with the necessary risk of performances being obscured by performers (Griffiths 2004). The recording industry, however, only plays an intermediary role in the performer-critic relationship, the critics being ultimately responsible for the construction, impact, and dissemination of a consumable identity (Godlovitch 1998).

This article raises issues such as: (1) the relative autonomy of performances as primary sources of professional music criticism, (2) the fallibility of the critical practice, and (3) the post-critical evaluation of performers.

### MAIN CONTRIBUTION

This article was prepared with the conviction that it is possible to recognize less-documented aspects of the performer's artistry and musicianship through quality critical practice. It should be noted that a form of skepticism towards scholarly preoccupation concerning critics can be found in current musicology (e.g. Kramer 2011), and it also coexists with the Internet age, where anyone can be, as Griffiths (2004) says, "a potential critic".

### Three pianists: Uchida, Gould, Pollini

#### *On Gould's Bach*

Bazzana (2005) writes that most of Glenn Gould's (1932-1982) critics focused almost exclusively on his Bach performances. However, a more misrepresented, distorted opinion of Gould's Bach performances occurs when one

simply refers to his characteristic non-*legato* playing and personal temperament while avoiding the question of which specific Bach composition and particular recording is under discussion. The dissemination of virtually all of his studio recordings began in 1992 with the release of *Glenn Gould Edition* by Sony Classical, followed by numerous releases of his private recordings, unreleased concert recordings, radio and television programs, etc. One of these CDs, *Glenn Gould: His First Recordings 1947-1953* (VAI 1198) includes a private recording of Bach's *Italian Concerto*, recorded in March 1948, when Gould was 16 years old. Gould's "personal authenticity" is barely audible, and the "inauthentic" rendering suggests also the use of a "practical" edition, in the manner of the Czerny, Griepenkerl, and Roitzsch's editions, "in which metronome markings are added to each movement, a tempo direction is given to the first and barely a note is left without a dynamic, a suggested phrasing or articulation" (Hellaby 2009, p. 87). The same piece recorded by Gould in April 1980 (Sony Classics 52620) receives an entirely different treatment: his usual non-*legato* articulation is now audible, as well his tendency to favor textural clarity by the use of both mixed articulation and voice-related dynamics.

Most of the features of Gould's style, however, cannot be easily mapped in a single performance since he implemented his interpretative individuality in several distinct periods of his life (Bazzana 2005). Tracing the origins of Gould's performance style is not the intention here, and to treat his recordings as primary sources is problematic due to the mixture of both authorial and contextual properties related to his playing philosophy and career.

### *On Pollini's myth*

Hoffelé (2003) writes about a "youthful" Maurizio Pollini (1942-) performing selections from Chopin's 24 *Préludes* (EMI DVA 4904379) "with a level-headedness, a containment, not to say a neutrality...." He contrasts this with the recording of Chopin by Samson François (1924-1970), saying that with Pollini "a new piano, a new Chopin were on the horizon." Schonberg's (1987) criticism of Pollini is somehow identical. He first recognizes Pollini as the "archetype of the modern style," defining "modern style" as objective, literal, severe, impersonal, and "dedicated to an accurate blueprint of the architecture of the music" (p. 482). Schonberg goes even further in his critique:

Even more than Brendel, more than anybody, [Pollini] is the very paragon of the modern style.... He can do anything he wants to do at the piano, and he does everything much the same way—objectively, standing

outside the music, refusing any fervent emotional commitments, just producing beautiful, well-organized, impersonal sounds (p. 487).

Pollini's performances of the romantic piano repertoire, however, give us a significantly different perspective; particularly, his renowned recordings of Chopin and Schumann. André Boucourechliev (1996), perhaps in response to certain established opinions, was able to identify a romantic side of Pollini's playing, writing: "the myth of Pollini as 'dry' is persistent (is it, because he plays Boulez?). When we heard his debut recording [of Chopin's *Préludes*] from 1975, we discover a romantic pianist" (p. 143). Fanning (2002) supposed certainties regarding the "objective" and "impersonal" side of Pollini's pianism. He gives us a sharper critique, recognizing in his playing "a nervous intensity, an increasing rigidity of phrasing together with a tendency to clip rhythms." Pollini himself, in a rare interview (Meyer-Josten 1989) admits his knowledge of many pre-war recordings, naming artists from previous generations, such as Cortot, Backhaus, Haskil, and Gieseking, as major influences.

#### *On Uchida's expressiveness*

Answering the question "what's the worst thing anyone ever said about you?" Mitsuko Uchida (1948-) replied in a recent interview: "a French critic once said about one of my Mozart concertos: 'She plays like a Japanese sewing machine'. I'd been told before that I was boring, and many other awful things, but I'll always remember that" (Barnett 2012). Griffiths (2004) observes the negative influence of critics on young performers and unknown interpreters, writing that "the critique can have a traumatizing effect on them" (p. 1064). However, this form of prejudice does not refer to a formal quality of her playing; it is only a metaphor and in concordance with what seems to be a strong tradition within music criticism of the provocative literary "zing" that uses insult or humorous remarks (such as George Bernard Shaw's *The Perfect Wagnerite* or Alex Ross's blog *The Rest is Noise*).

Alternatively, technology can substitute or establish a link with the critical language. A film of Uchida playing Chopin's Etude No. 2, Op. 10, recorded on the occasion of the Fifteenth Warsaw Chopin Competition in which she won second prize, is particularly unusual due to the use of several camera angles and the rapid change of shots which, when combined, accentuate the virtuoso-like stereotype of her performance. She respects the original metronome marking (quarter=144 bpm in Jan Ekier's PWM National Edition of Chopin's Works) and uses little pedal. A more recent recording of the same piece (Denon 7975770), recorded in 1992, is a contrasting experience: Uchida de-



liberately picks a seemingly moderate tempo (with a total duration of 1'52" against the previous 1'13") in order to project the polyphonic side and choral-like structure of the etude. A much more pronounced use of the right pedal and a wider dynamic range also suggest a more interpretative, personal, involvement with the score. She does not play "like a sewing machine," she simply plays in a sensitive manner. A comment on her maximum sensibility, delicate touch and eloquent phrasing can also be read in Harden and Willmes (2008).

### IMPLICATIONS

Both consumers and music audiences are primarily responsible for the over-valuation (i.e. fetishization) of elite performers, and thus heavily influence perceptions of the artistry and musicianship of their time. Music critics are also involved in this as they too explore the global qualities of individual performers. They have the right to be prejudiced, but they are responsible for definite, often sensational, statements regarding performers, and particularly concert soloists. Relating a particular performance to a certain performer is wrongly assuming that both tend to share the same specific context or background, and this remains an incomplete analysis. Also, performing habits, or matters of taste, change with time (e.g. when a pianist joins a "historically informed performance" ensemble or community). Repeated performances of the same work by the same performer, even when they do not demonstrate significant interpretative differences, also encourage the debate of the authority of the musical text when, for instance, the relationship of theoretical score-analysis to performance is questioned by a fresh rendition of the same work by the same performer.

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**Thematic session:  
Capturing musical movement**



# Effect of daily piano practice on finger kinematics and muscular load

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The present study aimed at assessing impacts of daily piano practice on kinematics and muscular activity of finger movements while musically-naïve individuals played the piano. Six participants were asked to play a certain melody with metronome with the non-dominant left hand. They practiced fifty trials per day over four successive days. Time-varying joint positions at the hand were recorded using a motion-capture system consisting of 13 high-speed cameras. Extrinsic finger muscular activities were also recorded using a surface electromyography (EMG). The amount of agonist-antagonist muscular co-activation was then computed. The joint angle averaged within each trial was also computed at the MCP, PIP, and DIP joints for each of the fingers. With practicing, the mean angle at the MCP joint became more flexed while the angles at the PIP and DIP joints became more extended. One-way repeated measures ANOVA confirmed significant changes in the joint posture with daily practice. The amount of co-activation of the finger flexor and extensor muscles also displayed a decrease, which indicates a reduction in joint stiffness. This study provided the first evidence demonstrating that daily piano practice reorganizes hand posture in playing and economizes muscular work for stiffening joints.

*Keywords:* motor control; motor learning; electromyography; kinematics; motion capture

Successful tone production in piano playing requires muscular compensation for the mechanical interaction between the fingertip and piano key. A previous study demonstrated that, while depressing a key, expert pianists configured more upstanding finger posture compared with novice piano players

(Furuya and Kinoshita 2008a). In addition, the pianists with superior skill produced smaller finger joint torque elicited by the key-reaction force as well as finger muscular torque (Furuya and Kinoshita 2008b). A simulation study also identified mechanical efficiency of the upstanding finger posture in piano keystrokes (Harding *et al.* 1993). It is therefore likely that pianists learned to configure upstanding finger posture during key-depression through practice. However, there remain several confounding factors, such as the effect of explicit instruction of the optimal finger posture by piano teachers and genetic effects. A longitudinal study is needed to directly assess whether extensive piano practice yields organization of the upstanding finger posture in piano playing.

To test a hypothesis that piano practice reorganizes hand posture so as to minimize muscular effort, the present study addressed the effect of daily piano practice on finger posture and finger muscular activity while playing a simple melody. To investigate this provides insights into not only the neural optimization process of the organization of redundant motor systems, but also into pathological mechanisms yielding repetitive strain injuries such as tendonitis, carpal tunnel syndrome, and focal hand dystonia that have been prevalent among pianists (Altenmuller and Jabusch 2009, Furuya *et al.* 2006).

## METHOD

### Participants

Twelve musically-naïve adult individuals (10 males and 2 females,  $M=22.4$ ,  $SD=1.2$  years, all right-handed) participated in the present study.

### Procedure

The experimental task was to play a certain melody with metronome (two strokes per second) with the non-dominant left hand. They practiced fifty trials per day over four successive days. The target loudness for the tone was set to approximately 90 MIDI velocity during the task and was monitored by an experimenter during each trial.

### Data acquisition procedures and analysis

The experimental apparatus used was a digital piano with a touch response action (P-250 YAMAHA Co.), a motion-capturing system consisting of 13 high-speed cameras (eight Eagle and five Hawk Eye, Mac3D system, Motion Analysis Co.), and a two-channel electromyography (EMG) system (Harada

Electronics Industry Ltd.). To collect positional data on anatomical landmarks, spherical reflective markers (5 mm in diameter for the hand and key and 9 mm in diameter for the wrist and elbow) were attached to 5 separate keys and on all joint centers of the right hand and arm (see Figure 1A, 1B). The joint angle averaged within a trial was also computed at the metacarpo-phalangeal (MCP), proximal-phalangeal (PIP), and distal-phalangeal (DIP) joints for each of the fingers. The amount of agonist-antagonist muscular co-activation was then computed based on the methods that we developed previously (Furuya *et al.* 2011).

Using the day as the independent variable, a one-way analysis of variance (ANOVA) with repeated measurements was performed for each of the dependent variables (joint angle and co-activation). We defined trials 1-5 as pre 5 trials and trials 46-50 as post 5 trials. Newman-Keuls post hoc tests were performed where appropriate to correct for multiple comparisons. Statistical significance was set at  $p < 0.05$ .

## RESULTS

### Joint angles of the striking fingers

Figure 2 shows the mean joint angle at the MCP, PIP, and DIP joints of the striking fingers (index, middle, ring, and little fingers) during keystrokes across participants at practice. ANOVA confirmed a practice effect on the MCP joint at the index and middle fingers, on the PIP joint at the index, middle, and ring fingers, and on the DIP joint at the middle finger (Table 1), which confirmed that the daily piano practice reorganized the hand posture in piano playing.

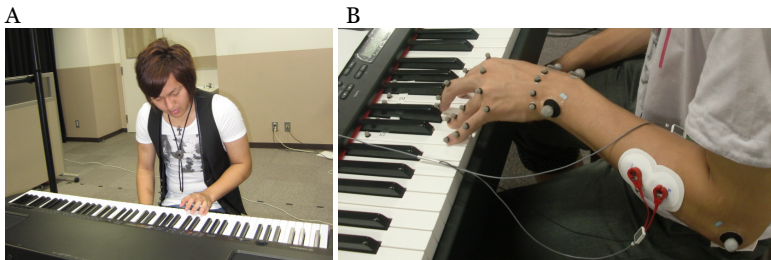


Figure 1. (A) Experimental appearance. (B) Reflective markers for the motion-capture system and surface electromyography. (See full color version at [www.performance-science.org](http://www.performance-science.org).)

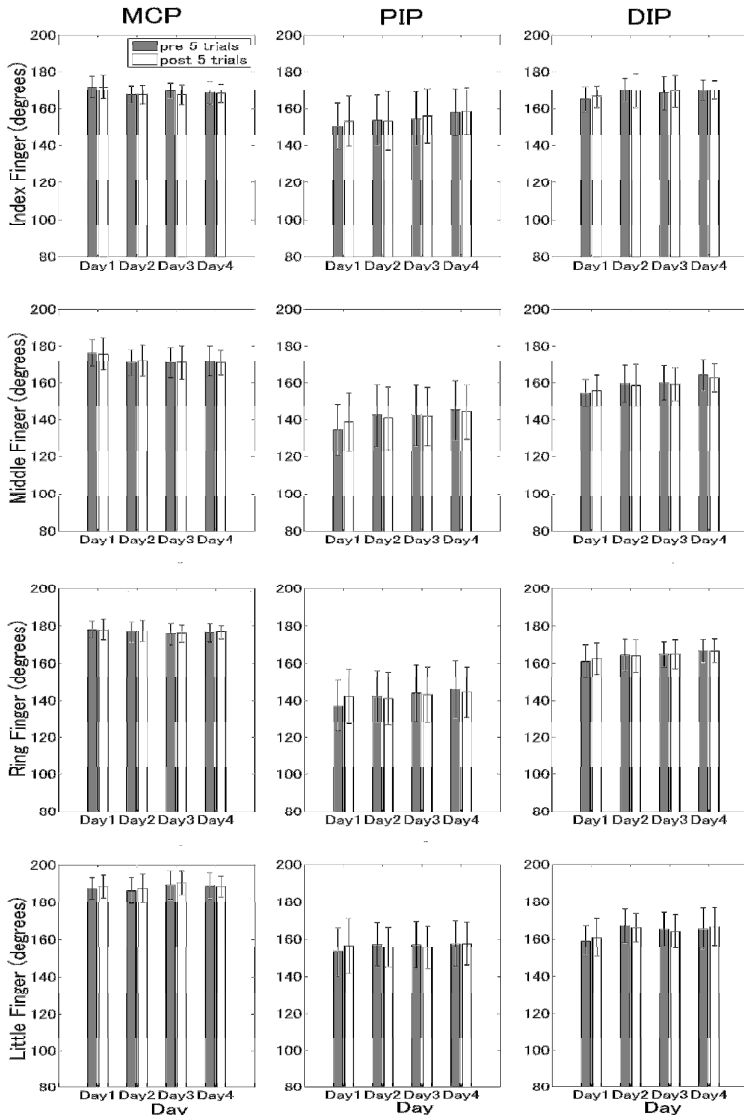


Figure 2. Group means of changes in the mean angle of joints during the training session over the four successive days. The 1st, 2nd, 3rd, and 4th rows correspond to the index, middle, ring, and little finger, respectively. 1st, 2nd, and 3rd columns correspond to the MCP, PIP, and DIP joint, respectively. A bar in grey and white indicates pre and post 5 trials the mean angle of joints, respectively.



Table 1. Results of 1-way ANOVA.

	MCP   $F_{7,35}$	PIP   $F_{7,35}$	DIP   $F_{7,35}$
Index	2.86*	5.11**	1.82
Middle	6.60**	9.06**	4.12**
Ring	1.71	5.66**	1.70
Little	1.33	0.76	1.46

Note. \* $p=0.05$ , \*\* $p=0.01$ .

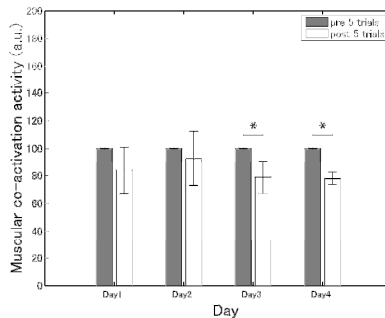


Figure 3. Group means of changes in the amount of agonist-antagonist muscular co-activation during the training session over the four successive days. A bar in grey and white indicates the amount of agonist-antagonist muscular co-activation of pre and post 5 trials. The value was normalized so that the pre-trials of each day became 100%.

### Muscular Activity

Figure 3 illustrates the group mean of the co-activation of the finger flexor and extensor muscles over four training days. The amount of co-activation also displayed a decrease with practice, which indicates reduction of finger muscular stiffness. A paired t-test confirmed significant changes in the muscular load on the third ( $p=0.02$ ) and fourth ( $p<0.001$ ) days of practice.

### DISCUSSION

We found that the mean joint angle was increased at the MCP joint of the index and middle fingers. In addition, it decreased at the PIP joint of the index, middle, and ring fingers, and at the DIP joint of the middle finger. Furthermore, there was a significant decrease of the amount of muscular co-activation through the daily practice. These findings suggest that the practice reorganized the hand posture so as to make piano performance more effi-

cient. This idea is in agreement with previous findings that pianists with superior proficiency play more efficiently (Furuya and Kinoshita 2008b, Furuya *et al.* 2011). The novelty of the present study is that the learning-dependent economization of movements occurred even without explicit instructions with respect to the optimal piano technique, suggesting spontaneous optimization process of the nervous system (Osu *et al.* 2002).

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# Memory of the piano key positions in pianists

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Accuracy of spatial memory of a piano key was investigated using 14 players with long term (>15 years) training (LT-group) and 13 players with short-term (<13 years) training (ST-group). The experimental task was to move his/her left or right index finger on the target key (C2, C3, E3, A4, C5, or C6 for each hand) position after touching the reference key (C4) position. The experiment was performed using either a real-scale photo copy of a C4 key (the No-keyboard condition) or a photo copy of the whole keyboard, and each was placed on a plain black-cloth-covered table. Kinematics of the fingertip was recorded using a 3D motion capturing system. For the No-keyboard condition, the LT-group had a mean absolute error of  $33.3 \pm 27.4$  mm, while the ST-group had that of  $55.9 \pm 41.5$  mm. The findings indicated that memory of the key position in proficient piano players was not as accurate as expected, though their accuracy was clearly better than less trained players. The right side of the keyboard and the right hand were more accurate than the left side and hand. This could also be related to the effects of training.

*Keywords:* piano; keyboard; spatial memory; reaching; training effect

Findings of recent neuro-physiological studies have repeatedly demonstrated that, after an extended period of using a tool, a neural network specific to its use is commonly formed in the user's brain. (e.g. Maravita and Iriki 2004, Johnsson-Fry 2004). Musical instruments, including the piano, can be regarded as one such tool for pianists. The tool thus can be represented in the

brain as a part of the user's body. To be an established pianist, he/she has to spend hours of deliberate practice in striking the keys of the piano daily for more than a decade (Ericsson *et al.* 1993). It is thus quite possible to assume that the keyboard itself is fairly accurately represented in his/her brain. Interestingly, spatial accuracy in locating the fingers on the keyboard based on memory established by piano training has not been fully investigated in previous research. On the stringed instruments, Chen *et al.* (2008) demonstrated that, while trained cellists located their left fingers on a target intonation without viewing the fingerboard, additional fine tuning of the intonation was commonly made by sound feedback. The findings indicated that cellists were intermittently re-calibrating and updating the spatial map during their performance. In our previous study, we reported that highly trained pianists had relatively inaccurate spatial memory of the key positions (Ohsawa *et al.* 2012). The aim of the present study was to investigate the difference in accuracy of spatial memory of the keyboard between two groups of pianists who had different lengths of training period.

## METHOD

### Participants

Fourteen active pianists with 22.7 (SD=6.2) years of piano training (the long-term group; LT-group), and 13 pianists with 8.9 (SD=3.6) years of piano training (the short-term group; ST-group) participated in this study.

### Experimental set-up and procedure

The experimental set-up consisted of a Qualisys 3D motion capture system with four Qqus300 cameras mounted on 2 m tripods, two PCs, a pair of speakers, a table-top type score stand, a cardboard sheet covered by a full scale piano keyboard (or only C4 key), and an experimental table and front panel boards all covered by a plain black cloth (see Figure 1).

The participants were seated on a height-adjustable piano chair and viewed a score with notes to be played. Pre-recorded MIDI tones corresponding with the score were given from the speakers. The score always had C4 as a reference note, followed by one of six target notes: C2, C3, E3, A4, C5, and C6. For each note the participants were asked to touch the designated key for 3 seconds, followed by a 3 second inter-note rest. The participants moved their finger to touch the key or assumed key position simply by following the tones, presented visually and aurally. Each participant performed these tasks with (the Keyboard condition) and without (the No-keyboard condition) the

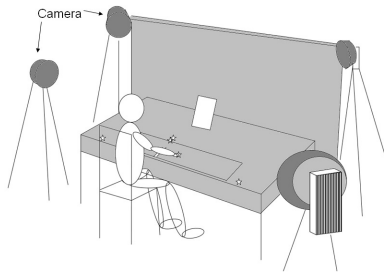


Figure 1. Experimental setup.

keyboard sheet, using the right and left hands. For the No-keyboard condition, only a copy of the C4 key was present. The order of presentation of the target tones was randomized for each participant, and 10 trial data were collected for each target tone.

After an adequate amount of practice, each participant first performed the No-keyboard condition task, and then the Keyboard condition task. The order of the hand used was counterbalanced for each participant. Kinematics of the fingertip was recorded by a motion capture system sampling at 60 Hz. All 3D fingertip position data stored were recalibrated off-line so that the midpoint of the near edge of the reference key was the origin of the 3D space in the subsequent kinematics computation. The fingertip-key contact point was determined by the mean horizontal displacement data for a 500 ms period of the steady state position in the latter half of the 3 second finger-target-key contact period. Three sets of two-way repeated measures ANOVA were performed for each of the experimental conditions using the absolute error data as a dependent variable. The independent variables for the first set were group (the LT and ST groups) and hand (the right and left hands), those for the second set were group and space (the right and left sides of the C4 key), and those for the third set were group and distance (6th, one octave, and two octaves). The statistical significance was set at 0.05.

## RESULTS

The mean absolute errors for the Keyboard condition for hand, space, and distance were 2.45 (SD=1.15) mm for the LT-group and 3.16 (SD=2.83) mm for the ST-group. The LT-group tended to be more accurate than the ST-group ( $F_{1,25}=3.32$ ,  $p<0.1$ ). ANOVA revealed no main effect of hand, space and distance.

### The No-keyboard condition

The mean value of all absolute errors for the LT-group was 33.3 (SD=27.4) mm, while that for the ST-group was 55.9 (SD=41.5) mm. This group difference was confirmed by ANOVA ( $F_{1,25}=6.48$ ,  $p<0.05$ ). The distance and hand effects were also significant. In both groups, all errors were larger for more remote keys ( $F_{2,50}=26.52$ ,  $p<0.01$ ; see Figure 2A), and also larger when the left hand was used compared to the right hand ( $F_{1,25}=4.57$ ,  $p<0.05$ ; see Figure 2B). Furthermore, the participants had smaller errors when the target was in the right side of the keyboard (higher than C4) than in the left side ( $F_{1,25}=5.84$ ,  $p<0.05$ ; see Figure 2C).

## DISCUSSION

The errors for most of the key detections without the keyboard exceeded 23 mm of the piano key width even for the LT group. The hypothesis that the piano is a centrally represented tool for highly trained pianists, and thus their spatial memory of key position is accurate, could not be reconfirmed (Ohsawa *et al.* 2012). The present study further demonstrated that the error of finger placement was apparently smaller for the LT group than the ST group. Clearly, there was a training effect on the accuracy of spatial memory of the key position. Still, spatial detection errors were found in highly trained pianists reaching a near-optimal level of proficiency. With the use of all sources of sensory information, this level of ambiguity in the memory of key position thus does not seem to be a factor disturbing their high quality piano performance. The fact that memory-based key detection was relatively poor further indicates that visual and other sensory (haptic, kinesthetic, and auditory) information plays a greater role in piano playing even in highly trained players.

We found that the greater the distance, the more the absolute error. This indicates that remote keys are less precisely represented in the pianist's brain. This can also be the effect of training because the vast majority of musical pieces focus on the keys located in the center in the keyboard. The higher accuracy of the right hand than the left hand and the right space than the left space can also be an effect of training. Ordinary musical pieces have more notes for the right hand than the left hand (Kopiez *et al.* 2011), and demand greater attention for playing a melody line in the higher and right-side pitch range than the lower pitch range.

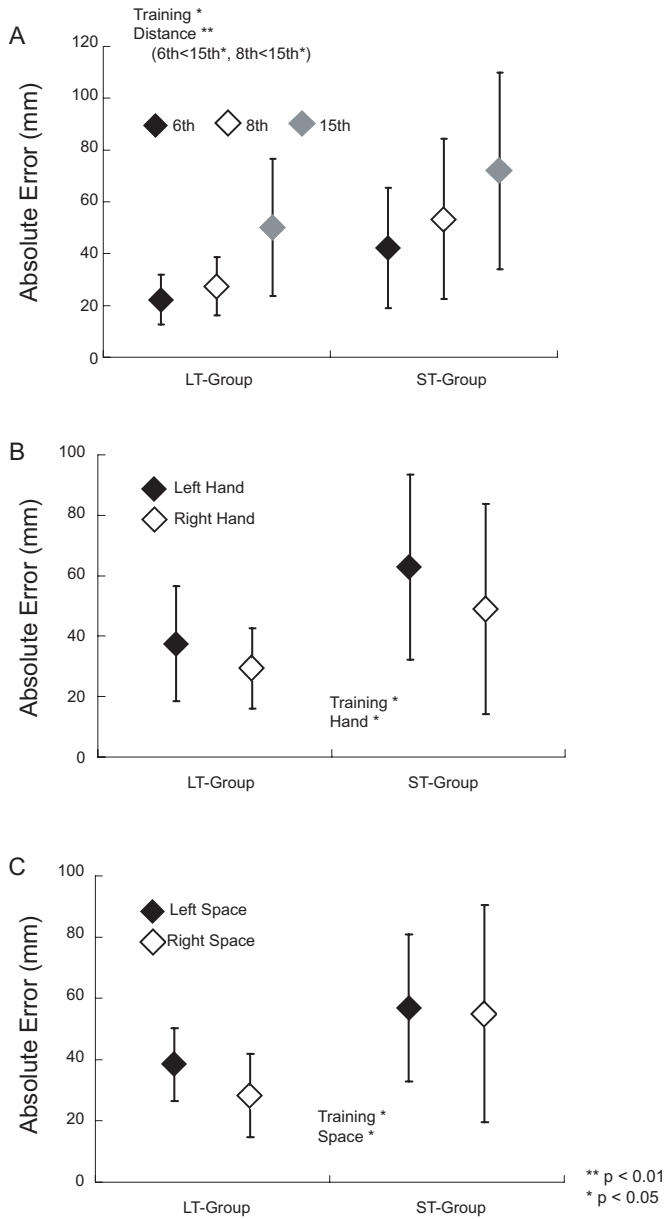


Figure 2. The mean and SD values of absolute errors for each group in relation to distance from C4 key (A), hand (B), and space (C) for the No-keyboard condition.

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# Frequency of coactivation of arm muscles in primary bowing tremor

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Task-specific tremors (TST) are a tremor entity occurring predominantly during a certain task. In violinists, TST may occur in the right arm while playing the instrument. This primary bowing tremor (PBT) is highly disabling for the affected musician and may threaten his/her professional career. To better understand the pathophysiological mechanism of TST, we measured antagonist EMG-activity to investigate a possible relationship between PBT and coactivation. We found EMG activity specific for PBT in the frequency range of 3-8 Hz as well as coactivation of antagonist muscles in the same frequency range (3-8 Hz) at a mean frequency of 6.6 Hz. Notably we did not find any PBT related EMG activity in at the resonance frequency of the wrist (8-12 Hz). Our findings firstly indicate an association between coactivation and PBT. Secondly, the absence of EMG-activity at the resonance frequency of the wrist indicates that mechanical reflex mechanisms play a less dominant role than central mechanisms.

*Keywords:* tremor; task-specific; musician; coactivation; dystonia

Task-specific tremors (TST) occur only or predominantly during a certain task (Deuschl *et al.* 1998). The most common TST is primary writing tremor (PWT; Rothwell *et al.* 1979), which can be sub-classified into two types: type-A, which refers to tremor induced by writing (task-induced); and type-B, which refers to tremor induced when holding the arm in the position for writing (position-sensitive). In string-instrument players, tremor may occur in the right arm while playing the instrument (Lederman 2007, Lee and Altenmüller 2012). This primary bowing tremor (PBT) is highly disabling for

the affected musician and may threaten his/her professional career. To understand its pathophysiological mechanism, EMG-properties in PWT have been repeatedly described. To our knowledge, however, coactivation of EMG-activity in TST has not been characterized in a quantitative manner so far. The aim of our study was thus twofold: first, to quantify EMG features in the spatial and frequency domains in PBT, and second, to assess the relation of coactivation to PBT.

## METHOD

### Participants

We included four professional violinists (patients), three male and one female, aged 48-62 years. Four gender-matched healthy violinists, aged 34 to 44 years, were measured as a control group (control).

### Materials

EMG was recorded with AG/AG2+ surface electrodes (*biovision*, Wehrheim, Germany), which were placed above the muscle belly of the wrist flexor and extensor of the right arm.

### Procedure

Two conditions were measured that required a slow bowing movement and clearly induced PBT, paced by a metronome at 40 bpm: (1) a G-major scale across three octaves, starting from the open g-string (GM) with two beats per bowing direction; and (2) open strings in the order of g-string, d-string, a-string, and e-string (OS) with four beats per bowing direction. To investigate an influence of bowing-speed or of bimanual coordination on tremor, bowing-speed was different for the two conditions and one condition (GM) required using the fingers of the contralateral hand.

EMG-data were filtered, rectified, and normalized and a fast fourier analysis (FFT) was applied to obtain the power spectra and the peak-frequency. We subdivided the frequency into three bands (1-3 Hz, 3-8 Hz, and 8-12 Hz) and calculated the mean power for each frequency band. We chose 3-8 Hz because it includes the frequency of TSTs (Elble *et al.* 1990, Bain *et al.* 1995, Deuschl *et al.* 1998, Bain 2011, Hess and Pullman 2012). To investigate a possible contribution of mechanical reflex mechanisms, 8-12 Hz—being the frequency band for the mechanical-reflex component of the wrist (Elble 1996) and for physiological tremor (Elble 1986, Hallett 1998, Deuschl *et al.* 2001)—was chosen. A third frequency range covering lower frequencies was chosen

to account for possible tremor as, for example, cerebellar or rubral tremor (Elble 1996, Deuschl and Bergman 2002). To investigate the role of coactivation in PBT, we calculated the time-varying coactivation of the wrist antagonist muscles by computing the overlap of the waveforms of these muscles (Furuya *et al.* 2012) and performed FFT to obtain coactivation frequency as mentioned above.

A t-test was performed for the two conditions (GM/OS). A 3-way ANOVA with group (patient/control), condition (GM/OS), and frequency bands (1-3 Hz, 3-8 Hz, 8-12 Hz) as independent variables and another 3-way ANOVA with factors conditions, group, and muscle group (flexor/extensor) as independent variables were conducted.

## RESULTS

Quantification of coactivation revealed a mean ( $\pm$ SD) of the peak frequency of the coactivation of 6.4 ( $\pm$ 0.4) Hz (OS) and 6.9 ( $\pm$ 0.4) Hz (GM). Difference between conditions was not significant ( $p=0.34$ ; see Figure 1, left). No coactivation was found in the controls (see Figure 1, right).

The first three-way ANOVA (condition; group; muscle group) showed a significant effect only for group ( $p<0.01$ ) and muscle-group ( $p<0.01$ ) but not condition ( $p=0.9$ ). An interaction between group and muscle-group was found. EMG-activity was higher for patients in both muscle-groups for both conditions ( $p<0.05$ ). The second three-way ANOVA (group; condition; frequency band) revealed a significant effect only for group ( $p<0.01$ ) and frequency-range ( $p<0.01$ ) but not condition ( $p=0.7$ ). An interaction effect was identified for group and frequency-range, indicating a group-difference at a particular frequency-range. Indeed, tremor-power was significantly higher in the frequency-range of 3-8 Hz ( $p<0.05$ ). Differences between 1-3 Hz and 8-12 Hz were not significant. Group difference was significant for 3-8 Hz only ( $p<0.01$ ; see Figure 2).

## DISCUSSION

We described EMG-properties of four professional violinists with PBT. A comparison to healthy controls demonstrated clear differences in the spatial and frequency features of muscular activity. This, to our best knowledge, provided the first quantitative evidence of altered muscular control in bowing tremor.

*Coactivation.* We found coactivation activity occurring at the same frequency as flexor and extensor muscle activity at a comparable intensity. Rather than a skipping between an alternating and coactivation activity (Bain

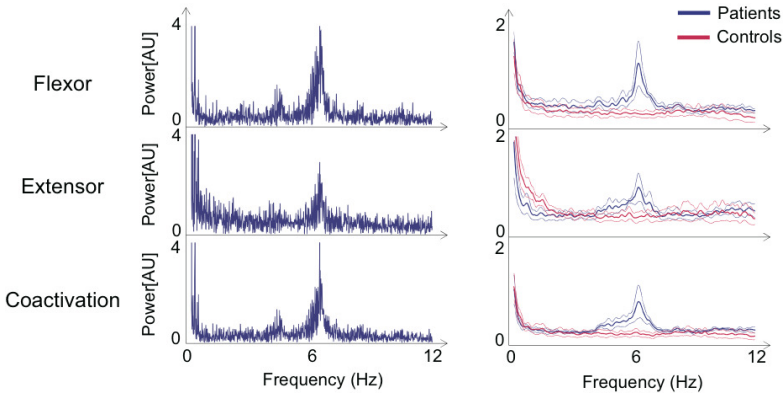


Figure 1. Left: FFT for patient 4 with a peak frequency at 6.2 Hz for the wrist extensor and flexor as well as the coactivation. Right: group mean of FFT for the OS-condition for patients and controls for the wrist flexor and extensor muscles and coactivation.

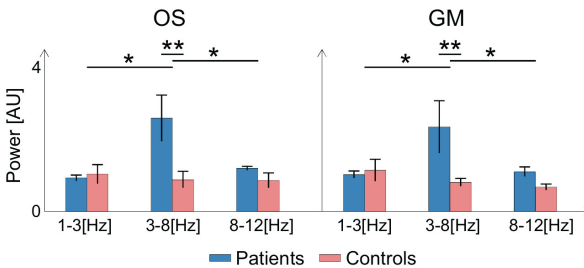


Figure 2. Group mean and SD of the mean frequency at each frequency band of patients and controls for the two conditions (OS/GM). (See full color versions at [www.performance-science.org](http://www.performance-science.org).)

2011) we observed a continuous coactivation throughout the entire movement. This provides evidence supporting a relation of coactivation to TST. Alternating as well as synchronous activity of antagonist forearm muscles has been observed in PWT. Elble *et al.* (1990) described coactivation in PWT as dystonia that increased as writing continued. Bain (2011) found coactivation only in type-B PWT. Kachi *et al.* (1985) found coactivation in only two out of ten patients. By contrast, all our patients (including type-A TST) had a coactivation of antagonist wrist flexor and extensor muscles. Explaining this find-

ing is not straightforward and remains speculative. Byrnes *et al.* (2005) found a reduced intracortical inhibition (ICI) in PWT. In healthy musicians however, ICI is already reduced as compared to healthy non-musicians (Nordstrom and Butler 2002, Rosenkranz *et al.* 2005). The emergence of PBT in violinists may therefore be associated with excess reduction of ICI elicited by musical practice.

*Frequency ranges.* Two findings became apparent. First, power of the EMG signal was significantly stronger for the 3-8 Hz range as compared to the other frequency ranges only within the patient group. Second, tremor was significantly stronger in patients as compared to controls only in the 3-8 Hz frequency range (see Figure 2). These findings suggest that neither mechanical reflex properties nor physiological tremor nor other neurological tremor with a slower frequency, emerged in the bowing tremor. In addition, no significant differences were found between the task conditions (OS, GM), which suggests robustness of the tremor-related muscular activity against bowing speed or bimanual coordination by using the fingers of the contralateral hand.

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**Thematic session:  
Performance education II**





# Instrumental lessons in pairs: Learning and/by performing together

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Instrumental group lessons have become an increasingly popular alternative in music schools, and in particular in private institutions, where they offer an appealing financial solution for students. However, does this practice only offer financial ease for learning an instrument or does it offer other advantages? What aspects should be taken into consideration when teaching groups? Focusing on instrumental lessons in pairs (in German: *Partnerunterricht*), our study discusses the benefits and shortcomings of this rather underappreciated pedagogical approach. For an examination of the current in-class situation at both public and private music schools in central Germany, we have interviewed teachers, talked to students and their parents, observed lessons, and contacted music schools and their directors for statistical and background information. Our findings indicate that learning with a partner has many more positive aspects than commonly perceived. Moreover, group learning facilitates more intensively and frequently a broad range of musical and social skills. We believe that this study will stimulate teachers to rethink their pedagogical methods and explore this genuinely positive alternative.

*Keywords:* instrumental lessons; performing together; instrumental duets; music pedagogy; music school

Instrumental lessons in groups have become a frequent alternative in music schools in Germany. Consequently, most institutions nowadays require instrument teachers with experience in teaching both individuals and groups (of all ages). For families this is an attractive financial solution because of the reduced lesson fees, while for pedagogues it can imply higher remuneration. Furthermore, ensemble playing is recommended to be incorporated in classes from the beginning (VdM 2010).

Already in the 1850s, the concept of learning in groups was supported by music theoretician Gustav Schilling and piano pedagogue Lina Ramann, who built a reportedly successful group teaching method (Grosse 2006). In the first half of the twentieth century, this approach reached an apogee in Germany as several institutions reported more students learning in groups than individually. After the Second World War, group learning started losing popularity. However, from c.1970, the discussion around the methodology and didactic of group teaching has been retaken (Grosse 2006, Heilbut 1970).

We concentrated our study on groups formed by two students, where focus lies on specifically learning to play an instrument rather than on learning music with an instrument (Heilbut 1970). Especially suitable for beginners—not only youth (VdM 2010, Varró 1929, Heilbut 1970)—learning with a musical partner is believed to offer several musical and social advantages for the pupils, such as mutual positive influence and supervision, development of listening and observational skills, sharpening of musical judgment, and diminution of stage fright. Furthermore, comparison with a classmate motivates students to a more effective practice (Varró 1929, VdM 2010). Nevertheless, deficits are thought to be, for example, the lack of technical and individual attention. In order to achieve better results with pairs, however, some criteria must be fulfilled, such as appropriate room conditions and consequent groups' composition according to age and learning level. Due to more intense teaching effort, it seems more appropriate that remuneration be different for group and individual classes.

The aims of this study were: (1) to examine instrumental group lessons (in pairs) in Germany, focusing on the current in-class situation; (2) to verify its pedagogical advantages; and (3) to identify constructively the deficiencies (in this practice) and how they can be mitigated.

## METHOD

### Participants

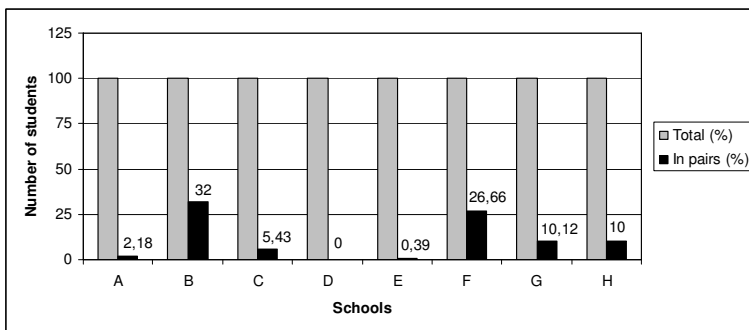
Eight music schools (4 in Berlin, 1 in Potsdam, 2 in Halle (Saale), and 1 in Merseburg (Saale); 5 public, 3 private), eighteen young students (12 females; age range 6-16 years; 2 pairs of siblings), two adult students (1 female) and ten teachers (7 females; piano=4, guitar=2, violin=2, recorder=1, and violoncello=1) participated in this study. Ten classes were observed from some of the eight schools, selected randomly (piano=3, guitar=2, violin=2, recorder=2, and violoncello=1). The students' total learning duration varied from 2 months to 3 years at the time of the study.

## Materials

Non-standardized written questionnaires were elaborated for the teachers. Students and their parents were interviewed orally (standardized and non-standardized questions, respectively). Interviews with music school headmasters were conducted either personally, by telephone, or in writing (e-mail). Group lesson observation constituted an important material for this research. The observed criteria were kept on record.

## Procedure

We surveyed (randomly) music schools which offered instrumental group lessons (see Figure 1). These provided information on staff members teaching groups of different instruments (when available). The headmasters were interviewed. All teachers with groups on the piano, guitar, violin, recorder, and violoncello were at first contacted by telephone for a pre-interview. Teachers were selected (with no specific criterion) and the study procedures were explained. Those who gave their consent to participate in the study were given the written questionnaires in advance and provided information on the available groups. Since our aim was to examine the general in-class situation of instrumental lessons in pairs, we decided to observe the most diverse groups. Within the period of one month, we attended the selected classes (in three of the mentioned schools) individually and took notes on general class structure, material/repertoire, student/teacher interaction as well student-student interaction, technical and aesthetical approach, evaluation of students at the



*Figure 1.* Percentage of students learning in pairs in the surveyed schools. F, G, and H represent private schools. School B was a special case as school direction usually recommends group lessons to beginners due to limited capacity.

individual level, students' motivation, and class effectiveness. Students and their parents were interviewed directly after each class. Teachers' questionnaires were given back afterwards (one day later up to one month after each class visit).

## RESULTS

Professionals' answers showed that most instrument-learning students applied for group lessons together due to previous social acquaintance (school, friendship, or siblings), joint participation in musical education programs for young children, or as a result of residing in the same neighborhood. Surprisingly, the lower costs were not acknowledged as the main reason for the choice (less than 50%). Other mentioned reasons for choosing group lessons included (1) parents assumption that it is more pleasant for their children to learn with a partner and (2) parents seeing it as a testing/adapting phase, i.e. to verify if their children are interested in instrumental lessons in the first place or whether the chosen instrument is the right one. Groups were generally composed of beginners of all ages, especially children between 6-10 years old. The guitar and the recorder, which are instruments that can be carried with ease, were reported as the most popular for learning in groups.

In most of the analyzed cases, the interest in group lessons came from the students/parents. Teachers and school directions recommended it mostly in exceptional cases, such as limited capacity or in the lack of vacancies for new students. Professionals especially recommended group lessons for beginners, for students who need additional motivation for learning, and for those not certain regarding the instrument of choice.

The majority of questioned professionals expressed themselves positively about group lessons. The main advantages and features for students learning in pairs, as reported, were: more joyful and diversified learning, leading practice in early stages, playing the teacher's role by listening and advising their partners, stronger self-reflection sense, and awareness of technical and musical difficulties. The social aspect was positively acknowledged. Students practiced more at home and prepared themselves better when attending classes with a partner.

Less than half of the questioned teachers found the learning progress from groups noticeably slower, compared to individual students. All teachers reported that technical work is present in their classes. One third of the teachers saw in this approach an advantage for practicing technique, because technical exercises are "especially suitable for pairs" and "can be approached playfully." Another third recognized that the time available for this is much

shorter in group lessons. Unexpectedly, this was not perceived by these teachers as a shortcoming. Half of respondents stated that they need more time and effort for preparing group classes. Pedagogues with experience in musical education for young children described this experience as an advantage on this matter. Concerning the available material for group lessons, only violin and recorder pedagogues reported themselves as satisfied. The others stated that they usually need to arrange pieces themselves. All interviewed students reported that they were less anxious of performing for an audience when playing together. All students stated that they preferred playing together than solo.

Class observation showed that methods are heterogeneous and vary from one teacher to another. Abilities trained in the observed classes included: listening and reacting to each other, starting and finishing together, mutual musical feeling, critical judgment, playing in (and maintaining) the same tempo, technique, improvisation, *prima-vista* playing (together), duet playing, and working and finding solutions to different tasks together. We verified that teachers had in almost every observed class a naturally lively atmosphere available. Interaction between students varied according to teachers' approach and ability to deal with both students as well as keep them focused and motivated.

Finally, data showed that costs for each student attending group lessons represented from 58.8% to 68.2% of those for individual lessons. Surprisingly, only one of the schools (a private one) reported differentiated remuneration for its employees, i.e. the benefits for group lessons were up to 10% higher.

## DISCUSSION

Our findings show that learning with a musical partner has in fact more advantages than commonly perceived. Some of the abovementioned abilities, which were trained in the observed classes, confirm those described in the available literature (Varró 1929, Ehrenpreis and Wohlwender 1999, Heilbut 1970), as well as presenting many other possibilities. This demonstrates that teaching two (or more) students simultaneously is a very positive pedagogical approach, providing innumerable advantages for both students and teachers. These may vary according to pedagogues' ability and inventiveness.

We verified that playing with a partner reduces performance anxiety. It also motivates students to perform publicly. All interviewed students described their stage experience as more pleasant when playing together.

We found that, unfortunately, professionals are seldom better remunerated for teaching groups. Even when available, this differentiation is reasonably small (up to 10% higher). Leading to demotivation of pedagogues (as described by different headmasters), this may hinder the dissemination and development of group lessons. Therefore, this is a crucial issue and must be taken into consideration by school directors.

The social factor was revealed as especially motivating. Many teachers reported that students are often upset when partners are absent. In some extreme cases, students quit after partners were unable to continue attending classes. In order to avoid that, teachers can incorporate solo pieces and individual single lessons alongside group classes.

Most teachers confirmed that groups should be dissolved after some time (approximately two years or when a certain level is reached; see Ehrenpreis and Wohlwender 1999) and, from then on, students should be taught individually for their further development. We hope that our study not only motivates pedagogues to explore the possibilities of teaching groups, but also encourages further studies in this field.

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# Reconstructing Schoenberg: Rehearsing and performing together

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When musicians perform from memory they draw on performance cues (PCs) or landmarks for retrieval. Many of these are prepared in practice but musicians also have spontaneous thoughts when performing. The aim of the present study was to identify the role of both in helping a singer recall a work from memory through analysing her use of musical cues from the accompaniment and verbal cues from the accompanist. Seventeen months after having given a public performance of the work, Schoenberg's Two Songs op. 14, the singer reconstructed and performed them again from memory, first without and then with the piano accompaniment, during the course of a 40-minute rehearsal that was recorded and transcribed. A total of 106 practice segments were analyzed. The singer sang the words and melody, listened to the pianist playing the accompaniment and talked with him in roughly equal proportions (around 30%); she also vocalized the melody. A content analysis of rehearsal talk will be presented. Typical errors included early entries and misremembering the words. While PCs are crucial features of the individual performer's mental representation of the work to be recalled, external cues from accompaniment and accompanist are also invaluable to the musician performing from memory.

*Keywords:* accompaniment; cues; retrieval; representations; talk

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# “Let’s go again from the top”: The role of collaborative rehearsal in learning music

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Research on musicians’ practicing and memorizing strategies usually focuses on the individual learner. The aim of the present study was to explore the extent to which students and their tutors report rehearsing with others and consider it to make a contribution to initial learning. Two questionnaire studies were undertaken and qualitative data gathered from tutors who participated in an interactive workshop. The comparison of students’ estimated and calculated working time showed that they largely discounted all activities other than solitary practice at the instrument with the score. Nevertheless, nearly 40% of the sample reported rehearsing with others. While few tutors recommended this as a learning strategy, a large minority did rehearse with others themselves. Collaborative rehearsal may play a more valuable role during the early stages of individual learning than students and their tutors realize.

*Keywords:* listening; practicing; strategies; instrumental; vocal

The development of strategies for learning music has been a topic of interest to researchers for many years. Practicing and memorizing have been investigated in several studies with the participation of children (e.g. McPherson and Davidson 2006), music performance students (e.g. Nielsen 2004) and expert musicians (e.g. Chaffin *et al.* 2002), but most of what is known about the learning of Western classical music is based on two assumptions that may well be faulty: practice involves playing one’s instrument, reading from a score, and in the early stages of practicing a new work, learning is a solitary activity.

In the present study, we explored the role of collaborative rehearsal in the first week of learning a new work, analyzing data gathered as part of a wider study of strategies for learning and teaching music with university and con-

servatoire-based students of music performance and their tutors. We asked: (1) During the first week of practice, what was the difference between musicians' reported practice time and the time they spent playing their instrument, reading from the score? (2) What proportion of their practice time did they report spending rehearsing with someone else? (3) To what extent could we infer that students' behaviors reflected their tutors' beliefs and recommendations?

## METHOD

### Participants

A total of 240 music performance students (91 m, 149 f) at eight UK higher education institutions (four conservatoires and four university music departments) and 39 instrumental and vocal tutors recruited from the same institutions (17 m, 22 f) responded to two questionnaire surveys (Ginsborg and Prior 2011, 2012). A further 30 instrumental and vocal tutors from a range of backgrounds and countries (including Austria, Australia, Spain, and Switzerland, as well as the UK), one of whom had been a respondent in the earlier study, took part in an interactive workshop at which the results were reported and group discussion held (Ginsborg *et al.* 2013).

### Materials

The first questionnaire was designed for students and consisted of 14 items including demographic information (sex, main instrument/voice, if the respondent also played a keyboard instrument in addition to their main [non-keyboard] instrument, year of study). Respondents were asked to name the last piece they practiced and its composer, when and how they had first encountered it, when they had first started learning it, and how they engaged with it. They were asked to estimate how much time they spent working on the piece during their first week of practice and then to estimate the time they spent on active and passive listening, playing alone, and rehearsing with others. If they reported active or passive listening while carrying out another activity, they were asked to specify that activity. The second questionnaire was designed for tutors and asked them to respond to the same questions as those addressed to the students, in relation first to their own practice and also in relation to the recommendations they had made to three of their students in the past week. Both questionnaires included open-ended as well as closed questions. Qualitative data were obtained from the participants in the interactive workshop.

## Procedure

The questionnaires were administered via SurveyMonkey. At the end of the tutor questionnaire, respondents were invited to attend the interactive workshop that would be held during the course of the conference at which the results of both questionnaires would be reported. All participants in the workshop were provided with information about the study, told that the workshop would be video-recorded and asked to sign a consent form when they registered for the conference. The discussion was moderated by the first author and recorded by the second author, who subsequently transcribed the discussion that took place. For the purpose of analysis, respondents to both questionnaires were grouped by instrument (strings, brass/woodwind, keyboard/percussion, and voice). Eight student composers and conductors were excluded. A thematic analysis of the qualitative data was undertaken using NVivo.

## RESULTS

Analysis of variance revealed a main effect of activity (reported vs. calculated) on time, such that the time respondents were calculated to have spent on practice and practice-related activities, including active and passive listening with and without the score, during the first week of learning, was significantly longer ( $M=11$  hours, 58 mins) than their estimated practice time reading from the score ( $M=4$  hours, 15 mins;  $F_{3,228}=10.59$ ,  $p<0.0001$ ) and estimated overall time “working on” the piece ( $M=5$  hours, 41 mins;  $F_{3,228}=3.75$ ,  $p=0.012$ ). Mean times are shown for each instrument group in Figure 1, although the interaction between time and group only approached significance ( $F_{3,228}=2.15$ ,  $p=0.095$ ).

As shown in Figure 2, the whole student sample spent more than a tenth of their estimated practice time rehearsing with other people. It should be noted, however, that 49 students (21.1%) reported learning works for solo instrument, and of the remainder, 114 (47.5% of the total sample) did not rehearse with other(s) even though they were working on duo or ensemble pieces. Thus, only 69 students (37.7% of the sample who was not working on solo pieces) rehearsed with others.

Thirteen of the 39 tutor respondents to the questionnaire reported suggesting to one or more of their students that they rehearse with someone else. Five rated this strategy as not very important, four as quite important, three as important, and one as essential. Three string players, three brass players, one singer, and one pianist had themselves rehearsed with someone else in

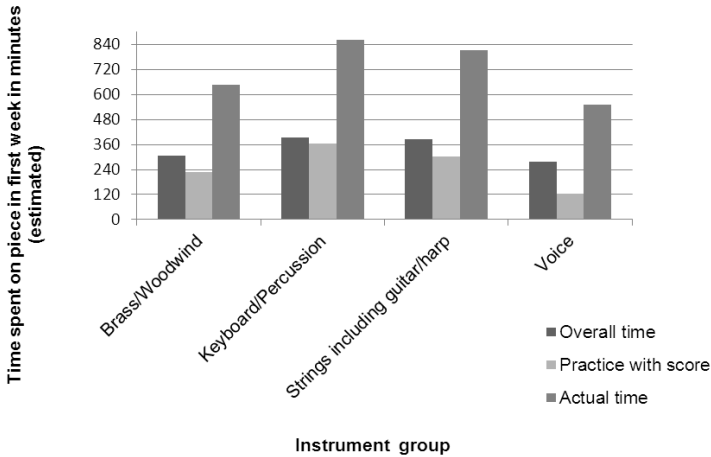


Figure 1. Estimated overall time spent on piece, practice with score, and actual time spent (by instrument group).

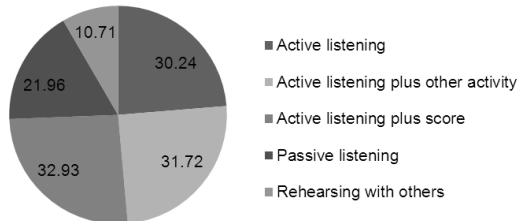


Figure 2. Other activities.

the first week of working on a new piece, although only three of them had reported suggesting this strategy, for a mean of 2:26 hours (range=1-6), representing a mean of 34.4% total working time (range=11.9-70.6%). Only one reference was made during the interactive workshop to collaborative rehearsal—"students are influenced by...other people they play with at school"—although one of the themes that emerged from the discussion was tutors'

partnership with students, involving discussion of works to be performed from the outset and joint listening activities.

## DISCUSSION

Asked to estimate the number of minutes they spent “practicing” and “working on” a new piece, the students we surveyed clearly believed that “practice” involved solitary effort: playing their instruments and reading from the score. Yet they also reported undertaking further activities that clearly had the potential, at least, for contributing to their learning of the music: active listening with and without the score, passive listening and—of particularly interest in the present study—rehearsing with others, at least for those students who were not learning a work for unaccompanied instrument.

It is perhaps not surprising that students did not consider these activities as “practice”, apparently sharing the assumption that practice is or should be carried out alone, since only a third of the tutors we surveyed reported suggesting to their students that they rehearse with someone else during the early stages of learning, and of these respondents, several rated this activity as not very important. Yet a substantial minority of the tutors told us that collaborative rehearsal had formed a part of their first week’s work on a new piece. It is true, of course, that there was not much overlap between the tutors who recommended rehearsal as a learning strategy and the tutors who used it themselves; and it may be that students take longer (or are thought by their tutors to take longer) than tutors, who are already professional musicians, to learn the pieces on which they are working to a standard sufficiently high for it to be useful to rehearse them with peers.

It is difficult to draw firm conclusions from so small a sample of tutors, but it is worth noting that those who strongly recommended their students to undertake rehearsal with someone else, early in the learning process, were a pianist—the type of musician most often to be invited to play with instrumentalists and vocalists—and a singer. For a variety of reasons, singers are more likely to work with keyboard players than any other kind of instrumentalist, or unaccompanied, whether the keyboard player fulfills the role of coach, accompanist or duo partner. In the interactive workshop from which qualitative data were obtained the main focus was on the comparative roles of listening to and reading music in the early stages of learning, rather than collaborative rehearsal. Nevertheless collaboration was raised by participants, typically in relation to tutor-student partnership. As one said, “...we have to develop a way of talking about it together, so the best way of doing it is actually the teacher and student looking at something or listening together...”;

and as another commented, "...prior to me having ready access to show them YouTube clips or going to the library [... there] would have been me sitting at the piano, providing the aural experience for them while they're looking over my shoulder and perhaps singing along with me."

While informal music-making activities have been studied in non-classical contexts, more research remains to be carried out on practice room and teaching studio behaviors such as those that were reported by our student and tutor questionnaire respondents, and discussed in the interactive workshop. We look forward to exploring these behaviors further, including collaborative rehearsal, in future studies.

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Thematic session:  
The science of dance I





# Body composition and injuries in professional ballet dancers

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Dancers are at a high risk of becoming injured, and most dancers sustain at least one injury per year. Research into injury risk factors is, therefore, imperative in order to identify strategies for prevention. The aim of this study was to examine professional ballet dancers, investigating their bone mineral density (BMD), body composition (lean and fat mass), menstrual history, company position, incidence and severity of musculo-skeletal injury, and the relationships among these variables. One hundred and eleven dancers (39 male and 72 female) volunteered for the study. BMD and body composition were measured by DXA. Questionnaires recorded menstrual, medical and family history, medications, use of oral contraceptives, smoking, and alcohol intake. Injury incidence and severity data were collected using physiotherapy records from the two consecutive years following DXA. Statistical analysis was performed using SPSS, with statistical significance set at  $p < 0.05$ . Frequency and severity of injury were not found to be significantly associated with body composition, nor company position. In dancers, where negative mean  $z$ -score values at the ultra-distal (UD) radius were observed, their below-normal upper body BMD values may suggest an increased risk of developing osteoporosis, with an associated risk of injury. Results suggest supplemental conditioning, aimed at increasing and maintaining normal levels of upper body BMD, may elicit health and performance benefits for professional ballet dancers.

*Keywords:* ballet; injury; BMD; dancer; training

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# A comparison of strength and stretch interventions on active and passive ranges of movement in dancers: A randomized controlled trial

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The *grande battement* (PROM) and *développé* (AROM) are integral aspects of dance performance and have been closely linked with artistic virtuoso. The purpose of this study was to assess the effect of three strengthening or stretching interventions on hip and lower limb active (AROM) and passive (PROM) ranges of movement. Thirty-five female dance students ( $17.00 \pm 0.52$  years,  $61.70 \pm 8.48$  kg,  $164.40 \pm 5.49$  cm) volunteered. They were randomly divided into three groups: strength training ( $n=11$ ), low intensity stretching ( $n=13$ ), and moderate-high intensity stretching ( $n=11$ ). All groups carried out a six week intervention. The strength training group focused on end of range hip flexor strength; the low intensity and moderate intensity stretch group carried out a series of stretches at 3/10 and 8/10 perceived exertion, respectively. AROM and PROM were measured pre- and post-intervention using 2D video analysis. Repeated measures analysis indicated that all three groups improved their PROM (range increase:  $9-20^\circ$ ,  $p < 0.01$ ), and AROM only significantly increased for the strength training and the low-intensity stretch groups ( $p < 0.01$ ). The present data show that non-traditional interventions based on strength training and low intensity stretching are beneficial in the development of both active and passive ranges of movement.

*Keywords:* dancers; microStretching; supplemental training; *développé*; *battement*

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# Dancing in the dark: The effect of vitamin D status on muscle function and injury incidence

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As dancers train indoors they are vulnerable to vitamin D deficiency. The aims of the study were two-fold: initially, to evaluate the vitamin D status of elite dancers during winter and summer and assess the impact on bone metabolism and risk of injury; secondly, to measure the effect of oral vitamin D<sub>3</sub> supplementation on muscle function and injury occurrence. Nineteen elite ballerinas volunteered for the first study, 25-hydroxyvitamin D [25(OH)D], PTH, blood serum bone turnover markers, and injury incidence were monitored over a six month period. In the second study, a group of 26 elite classical ballet dancers (intervention n=19, control n=7) had their muscle function measured before and after a four-month oral supplementation of vitamin D<sub>3</sub> (2000 IU per day), and injury data were recorded. Significant changes were noted between the winter and summer test dates for 25(OH)D ( $p<0.001$ ), PTH ( $p<0.001$ ), PINP ( $p<0.01$ ), and injury incidence ( $p<0.05$ ). In study 2, the intervention group had significant improvements in muscles function ( $p<0.05$ ) and decreases in injury incidence ( $p<0.01$ ). There is a high incidence of low vitamin D levels in professional ballerinas which seems to have an effect on bone metabolism, muscle function, and injury incidence. This can be negated by supplementation.

*Keywords:* dancers; vitamin D; muscle function; bone markers

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Thematic session:  
Approaches to motor learning





# Development of a measure of self-regulated practice behavior in skilled performers

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The purpose of this study was to develop and test the internal consistency of a self-report instrument for measuring self-regulatory behaviors in skilled performers during practice. 49 classically trained instrumentalists completed a web-based questionnaire designed to assess 5 hypothesized dimensions of self-regulation. Internal consistency was demonstrated through exploratory inter-item and item-total correlational tests. After suggested item deletions, reliability tests revealed that the sub-scales achieved good internal consistency.

*Keywords:* self-regulation; practice; skilled performers; questionnaire; internal consistency

Being able to guide one's own goal-directed activities across time and changing circumstances is of paramount relevance for the skilled performer. Commonly referred to as self-regulation, this competence includes the modulation of thoughts, feelings, and behaviors via deliberate or automated use of specific mechanisms and supportive meta-skills in order to pursue personal goals (Karoly 1993). The general psychological literature has stated that individuals with high levels of self-regulation benefit from a sense of psychological stability and personal control (Hoyle 2010). Effective self-regulation also improves wellbeing, and people who exert self-regulation typically have well-defined goals and adopt appropriate standards of behavior (Hoyle 2010).

Previous research has demonstrated how expert musicians are actively and meaningfully engaged in their own learning and performance processes (Williamon 2004, Chaffin *et al.* 2002, Hallam 1995a, 1995b). Skills improvement is attained through solitary deliberate practice (Ericsson *et al.* 1993), and salient qualitative properties of their practices (e.g. task analysis, goal setting, strategy choice, self-monitoring, and self-evaluation) have been recently studied as key components of self-regulation in music students

(McPherson and Zimmerman 2002, Austin and Berg 2006, Miksza 2012, Ritchie and Williamon 2013). The results of several studies have revealed that testimonials on self-regulation strategies have been presented as predictors of performance improvement. Students with high self-regulatory skills are more apt to manage technical and interpretation problems of a given work and to use mental strategies, showing organized practice behavior (McPherson 2005). Other positive correlations between self-regulatory skills and practice have been mentioned, including the good use of time in practice (Austin and Berg 2006), time spent in formal practice (McPherson and McCormick 1999, 2006), self-efficacy beliefs (McPherson and McCormick 2006, Ritchie and Williamon 2011), and use of cognitive and metacognitive strategies (Nielsen 1999).

As shown, self-regulation in music has been mainly used to understand the processes and methods of self-sufficient music learners. Nevertheless, few studies have researched self-regulation in skilled performers. We hypothesize that the levels of self-regulatory practice behaviors may correlate with the positive psychological states experienced by skilled performers during their practice processes and concerts. There is a need for the development of a valid and reliable instrument to measure self-regulatory behaviors in this context. This study aims to report a pilot of a new instrument for measuring the self-regulatory behaviors of skilled performers during practice, and to test the questionnaire's preliminary reliability using inter-item and item-total correlational tests and the Cronbach's alpha coefficient.

## METHOD

### Participants

The sample comprised 49 classically trained instrumentalists (male=52%, female=48%) from a Portuguese university, ranging in age from 18 to 58 years ( $m=25.36$ ,  $SD=7.87$ ). The musicians were engaged in undergraduate (41%) and graduate music performance degrees (masters=43%, PhD=16%). Their experience playing their instruments spanned from 5 to 52 years ( $m=12.65$ ,  $SD=7.48$ ). Among the instrumental categories investigated, strings represented the majority of respondents (45%). Other categories included woodwinds (25%), followed by keyboards, brass, and percussion (10% each).

## Materials

The initial item pool consisted of 36 items designed to assess 5 self-regulatory dimensions: self-efficacy, goal orientation, goal setting, metacognition, and self-evaluation.

The self-efficacy scale was adapted to a musical context from Schwarzer and Jerusalem's (1995) General Self-Efficacy Scale, as it has demonstrated reliable psychometrics ( $\alpha=0.80s$ ) and better adapted to expert, adult musicians. Participants responded to 10 items regarding their personal beliefs of competence to solve problems during practice. Minimal wording changes were made for the purposes of this study. For example, "I can always manage to solve difficult problems if I try hard enough" became "During practice, I can manage to solve difficult problems if I work hard enough."

The goal orientation scale comprised 5 items to assess learning and outcome orientations. Items assessing learning orientation such as "I practice with the main purpose of learning a great deal" contrast with outcome orientation items such as "It is important for me to prove that I am a good musician."

Self-regulated individuals tend to set specific and clear goals for an activity (Hoyle 2010). A 6-item scale was designed to assess the frequency of these behaviors (e.g. "I set specific practice goals") comprising the goal-setting subscale.

Metacognition was assessed through an adaptation of regulation of cognition items from Schraw and Dennison's Metacognitive Awareness Inventory (1994). The scale comprised 10 items assessing sub-processes that affect the control aspect of practice, such as notion of used strategies (e.g. "I find myself analyzing the usefulness of strategies while I am practicing"), time control (e.g. "I organize my time to practice to best accomplish my goals"), environment control (e.g. "I try to isolate/eliminate or minimize environment distractions for practice"), and social aspects (e.g. "I usually ask teachers or colleagues to listen to me playing").

Finally, self-evaluation was measured through 5 items assessing self-evaluation at the end of a practice session (e.g. "I ask myself how well I accomplish my goals once I'm finished").

## Procedure

Respondents completed the online questionnaire from 28 November 2012 to 11 February 2013. For items comprising frequency of behavior, musicians indicated responses on 5-point Likert-type scales from 1 (never) to 5 (always). For items that required levels of agreement, musicians rated responses on 7-

point Likert-type scales from 1 (completely disagree) to 7 (completely agree). Statistical analyses were run with IBM SPSS 20 statistics software.

## RESULTS

Exploratory inter-item and item-total analyses were conducted for each of the 5 hypothesized self-regulation subscales. The results suggested that deleting items from the self-efficacy (4 items), goal-orientation (1 item), goal setting (2 items), and metacognition (2 items) sub-scales would increase internal consistency. Following the removal of these items, analyses revealed that all inter-item correlations were significant ( $p < 0.01$ ), and that all item-total correlations were  $r = 0.30$  or greater.

Reliability coefficients and descriptive analyses for each subscale are presented in Table 1. The sub-scales had a moderate-to-high level of internal consistency, as determined by Cronbach's alpha reliability coefficients ( $\alpha = 0.74$  to  $0.86$ ).

## DISCUSSION

This study has developed a self-report measure of self-regulatory practice behaviors in skilled performers. The questionnaire was employed to measure underlying hypothesized dimensions of self-regulation relevant in the practice of skilled performers (self-efficacy, goal orientation, goal setting, metacognition, and self-evaluation). After deletion of items suggested by inter-item and item-total correlational tests, the five sub-scales achieved moderate-to-high internal consistency (Cronbach's  $\alpha$  from  $0.74$  to  $0.86$ ).

Providing insight into the self-regulated behavior of skilled performers may help illuminate the impact of individual and demographic factors on approaches to practice. A reliable and valid measure of self-regulation in

*Table 1.* Means, standard deviations, and Cronbach's alpha overall reliability coefficients across the 5 hypothesized dimensions of self-regulatory practice behaviors of skilled musicians.

<i>Variable</i>	<i>Means</i>	<i>SD</i>	<i>Cronbach's <math>\alpha</math></i>
Self-efficacy (6 items)	30.42	6.29	0.86
Goal orientation (4 items)	19.35	5.41	0.80
Goal setting (4 items)	14.00	7.17	0.74
Metacognition (8 items)	25.76	5.36	0.81
Self-evaluation (5 items)	17.69	2.97	0.78

skilled performers may also be useful for correlational studies intending to investigate relationships between self-regulation and performance achievement, as well as with psychological states experienced by musicians (e.g. flow state).

Next steps in this research include the analysis of variances as a way to identify whether self-regulation may statistically correlate with demographic factors of the participants and the necessary analysis of the construct validity.

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# Transfer of practice strategies: From primary to secondary instrument

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This study explored the transfer of strategic thinking and self-regulated learning in practice with musicians by observing seven undergraduate music students in practice sessions on both a newly learned instrument and their primary instruments. Students chose how to structure the sessions and were presented with the music, a pencil, and a piano. The timed, recorded practice sessions included a scale and a short, unseen melodic extract. Questionnaire results showed there to be no differences in self-reported goal-orientation, self-satisfaction, global efficacy, or self-efficacy for the two instruments. Although highly individual, both positive and negative observed behaviors such as verbalization, the approach to the material, and even avoidance of certain elements were consistent in both contexts, supporting the transfer of strategies across instruments. This suggests an opportunity for enhancement and acceleration of progress with carefully directed education and conscious application of self-regulation.

*Keywords:* self-regulation; practice; learning; transfer; teaching

Self-regulation and strategic thinking are recognized as integral to learning and achievement in any discipline. Zimmerman (2002) has defined self-regulation as “self-generated thoughts, feelings, and behaviors that are oriented to attaining goals” (p. 65). Research into self-regulation has identified processes such as goal setting, self-instruction, and help-seeking that distinguish experts from sub-experts in domains such as sport, music, and academic study (DiBenedetto and Zimmerman 2010, Kitsantas and Zimmerman 2002, McPherson and Renwick 2001). These processes are proposed to be responsible for the development of expertise through elevating the quality of practice (Bloom 1985, Ericsson *et al.* 1993).

Within music, a range of studies have identified how self-regulatory strategies change with an increase in skill level (Duke *et al.* 2009, Gruson 1988, Hallam 2001, Nielson 1999). With an increase in skill level observed changes include a shift from repeating individual notes to repeating sections, an increase in the identification and focusing on difficult sections, and increased practice at varying tempos. While these cross-sectional studies provide an overview of the development of learning strategies that matches the longitudinal perspective provided by Sosniak (1985), there is a lack of research identifying how, or indeed if, individual learners adapt their self-regulatory strategies in response to changes in the context of learning. Within undergraduate music degrees, many musicians face an extreme change of context in that they must learn a new instrument. Just as a teacher modifies teaching to meet the needs of the individual learner and context, it is important to investigate whether the learner also adapts self-regulatory strategies to meet changes in the learning context. There are indications that self-regulatory strategies are context dependent. For example, in a case study of a nine year old clarinet player, Renwick and McPherson (2002) reported superior self-regulatory behaviors during the practice of a self-selected piece, compared to the practice of a teacher-assigned piece. While changes in self-regulatory behavior between musicians of differing skill level have been well documented, there appears to be a gap in the literature in terms of identifying the extent to which learners adapt their self-regulatory strategies to changes in learning contexts.

The present research seeks to extend the literature and serve as a pilot for future studies by comparing the self-regulatory processes utilized by musicians when practicing both their primary instrument and a newly learned instrument. It examines participants' perceptions of learning and, through practical observation, investigates participants' practice behaviors on the two instruments.

## METHOD

### Participants

Seven undergraduate second-year music students, six female and one male, who were learning a completely new instrument for one semester as part of their studies, volunteered to complete questionnaires and have their practice video recorded. The students' main instruments were clarinet, violin, piano (n=2), flute, French horn, and trombone and the new instruments were violin (n=3), cello (n=2), and clarinet (n=2).



## Materials

After six weeks of group lessons on their new instruments, students completed questionnaires in relation to both their new and main instruments covering daily practice habits. The Self-efficacy for Musical Learning questionnaire (Ritchie and Williamon 2011) and an adaption of Miksza's Self-regulation measure on their satisfaction with, and efficacy of, practice methods and behaviors (Miksza 2012) were also completed. Performance material for the recorded practice session with the new instrument consisted of a scale chosen by the participant and a pentatonic Russian folk song, which was deliberately chosen for its repetitive nature so it would be easily discernible for someone with musical knowledge. For the primary instrument, participants chose a scale and the melodic material was a full piano and vocal score of the traditional song *Danny Boy*.

## Procedure

Each participant was brought to the practice room, containing a piano, chair, stand, and pencil. They were informed that researchers were interested in their practice methods and habits, and for a short five-minute session they were to practice their new instrument, covering both a scale of their choice and the short melodic extract provided. Participants were told that the structure and what they did in the time was completely up to them. This process was repeated one week later with participants' main instrument. Ethical approval was granted by the University of Chichester Research Ethics Committee.

## RESULTS

There were no significant differences in any of the self-reported measures of practice habits between the primary and new musical instrument: time spent practicing, percentage of practice time with a specific goal, global efficacy of practice sessions, or self-satisfaction with practice. There was no significant difference between the reported self-efficacy for musical learning with respect to the primary instrument (mean=57, SE=3.5) and the secondary instrument (mean=54.6, SE=3.8),  $t_8=1.18$  ( $p>0.05$ ).

Practice behaviors from the recorded sessions were analyzed for differences between the primary instrument and new instrument in terms of time on piece, time on scale, deliberation on piece, deliberation on scale, avoidance on piece, avoidance on scale, total deliberation time, and total avoidance time (see Figure 1). Of these, only the time on piece differed significantly between

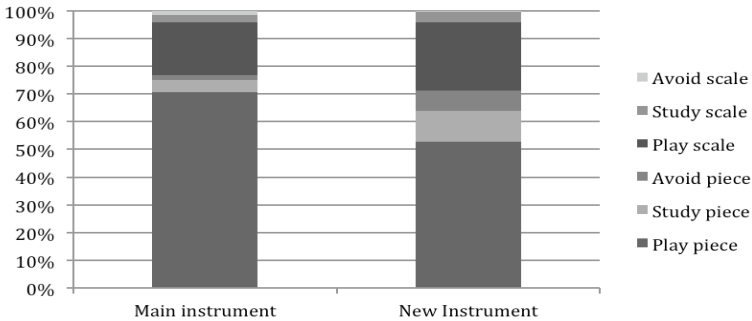


Figure 1. Percentage of time dedicated to different activities within the recorded practice sessions.

the two practice sessions, with participants playing the piece for significantly longer on their primary instrument (mean=215 seconds, SE=22 seconds) compared to their new instrument (mean=155 seconds, SE=10 seconds),  $t_6=3.33$  ( $p=0.016$ ,  $r=0.78$ ).

Overwhelmingly, participants adopted a linear, note-by-note approach to playing: working directly from beginning to end on both instruments, and if time allowed, repeating the entire scale or piece. Nobody used the piano to assist learning on the new instrument. Observed behaviors such as verbalization or patterns of repeating notes or sections from the beginning of the piece were found across both instruments. Playing time on the piece decreased significantly from primary instrument to new instrument. The change in time (to avoidance, deliberation, practice of scale) was highly individual. This lack of strategic practice contradicts the high self-reported measures on efficacy of practice methods and behaviors.

## DISCUSSION

Observing comparable methods and habits in both primary and new instrumental practice suggests that practice behaviors and strategies, whether positive or negative, do transfer to new, different musical pursuits.

These students were at the beginning of learning a second instrument and were aware of the differing technical requirements, for example, in playing a brass instrument and playing the piano. Yet, they adopted similar approaches for both instruments, regardless of whether behaviors were necessarily appropriate, and demonstrated a particular lack of strategy with the melodic material. In the scale, across both instruments, students played long notes,

changed articulation, or tempo, but strategic methods were minimal, and several merely played through the scale once or twice. The melodic material was quite short and very repetitive, but without a holistic understanding of the tune before attempting it on their new, less familiar instrument, the technicalities of producing individual notes became the focus of the practice. These results echo the approach of some young learners who, at the beginning of their studies, showed little self-regulation in terms of goal setting or strategic planning (McPherson 2005).

The lack of connection between the technical and melodic work raises questions of how awareness of effective learning strategies can be enhanced; these students demonstrated confidence in their capabilities for effective practice, but self-regulation was not evident in the sessions. Identifying structures, patterns, and having a hierarchically planned approach can greatly increase the productivity of the practice (see Miksza 2007). Consistent with previous research (Hallam 2001), discrepancies between self-reported and observed self-regulation were evident, suggesting that greater self-observation and reflection may be necessary to develop self-regulation.

The present study investigated the extent to which undergraduate music students adapted their self-regulatory strategies to meet the demands of a novel learning context. Results indicated that practice habits, both positive and negative, transfer across practice contexts. This application of behaviors from one instrument to another highlights the possibilities for and limiters of progress in new, related pursuits.

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# When less of the same is more: Benefits of variability of practice in pianists

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Variability of practice has been demonstrated to have beneficial effects for motor skill acquisition, transfer, and retention. This study extends the line of research to musical practice. Pianists were trained to perform a wide interval leap on the piano with their left hand. Performance at the target distance was tested before and after a 30-minute controlled training. One group (FIX) practiced the target interval only. The other group (VAR) received variable training on four different intervals including the target. Transfer was tested on an interval novel to either group. Retention was assessed in a retest 24 hours later. Leap Distance Error (LDE) and Leap Execution Time (LET) were measured. After training, LDE improved non-significantly in both groups. In the VAR group significant improvement was seen on the next day. This was not the case in the FIX group. In contrast to the FIX group, the VAR group showed significantly faster LET after training compared to baseline, which was stable at retention. The findings are discussed with regard to predictions made by theories of motor learning and implications for musical practice.

*Keywords:* variability of practice; piano; motor skill acquisition; musicians; schema theory

Playing music is a difficult motor skill orchestrated by goal-directed movements. Findings from motor learning research may be applicable to instrumental practice. Schmidt's "schema theory" (1975) formulates a schema as an abstract code for a class of movements with a common pattern. Schema learning is the gradual formation of a central prototype from a number of specific experiences within a motor class. The *variability of practice* (VOP) hypothesis predicts that practicing a particular skill under variable, as opposed to constant, conditions builds a more effective generalized motor pro-

gram. This would be reflected accordingly in superior learning, retention, and transfer compared to constant learners. Shea and Zimny (1983) suggested that variability effects were due to *contextual interference* (CI), which may be (1) emphasized by inter-trial elaboration and distinctive processing of representations in memory (Shea and Zimny 1983) or (2) an increase in effortful processing activity (Magill and Hall 1990). The CI hypothesis, like the VOP hypothesis, predicts better transfer and retention but poorer performance (in variable compared to fixed learners) during the initial acquisition phase.

McCracken and Stelmach (1977) presented a task involving time-constrained hand movements to targets at defined distances. The training phase consisted of 300 trials on four randomly alternating distances for one group, and of 300 trials on just one distance for another group. Our aim was to utilize a similar leap motion (musical interval on a piano) in musicians in order to test whether or not the predictions made from VOP and CI apply to musical practice.

## METHOD

### Participants

Twenty right-handed music students took part in the experiment (9 female, age  $20.5 \pm 2.2$  years). All participants studied piano as their minor subject, a choice made in order to avoid ceiling effects. Demographic information, handedness, practice habits, and musical biography were obtained through a questionnaire. Participants were randomly assigned to one of two experimental groups.

### Materials

The experiment was performed on a digital piano. The tasks were presented as musical notation via a monitor. Performance data were collected via MIDI interface. Statistics were analyzed using SPSS (IBM).

### Procedure

The core task for the pianists was to train to perform a wide interval leap on the piano with their left hand. At both starting and end position of the leap, two notes at an octave distance were played by the thumb and fifth finger respectively. In the time domain, the training goal was to execute the metronome-guided leap in 187.5 ms (as a semiquaver at 80 bpm per quarter note).

Both groups exercised a 190-trial standardized computer-interactive training session. One group of participants (FIX) practiced the target interval

only (spanning 15 semitones, i.e. a musical minor tenth). The other group (VAR) received variable training on the diatonic intervals of 8, 12, 15, and 22 semitones, thereby spending only 25% of their trials on the actual target interval. The intervals were presented in small blocks of five trials each and the block order was randomized. For either group, the first (PRE) and the last (POST) fifteen trials of the training sessions, respectively, consisted of target trials only. A novel transfer task was administered following the completion of training; in this case, a diatonic 19-semitone leap.

Following a 24-hour period without further exposure to the instrument, retention (RET) on target and transfer intervals was tested. Performance measures were Leap Distance Error (LDE) and Leap Execution Time (LET). Comparisons were carried out using Mann-Whitney (between-subjects) and Wilcoxon (intra-subject) tests and Holm-Bonferroni corrections for multiple comparisons. Global alpha was set at 0.05.

## RESULTS

### Leap Distance Error

LDE (see Figure 1, left) improved non-significantly in both groups (FIX: PRE median=0.44 semitones off-target, min=0.1, max=1.4; POST 0.31, 0.13, 0.83; VAR: PRE 0.51, 0.27, 0.94; POST 0.35, 0.00, 0.78). In the RET data, significant improvement was seen compared to PRE for the VAR group (0.35, 0.10, 0.61;  $p=0.037$ , Wilcoxon), while in the FIX learners the RET performance (0.41, 0.14, 1.14) did not differ significantly from the PRE-training baseline. For transfer conditions, no significant differences compared to PRE were found in either group after training and at retention (medians: POST: VAR 0.34, 0.08, 0.71, FIX 0.32, 0.23, 0.61; RET: VAR 0.36, 0.11, 0.66, FIX 0.40, 0.14, 0.77).

### Leap Execution Time

For LET (see Figure 1, right), the VAR group improved their LET from 277 ms (214 ms, 378 ms) at PRE to 238 ms (217 ms, 272 ms) at POST ( $p=0.021$ , Wilcoxon). The effect was stable at RET (243 ms, 219 ms, 286 ms;  $p=0.026$ , Wilcoxon). The FIX group showed no significant changes (PRE: 267 ms, 228 ms, 404 ms; POST: 233 ms, 209 ms, 482 ms; RET: 254 ms, 224 ms, 341 ms). For transfer conditions, no significant differences compared to PRE were found in either group (POST: VAR 257 ms, 218 ms, 318 ms, FIX 260 ms, 214 ms, 456 ms; RET: VAR 255 ms, 218 ms, 302 ms, FIX 272 ms, 224 ms, 344 ms).

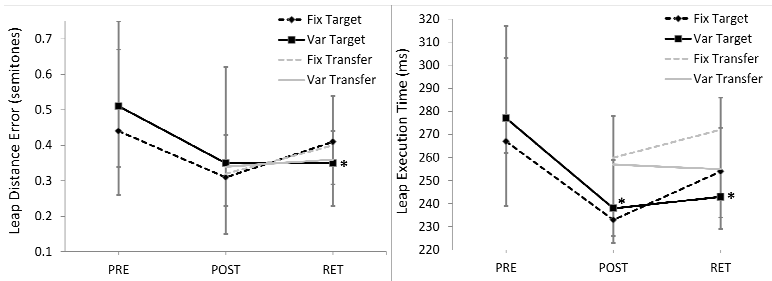


Figure 1. Group medians of LDE (left) and LET (right) for the groups VAR (solid lines, N=10) and FIX (dashed, N=10); before (PRE) and after (POST) training, and after 24 hours (RET). The grey lines indicate performance at a transfer task for the respective groups/sessions. Error bars represent upper and lower quartiles. \* $p < 0.05$  (Wilcoxon) compared to PRE.

## DISCUSSION

The overall results of the present study are consistent with Schmidt's (1975) *variability of practice* hypothesis. However, a *contextual interference* effect could not be observed; rather than showing an initially worse performance than the FIX group at the end of the acquisition phase, the VAR group performed similarly well for the reported performance measures.

The advantages of variable learning over fixed learning in this specific paradigm can be summarized as follows: after training, learners who underwent a variable practice schedule showed no disadvantages with respect to accuracy and timing precision compared to constant learners. This is worth highlighting insofar as their number of different content items, acquired within the same amount of practice time, was *four times as high* compared to constant learners. With respect to accuracy and timing precision, variable learners *consolidated* their skill into a stable representation more successfully than constant learners.

One reason why several of the within-subject and between-group differences were not significant (besides the small sample size) may be attributed to the limited impact of a single and short training session. In the motor learning literature, interventions typically last up to several weeks. Although for the training of more complex sequences at the piano, some training effects within a single session have been demonstrated for novices (Bangert and Altenmüller 2003). The outcome from a single session in advanced piano students, however, may not represent a typical scenario of rehearsing music.



While the present results indicate possible advantages of variable learning for long-term consolidation in the task investigated here, constant learning is known to provide superior results in other contexts. Various empirical accounts have indicated that the complexity of a task is of crucial relevance (Wulf and Shea 2002). As complexity increases, learners seem to benefit more from the opportunity to repeat and refine their responses on successive trials. As a consequence, CI tends to be reduced or eliminated with more complex tasks. Musical movement sequenceness are more complex than the task in the present study. However, an additional advantage of VOP may be motivation. Because variable learners are frequently changing tasks, practice may seem less repetitive, potentially increasing the level of engagement. A higher diversity within practice schedules may give learners a larger “work-space” (Davids *et al.* 2001), keeping them motivated and encouraged (Simon and Bjork 2001). However, this issue has not been addressed in the present study.

Building upon the present findings, further research can extend and complement the paradigm in a number of ways. As elaborated above, the degree of complexity is an important parameter which can be systematically varied on the piano. Another interesting option might be to design transfer paradigms that involve the transfer of a unimanual motor skill to the “naïve” contralateral hand.

We conclude that variability of practice might be advantageous over constant practice in specific contexts of musical practice.

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**Thematic session:  
Performance education III**



# Promoting schema formation among wind musicians of varying abilities

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Cognitive load theory identifies three types of cognitive load present during learning: *intrinsic*, *extrinsic*, and *germane*. To optimize learning, cognitive load theory recommends optimizing germane load. The purpose of this study was to examine the interactions among intrinsic and germane cognitive loads when practicing a wind instrument. The study will determine which of two practice strategies is most effective for three levels of learners on a woodwind instrument. Forty-five participants were university music majors and minors with either (1) no experience playing a woodwind instrument, (2) limited experience, or (3) a woodwind major or minor. In a repeated-measures design, students practiced three technical tasks in a random order (high cognitive load) and three technical tasks in a repetitive order (low cognitive load). Participants practiced on a MIDI wind controller, which is similar to a saxophone. Twenty-four hours following practice, participants completed a second study session for retention measurement. Performances were scored for pitch accuracy and speed. Within-subjects comparisons examined which level of cognitive load was most effective for each level learner. Results will be situated in prior research on cognitive load theory, and implications will be drawn for practice.

*Keywords:* cognitive load; practice; MIDI; wind instrument; schema

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# Simply the best: Presenting Australian art song pedagogical performer's analyses to singing teachers

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This paper is a report of the third phase of research in a larger study designed to ascertain the most suitable pedagogical issues and frames by which both singers and singing teachers could more easily approach the learning, teaching, and performance of Australian art song. Ten pedagogical analyses of Australian art songs of varying voice types, ability, and styles were written and co-graded by the researcher and a “critical friend” (i.e. another professional singer and singing teacher). Nineteen of 28 professional international singing teachers responded to a “song package” sent to them including a questionnaire, information about the included song with suggested performance strategies, a suggested grading based on the (adapted) Ralston Repertoire Difficulty Index (RRDI), a copy of the score of the song, and a representative recording of it. The questionnaire asked teachers to evaluate the presentation of the analysis, the grading of the song using the information grading sheet, music of the song and the included recording, and to provide some personal details related to their teaching. Eighteen of the teachers agreed that contextual, performative, and pedagogical/musical information, coupled with an accompanying performer's analysis of a song that was graded, was “simply the best” way to pedagogically frame an Australian art song.

*Keywords:* Australian art song; performer's analysis; practice-led research; teaching; learning

Australian art song, like art song of many countries, is seldom performed, not because of its quality, but more from a lack of public performances that would allow performers and audiences alike to become accustomed to it. The issues that challenge both singer and singing teacher in learning and teaching two-

tieth/twenty-first century art song, including those of melody, original manuscripts, out-of-print scores, and copyright issues, all present challenges to the performer and teacher before beginning to learn a song. “Melody” may become melodic fragments or “cells” and may be perceived differently in contemporary music, challenging the singer to adopt new strategies to encourage confidence in securing pitch (Mabry 2002, Aggett 2008). Rink’s (2002) writing on performer’s analysis—the relatively recent approach to writing critically about performance and preparation—has been adopted in this study when designing performer’s analyses of all vocal works. A review of 18 vocal (n=11) and instrumental (n=7) surveys determined that a survey design or “frame” which presented information that included a difficulty grading plus a detailed explanation of the grading (Mabry 2002, Pellerite 1965), pedagogical information (Magrath 1995, Miller *et al.* 2005), and some annotation of the presented repertoire, were the most effective. Ralston’s (1999) Repertoire Difficulty Index (RRDI), which draws on previous research by Jones (1988) and Hu (1991), was found to be the only tested grading system for vocal repertoire. This index was adapted (Aggett 2008) to make it relevant for grading repertoire of the twentieth and twenty-first centuries for all voice types—important information for singers and singing teachers.

Phase one was an international, qualitative e-mail study with sixteen professional singers into the ways in which they prepare and select solo vocal repertoire for a performance to ascertain the strategies they used. Phase two involved four professional singers (including the researcher) and four accompanists in practice-led, performance-based research in preparation for two public recitals of 41 Australian art songs, applying some phase one strategies in their preparation, documented through practice-led processes. Strategies gathered in the first stage of the research informed the performances, and in some cases, expanded upon them. Nineteen international professional singing teachers participated in the third and final phase, reported here, which aimed to ascertain the most suitable pedagogical issues (e.g. grading level, pedagogical information) and pedagogical frames by which singers and singing teachers could more easily approach the learning, teaching, and performance of Australian art song.

## METHOD

### Participants

Nineteen professional singing teachers completed the study from five different countries. The singing teachers ranged in experience from 4 to 30+ years, teaching in private studios (n=12), institutions (n=7), as well as in both school



and private studios (n=2). The student profile of the teachers' studios varied greatly, comprising of: postgraduates (n=6), advanced students (n=3), teens (n=2), studios varying in ages from 4 to 77 years (n=6), and studios with students of unknown age (n=2).

## **Materials**

Following the practice-led/practice-based phase two, ten of the 42 Australian art songs covering a range of voice types, styles, genres, and abilities were selected to write up as pedagogical performer's analyses (Rink 2002; see Table 1). Songs were graded using Ralston's (1999) Repertoire Difficulty Index (RRDI) adapted by Aggett (2008). The index grades each of the seven criteria (range, tessitura, rhythm, phrases, melodic line, harmonic foundations, and pronunciation) as easy (E), moderate (M), or difficult (D), and was expanded to encompass aspects of twentieth and twenty-first century vocal repertoire to suit all voice types and levels of ability. Songs were also allocated an holistic grading from 1 to 5, the grading allocated to each of the seven graded RRDI criteria taken into account when assigning the holistic grading, which took into consideration all factors, including the performer's analysis.

## **Procedure**

Phase three of the study, the focus of this paper, began with all performance analyses being sent to a "critical friend" for comment. After responding to the feedback, a "song package" was piloted by three Australian singing teachers. The "song package" included a questionnaire, pedagogical information about the included song with suggested performance strategies (a performer's analysis), a suggested grading based on the adapted RRDI, a copy of the score of the song, and a representative recording of it. After responding to the pilot participants' responses, the "song package" was sent to singing teachers seeking their opinions of the ten pedagogical analyses of Australian art songs of varying voice types, ability, and styles with strategies that had been trialed in performance by singers and pianists. All songs were graded using the adapted RRDI. It was decided when designing the pedagogical analysis sheets that the learning and practice strategies would be listed for both singers and teachers, and then be systematically discussed in the performer's analysis, with the analysis discussing how those strategies could be applied in the learning and performance of the song, given all of the different aspects listed as features of the song on the sheet. The questionnaire asked teachers to: evaluate the presentation of the analysis, the "frame" (3 questions) and the grading of the song using the information grading sheet, the score of the song,

Table 1. 10 Australian art songs sent to professional singing teachers in phase three of the research as pedagogical performer's analyses.

	<i>Song title</i>	<i>Composer</i>	<i>Poet/author</i>	<i>Voice type</i>	<i>Grade</i>
1	Nightwind (1914)	Margaret Sutherland	Emily Brontë	(any)	2
2	The Wallaby and the Bullant (1980)	Colin Brumby	"The Perfesser and his Alter Ego"	Child	1
3	Moonrise (1983) (Pilot)	Gordon Kerry	Carolyn Masel	Sop	4
4	Son of mine (1992)	Mary Mageau	Oodgeroo Noonuccal (Kath Walker)	Sop	3
5	I'm Nobody, <i>Frogs</i> (1995)	Nigel Butterley	Emily Dickenson	Med-high	5
6	And no bird sings, <i>The Hermit of the Green Light</i> (1979)	Ross Edwards	Michael Dransfield	Counter-tenor/ contralto	3
7	Spirits, <i>Remembering Babylon</i> (1997)	Diana Blom	David Malouf	Ten	4
8	At Telegraph Bay I (1984)	Anne Boyd	John Spencer	Bar	4
9	Curtain (1930s)	Esther Rofe	Grant Uden	(Suit bar)	3
10	Song of the Cattle Hunters (1956)	Miriam Hyde	Henry Kendall	Bar	2

and the recording (1 question); answer a question as to whether they taught Australian art song or art song by composers of their country, with space for comment on both the analysis of the song and any other comments (2 questions); and to provide some personal details related to their teaching (7 questions). Main themes evident in the data were identified using the qualitative data analysis software program *NVivo*.

## RESULTS

Thirteen of the teachers found this presentation (framing) of the performer's analyses to be effective. Blake (pseudonym), for example, commented that *Telegraph Bay* by Boyd was "presented clearly and concisely." Eighteen of the teachers agreed that the inclusion of contextual, performative, and pedagogical/musical information was "quite helpful," offering a possible saving of time for both singers and singing teachers, and offering a "springboard for learning and teaching" (Donna, writing of Kerry's *Moonrise*). Lucy noted that "all the

strategies could come in handy and be easily achieved” (in Mageau’s *Son of Mine*) and were “clear, to the point” (Nina, in Blom’s *Spirits*). Mia commented that the presented sections in the pedagogical analyses—contextual, pedagogical/musical, performative criteria, and the performer’s analysis—were “really helpful for beginning teachers, as every one of the teaching points are laid out and all of the features are what I would be following.” The teacher who did not find the material helpful felt the performer’s analysis was “far too long” and they “doubted if a busy teacher would read it” (Isabelle in Edward’s *And no bird sings*).

Fourteen of the nineteen participants agreed with the grading assigned to the songs, with five participants adding reasons for their opinions. Their responses indicated thorough readings of the vocal scores and accompanying recordings and in some cases, trying out the score themselves. The grading was considered complex by some and those offering a negative or no opinion of the grading may reflect this aspect. The majority of teachers (n=17) teach either Australian or national repertoire of their country to their students, giving reasons for teaching such repertoire within a balanced program. Those teaching international repertoire made comments about the way in which they use songs from their heritage, as well as including examples of the songs or composers they teach. Hanna believes it “important for her students to be aware of the large and varied repertoire available to them, much available for free loan.” Sophie teaches both New Zealand solo art songs to teenage girls and older students and arrangements of Maori Waiata. Kylie accesses songs from Sounz, the New Zealand Music Centre. Responses reflected the diversity of repertoire being taught and of the different geographical approaches and perspectives that influence them and, consequently, their students.

## DISCUSSION

The framing of information of the pedagogical performer’s analyses from a number of viewpoints, particularly as time saving, was highlighted by many participants as being helpful and welcomed. For the majority of singing teachers (18 of 19), contextual, performative, and pedagogical/musical information, coupled with an accompanying performer’s analysis of the song that was graded in some way, was “simply the best” way to pedagogically frame an Australian art song. Participants had a lot of information to absorb. This was particularly so with the grading, deemed an important aspect of repertoire selection from the initial literature review; the RRDI being identified as the only tested repertoire difficulty index was seen as an important issue to include in the study. More work needs to be done in this area, and the attempt

to adjust the index to suit twentieth and twenty-first century vocal repertoire seems to have been at least partially successful.

It was expected and evident from the responses that there were differences in the way teachers approach the teaching of a song in the same way that singers differ in the way in which they approach its learning. Influences including philosophical, pedagogical, geographical, contextual, and institutional factors, as well as age and gender differences, arguably all impact on the responses given by singing teachers presented in this phase of the research. The performer's analyses of the study hope to encourage singers and singing teachers currently not engaging with singing and teaching contemporary Australian art song to do so and add their voices in this quest to discover "simply the best" way to learn and teach contemporary Australian art song.

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# The *Orff-Schulwerk* approach and optimal experiences: A case study in a music education context

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This study's main objective was to share results and *Flow Theory*-based analysis of an on-going longitudinal study on music pedagogy and development in a Portuguese music education context. *Optimal experiences/flow states* were experienced by fifth and sixth grade students during music education classes based on the *Orff-Schulwerk* approach. In order to assess musical engagement, questionnaires (based on *AFIMA - Adapted Flow Indicators in Musical Activity*) were given to students. The results obtained were related to the indicator "challenges and skills," which is an AFIMA dimension and a fundamental parameter of flow state occurrence. The objective of this longitudinal study was to show that musical activities based on the *Orff-Schulwerk* approach provide a flow-sustaining strategy during music education classes. This research also intends to contribute to an area where information is still scarce on the connection between learning through the *Orff-Schulwerk* approach and the flow-related behaviors of optimal experience. This holistic music learning experience may prove to be important not only in relation to how students acquire music knowledge, but also in how to develop their personalities in a holistic way.

*Keywords:* *Orff-Schulwerk* approach; optimal experience; flow theory; music education; Portugal

At the end of the last century, Sloboda (1999) brought attention to the poor quality of music education in many schools, in which he claimed that the message given was that "if you haven't got talent, you should stop wasting your time messing around with music, and concentrate on your maths or business studies" (p. 455). Today, UNESCO (2012) reports benefits to introducing art education into learning environments. This allows for balanced

intellectual, emotional, and psychological development of individuals and societies. Such educational tools not only strengthen cognitive development, but also aid in the acquisition of life skills. In most cultures the arts are integral to life, as function, creation, and learning are intertwined (UNESCO 2012). Therefore, music education experiences, such as singing, playing, and movement, bring benefit to children's holistic development as human beings. Regrettably, under the current Portuguese education system, as defined by the music education curriculum (Ministério da Educação 1986, 2005), students enrolled in the fifth and sixth grades only experience formal compulsory musical education once per week, and most of them only start to learn music at the age of 10 and continue for a two-year period. Based on collective experience, the authors strongly believe that the *Orff-Schulwerk* approach of "live, learn, and enjoy" can allow these students to fully experience music in this short period of formal learning.

*Orff-Schulwerk* is a particularly flexible and effective approach to music education due to the wealth and balance of different learning forms involved. Developed by Carl Orff and Gunild Keetman, *Orff-Schulwerk* is supported by a wide range of integrated forms such as speech, music, movement, and dance, and is an "all learning process" that can be developed into a complex range of forms, motives, and structures. Carl Orff's principal approach to music education was to always awaken human potential for "being musical" (meaning to be able to understand and use music and movement as forms of expression), and to place practical knowledge in the center of the teaching-learning process (Orff 1932, 1963). Attaining a higher level of development is fundamental and timeless, and creativity has a central role. Connectivity between multiple sources, aspects, and parameters (such as rhythm, melody, movement, and language) is a requirement. In an Orff classroom children sing, move, and play *instrumentarium*. They improvise rhythms, melodies, and movements (Cunha and Carvalho 2012).

Based on the *Experience Sampling Method (ESM)*, Custodero (2005) developed and applied *FIMA (Flow Indicators in Musical Activity)* and *AFIMA (Adapted Flow Indicators in Musical Activity)* in a music education context in order to verify and to analyze what Csikszentmihalyi (1990) described as *optimal experiences/flow states*.

*Flow theory*, based on optimal experiences, uses four essential components: control, attention, curiosity, and intrinsic interest (Csikszentmihalyi 1990). Flow states occur when someone is in self-control, is goal-related, and identifies with meaningful actions. According to Csikszentmihalyi (1990) there is a *flow channel* between "boredom" and "anxiety" states, produced by the equilibrium between increasing levels of "challenges" and "skills." Flow

state moments are lived in the flow channel, and usually occur when a person's body or mind is stretched to its limits in a voluntary effort to accomplish something difficult and worthwhile. Therefore, by balancing high levels of "skills" and "challenges" we are able to generate high output of ideas, productivity, satisfaction, and forward momentum.

Following previous research (Cunha and Carvalho 2012) and using FIMA and AFIMA (Custodero 2005), this paper aims to share results concerning the monitoring indicators "challenges" and "skills" as flow state elements, as presented in Figure 1 (*Flow Theory Schematic Representation*; Csikszentmihalyi 1990). The produced data adds relevant information to the authors' preliminary studies where different examples of FIMA and affective indicators were observed in relation to emotions lived by the students in classes based on the *Orff-Schulwerk* approach (Cunha and Carvalho 2012).

## METHOD

### Participants

This study involved 50 students aged between 10 and 12 years old. The students were attending the fifth and sixth grades of a Portuguese public general school. The fifth grade students were in their first year of formal music education.

### Materials

In order to observe flow states in the context of music education we have constructed a questionnaire with three different flow monitoring dimensions (affective indicator, challenges and skills indicator, and subjective indicator) based on ESM and, subsequently, on AFIMA (Custodero 2005). In order to better capture the qualities of the indicators, data were descriptively (affective and subjective indicator) and statistically (challenges and skills indicator) coded and analyzed.

### Procedure

Guided by the teacher-as-researcher methodology, data were collected over twenty-five music education classes for a full academic year. Based on the *Orff-Schulwerk* approach, classes were divided into three pre-defined categories: (1) thirteen "general" classes, (2) six "music laboratory" classes, and (3) six "music and movement" classes (for short descriptions and examples see Cunha and Carvalho 2012). In the end of each class students individually answered the questionnaire in order to identify the experienced monitoring

flow indicators. In total, 637 questionnaires were answered and served as data that were then treated and analyzed using statistical analyses of monitoring indicators used by Custodero (2005). With respect to the current stage of the ongoing research, the following results (specifically, the challenge and skills indicator dimension of AFIMA) have been measured using a Likert scale of, 0-1=no (not at all), 2-4=somewhat, 5-7=quite, and 8-9=very.

## RESULTS

The results presented in Table 1 concern all twenty-five classes (fifth and sixth grades). The “general,” “music laboratory,” and “music and movement” categories are represented in Figure 1 by the A, B, and C points, respectively. The D point represents the average of all categories and reveals the global challenges and skills indicator.

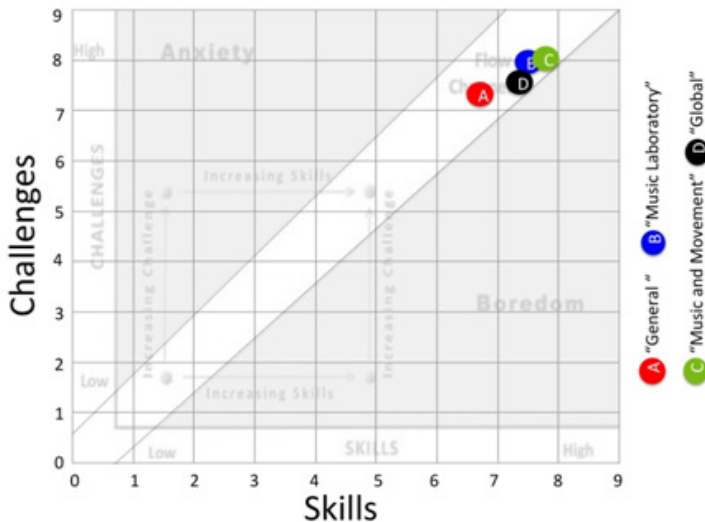


Figure 1. Challenges and skills indicator responses of Orff-Schulwerk students in “general,” “music laboratory,” and “music and movement” classes presented in relation to Csikszentmihalyi’s (1990) *Flow Theory Schematic Representation*. (See full color version at [www.performance-science.org](http://www.performance-science.org).)



*Table 1.* Means (and standard deviations) of challenges and skills indicator responses.

<i>Class category</i>	<i>n</i>	<i>Challenges</i>	<i>Skills</i>
General (A)	308	7.17	6.86
Music laboratory (B)	163	7.90	7.49
Music and movement (C)	166	7.98	7.73
Global (D)	637	7.68	7.36

## DISCUSSION

Consistent with the results obtained in the pilot study to this project, and considering Csikszentmihalyi's *Flow Theory Schematic Representation* (1990; see Figure 1), these results reveal the existence of a balance between challenges and skills as a crucial element to the occurrence of flow states. Accordingly, the present findings support the notion that flow is an optimal state determined by an individual perception of high skill and high challenge for a given task (Custodero 2005), reporting high values in response to challenges and skills indicators.

In conclusion, according to affective indicators previously presented (Cunha and Carvalho 2012), these results not only corroborate the occurrence of flow states, but also correlate them with high AFIMA levels, which implies that the *Orff-Schulwerk* approach may prove to be a flow-sustaining strategy in the context of music education. Therefore, while experiencing the activities of the *Orff-Schulwerk* approach students not only acquire musical knowledge (through singing, moving, dancing, and playing percussion instruments), but may also live out optimal experiences.

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**Thematic session:  
The science of dance II**



# Entrainment in ballroom dances: The influence of the pair in the synchronization with the music

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In personal interactions, such as ballroom dances, there is an element of competition tending to keep the rhythm of each element of the pair (*maintenance tendency*), as well as a component of cooperation (*magnet effect*) and attraction by the rhythm of the other. Not everyone has the same ability to synchronize their movements with timekeepers, such as musical beats. In this study we intended, in a first phase, to measure this ability to change the *spontaneous motor tempo* (SMT) to synchronize the movements of ten different styles of dance with the tempo imposed by a metronome (*compulsory motor tempo*; CMT). Then we intended to verify the influence of the other, in experienced pairs, in the synchronization of the CMT. The results indicated that male participants presented higher SMTs than the female members of the same pair and higher values in *Latin* styles relative to *standard* styles. For the central objective of the study it was found that couples tended to help one another positively when synchronizing with the CMT, with a decrease of 9% of individual mistakes and 18% of mistakes per couple.

*Keywords:* entrainment; ballroom dances; spontaneous motor tempo; synchronization; interpersonal coordination

To dance at a professional level requires several physical and psychological capacities. Among them are coordinative abilities (rhythm, balance, spatial orientation, etc.) and the capability to synchronize movements with timekeepers, such as musical beats. Ballroom dances are always performed in pairs, demanding interpersonal coordination capacity and the entrainment of two people to perform the same motor task. For many authors, such as Brown *et al.* (2006), dance movement generally mirrored the hierarchical arrangement of strong and weak beats found in musical rhythm patterns. But this

situation does not arise when dancers dance without music, being forced to find their own rhythm internally, in the absence of an external sound stimulus. Igor Stravinsky spoke of the need for choreography to realize a form independent of that of music, while still being measured against it (Craft 1934). From his work with choreographers he conceived the idea that movement was structured independently of music. There seems to be evidence that, regardless of musical structure, we all have a spontaneous motor tempo (SMT): a person's preferred rate of moving (walking, running, tapping, dancing); a comfort zone, expressing an individual tempo to perform motor tasks. The main objectives of the present study focused on the assessment of the capacity of each participant to get away from their SMT (measured without any sound) and to synchronize with a required metronome tempo (CTM), in a range between 95 and 155 bpm, executing the basic steps of each of the ten ballroom dances that are part of international competitions. Then we sought to determine the influence (positive, negative, or neutral) of the pair in the performance of that task.

## METHOD

### Participants

The sample consisted of 12 (6 female, 6 male) competitive level ballroom dancers (professional and pre-professional). The average age was 25.92 years ( $SD=4.32$ ), ranging between 21 and 33 years. The average dance experience was 9.17 ( $SD=3.99$ ) years, with a minimum of 5 and maximum of 17. On average pairs danced together for 4.67 ( $SD=1.97$ ) years. The criteria for sample selection were the experience of regular participation in international competitions, the practice of the ten styles of ballroom dances (*standard* and *Latin*), and a minimum of three years of work with the same pair.

### Materials

In this study a digital metronome (EMT-888) was used to impose different tempos as well as a digital video camera (Panasonic Model No. NV-GS60E) to record the performances.

### Procedure

Participants were asked to dance ten ballroom dances in front of a camera without any sound (SMT). After that, subjects were asked to follow the tempo imposed by the metronome for each dance (CMT), as solo and in pairs. Three observers (experts in dance) identified the SMT by watching the collected

images and adjusting the metronome to match. In a second phase the observers analyzed the images taken with CMT to assess individual and paired performances and choose one of three possible conditions for each of the ten dances: synchronized, faster, or slower.

## RESULTS

Regarding the average for the ten individual dances studied, the SMT ranged between 96.40 (SD=15.31) and 103.60 (SD=14.59) bpm, *rumba* being the slowest (M=79.41, SD=3.42) and *jive* the fastest (M=124.91, SD=5.46). *Waltz*, *foxtrot*, and *tango* showed low values (M=84.58, SD=3.94; M=84.75, SD=5.02; M=86.83, SD=4.70) and the remaining five dances were much higher: *paso doble* (M=101.66, SD=2.36), *samba* (M=105.50, SD=3.23), *cha-cha-cha* (M=105.66, SD=3.77), *quickstep* (M=106.50, SD=5.00), and *Viennese waltz* (M=107.75, SD=4.99), though still far from the *jive* values. Two clear tendencies were observed when comparing the two groups of dances and tempos of each subject in relation to its pair. The masculine partners always presented higher tempos than his female pair (see Table 1), with the average value of this difference equaling 3.71 bpm. All subjects showed higher values in *Latin* dances compared with the *standard* dances, retaining the previous intra-pair difference for all the cases.

Table 1. Spontaneous Motor Tempos in bpm (SD), without metronome.

	<i>10 styles</i>	<i>5 Latin styles</i>	<i>5 standard styles</i>
M 1	99.10 (12.58)	99.40 (14.36)	98.80 (12.24)
F 1	96.70 (13.70)	99.20 (14.89)	94.20 (13.61)
M 2	100.00 (14.97)	104.00 (17.23)	96.00 (12.94)
F 2	97.40 (14.18)	102.60 (15.37)	92.20 (12.19)
M 3	100.30 (14.39)	106.40 (16.50)	94.20 (10.03)
F 3	96.40 (15.31)	102.60 (18.06)	90.20 (10.26)
M 4	103.60 (14.59)	107.20 (18.50)	100.00 (10.22)
F 4	97.00 (16.32)	104.60 (16.83)	89.40 (13.11)
M 5	100.40 (15.59)	106.60 (17.11)	94.20 (12.56)
F 5	97.40 (14.71)	103.00 (16.05)	91.80 (12.30)
M 6	100.30 (15.30)	104.60 (15.84)	96.00 (15.17)
F 6	96.50 (15.28)	101.00 (16.36)	92.00 (14.40)

The values of CMT (with metronome) were higher (on average 25.75 bpm greater) than the ones presented for the SMT, but similar to those found in the world champions of recent years. Most of the participants (46%) had difficulty in getting out of their comfort zone, presenting an execution closer to the SMT than to the value requested in the CMT condition. In Table 2 we can see the results of the analysis carried out by experts for solo and pair situations. In general we can see that the presence of the other has reduced the mistakes, helping to fulfill the task of synchronizing with the CMT. With the help of the pair the individual mistakes decreased 9%, from 46% to 37% (from 55 to 44 in 120 possible). But this synchronization increase is even more marked when analyzing mistakes per pair, in which there was a decrease from 60% to 41% (from 36 to 25, in 60 possible). In the slower and faster dances there was a positive influence, while in two dances placed in the middle of the scale (*tango*=120 bpm, *cha-cha-cha*=125 bpm) the number of desynchronized pairs increased from 3 to 4.

## DISCUSSION

We can say that the *magnet effect* overlapped the *maintenance tendency*, to use the concepts described by von Holst (1973) and Polemnia *et al.* (1995), which characterize the complexity of interactions. Coordination between the two individuals of the same pair will result from the combination of competition (maintenance of the preferred frequency of each one) and cooperation (attraction to the frequency of the other). In the present study the influence

Table 2. Number of individual and couple mistakes in solo and dance pairs when synchronizing with the metronome.

	Metronome (bpm)	Solo: Individual mistakes	Solo: Mistakes per pair	Pairs: Individual mistakes	Pairs: Mistakes per pair
<i>Rumba</i>	95	8	5	6	3
<i>Waltz</i>	100	1	1	0	0
<i>Foxtrot</i>	110	6	4	4	2
<i>Paso doble</i>	115	0	0	0	0
<i>Tango</i>	120	5	3	8	4
<i>Cha-cha-cha</i>	125	5	3	6	4
<i>Samba</i>	135	4	3	1	1
<i>Quickstep</i>	140	11	6	8	4
<i>Vienese waltz</i>	150	9	6	8	5
<i>Jive</i>	155	6	5	3	2



of the pair was mostly positive in the improvement of individual synchronization with an imposed external sound stimulus. But this effect is not linear since in two dances (*tango* and *cha-cha-cha*) a slight increase of errors was verified in the pair situation. Ballroom dances are mainly characterized by men who lead the women. By choosing pairs with at least 3 years of experience we tried to ensure that pairs were familiar and could interact with stability in the execution of the tasks. We found that all the male participants had a SMT above his pair, so to accomplish a task with a considerably fast tempo, the mutual support worked and the cooperation allowed the pair to carry more elements out of their comfort zone to successfully accomplish the required tempo. This cooperation strategy with faster elements looks natural and supports previous studies (Xarez 2011). Another interesting aspect relates to the type of motor tasks performed. In that sense it should be noted the total number of hits found in *paso doble* in both conditions, which may be justified by the rhythmic structure of this dance: it is more marked, binary, and similar to a march. Also, relatively good synchronization was demonstrated in the *slow waltz*, which had only one mistake in the solo situation that was corrected by the presence of the pair. On the other hand, in both the faster and slower dances the role of the pair has shown to be decisive for the reduction of errors and better synchronization to the imposed tempo.

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# Anthropometry and body figure in dance: Comparison between dance styles

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Anthropometry in dance and aesthetic sports has been shown to play an important role in selection and performance criteria. The purpose of the present study was to compare anthropometric variables and aerobic capacity between three different groups of dancers: classical ballet, contemporary dance, and DanceSport. Two hundred and eighty six professional dancers from three dance genres took part in the study: 89 ballet, 137 contemporary, and 60 DanceSport. Anthropometric measurements, somatotype characteristics, and aerobic capacity ( $VO_{2max}$ ) were measured. Female contemporary and DanceSport dancers had higher body mass, body fat, and BMI values compared with ballet counterparts. DanceSport participants had significantly lower endomorphy and mesomorphy scores than the other genres. Aerobically, DanceSport had significantly higher  $VO_{2max}$  values compared with ballet dancers. In conclusion, female contemporary dancers are generally more muscular than their ballet counterparts, while DanceSport dancers are taller and heavier, less muscular, and have slightly greater adiposity compared with the classical ballet and contemporary dancers. Ballet dancers had lowest body fat percentage, weight, and BMI values. DanceSport dancers had greater aerobic capacity compared with the ballet dancers.

*Keywords:* ballet; contemporary dance; dancesport; anthropometric profile; aerobic capacity

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# Dietary and lifestyle patterns of pre and professional dancers: An international survey

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The importance of nutrition in dancers is well established, and its influence on health, lifestyle, body composition, energy availability, and especially dance performance is widely accepted among dance and nutrition scientists. However, the aesthetics of some dance genres expose dancers to body image ideals that may be considered unhealthy and often result in students and professionals taking unnecessary risks to achieve those stereotypes. This study investigated dietary and lifestyle habits in student and professional dancers. 411 participants started this survey, and 350 (F=272, M=78) completed all questions, representing an 81% response rate. Student and professional dancers from 53 countries on five continents completed a cross-sectional survey detailing demography, anthropometry, professional status, dietary patterns, and lifestyle questions. In terms of diet, 35% considered themselves carnivore and 36% omnivore, while 2% were vegan. 30% ingested three or more servings of vegetables per day, 61% reported 1 to 2 servings of protein daily, and 14% ingested no dairy products daily. 62% considered themselves very healthy. These findings suggest no detrimental dietary or lifestyle patterns in this cohort, though continued efforts should be encouraged to educate dancers on more healthful behaviors and lifestyle choices.

*Keywords:* nutrition; dance science; international; lifestyle; health

Dance is currently enjoying a veritable explosion in popularity. From street dance to Bollywood, ballroom to ballet, all have helped bring dance to a larger, more diverse audience. This increased exposure to dance, as with other forms of physical activity, raises concerns about the health of dancers, which may be compromised due to inadequate diet. Dietary patterns may be

influenced by myriad factors, such as lack of time, hectic class and rehearsal schedules, and lack of nutritional knowledge. Several studies have shown that many dancers do not ingest enough nutrients or calories, which can impact both health and dance performance. Bonbright (1990) studied the dietary practices of elite female ballet dancers. The typical dancer consumed 1584 kcal/d with 70% failing to meet the 2000 kcal/d recommendation. Frederick and Hawkins (1992) evaluated the nutritional knowledge, attitudes, dietary practices, and bone densities of four groups of women, one of which consisted of female collegiate dancers. Results revealed that the dancers' mean food frequency score was significantly lower than those of the other three groups. In particular, the dancers reported fewer calcium-rich foods in their diets over a longer period. This indicated reduced caloric intake and a poor dietary choice. Whole grains, complete proteins, and a variety of dietary fats are of particular importance in a population with a propensity towards lean body mass and disordered eating behavior.

In dance, additional pressure from choreographers, instructors, and peers, anxiety during performance and competition, and the need for control are factors that may only exacerbate attempts to make healthier dietary choices (Yannakoulia *et al.* 2004). Given that aspiring students and professionals may be prepared to take risks to achieve their ideals, investigating food choices and lifestyle patterns could prove crucial in improving educational and nutritional advice provided to this vulnerable cohort. Therefore, this study investigated dietary and lifestyle patterns and attitudes in student and professional dancers.

## METHOD

### Participants

A total of 411 participants started our survey with 334 completing the questions, indicating a response rate of 81%. Participants' anthropometric and dance genera characteristics can be found in Tables 1 and 2. To enhance compliance and alleviate anxiety, the aims were clearly stated on an introductory page, which also carried a statement ensuring anonymity. Consent was obtained from all participants. The study gained ethical approval from the School of Sport, Performing Arts and Leisure, University of Wolverhampton Ethics Committee.

## Materials

A survey consisting of thirty-five questions aimed to glean information on different variables: dance education, professional status, dance genre, activity and dance training schedules, basic dietary choices, and patterns of dietary supplementation. A certified athletic trainer, an exercise physiologist, a certified sports nutritionist, and two dance educators reviewed the questionnaire for inconsistencies.

Table 1. Summary of participant characteristics.

<b>Characteristic</b>	<b>Males</b>	<b>Females</b>
<i>Age category (years)</i>	<i>Frequency, n (%)</i>	
<18	1 (1)	9 (4)
18–20	9 (12)	47 (20)
21–29	33 (45)	127 (53)
33–39	22 (30)	33 (14)
40–49	8 (11)	15 (6)
50–59	1 (1)	8 (3)
60–69	0 (0)	1 (0.5)
Height (m), M±SD (range)	1.78±8.86 (1.40-1.95)	1.65±6.9 (1.30-1.84)
Weight (kg), M±SD (range)	73±8.79 (49-97)	57±8.35 (38-98)

Table 2. Dance profession or educational status (N=280).

<b>Category</b>	<b>N of respondents</b>	<b>% of respondents</b>
Pre-professional student/university	11	34
Pre-professional student/academy or conservatoire	53	17
Recreational dance student	48	16
Professional dancer (classical)	45	15
Professional dancer (contemporary)	61	20
Professional dancer (hip-hop/urban/street)	2	1
Professional dancer (style/ballroom)	2	1
Professional dancer (world dance)	3	1
Dancing/performing choreographer	33	11
Dancer/entertainer	4	1
Dance teacher	18	6

## Procedure

To test for English language comprehension and applicability, a version was circulated to twelve non-native English-speaking participants before distribution of the questionnaire commenced. Their answers were not included in the statistical analysis. Several distribution channels were utilized in order to recruit participants, including social media, dance-specific websites, and email communication with company teachers, rehearsal directors, and dance school/university department administrators. All questionnaires were filled in online via an SSL IP-address secure survey system. All data were entered into StatsPlus (v.5.8). Analyses were calculated for all participants, age groups, dance categories, and genders separately. Associations between age, gender, dance group, and motives were assessed via Chi-square ( $X^2$ ) tests. Associations and differences were considered statistically significant if the probability of error was less than  $p=0.05$ . All data are presented as frequency (in %) or as  $M\pm SD$ .

## RESULTS

In terms of diet, 35% considered themselves carnivore, 36% omnivore, 19% were 'flexitarian' (i.e. semi-vegetarian), and 2% were vegan. 30% had three or more servings of vegetables per day, 61% had 1 to 2 servings of protein daily, and 14% ingested no dairy products daily. 51% of participants took dietary supplements ranging from vitamin/mineral supplements (67%) to omega 3/6 fish oils (47%). 33% of participants consumed wine while 39% ingested hard liquor or spirits in the last month. 14% of respondents reported smoking on occasion, 76% never smoked, 12% smoked daily, and 5% smoked to control their weight. 33% danced six days per week while 22% did some kind of sport or physical activity at least twice per week. 62% considered themselves very healthy. Chi-square ( $X^2$ ) tests revealed no significant associations between age, gender, and dance genre.

## DISCUSSION

Participants from fifty-three countries on five continents represent, to our knowledge, the first international study describing lifestyle and dietary patterns in student and elite dancers. Results reported by our respondents appear in line with the general U.K. Food Standard Agency recommendations for maintaining good health (2002). Interestingly, 14% of our cohort ( $n=41$ ), twenty-eight of whom were female, reported no ingestion of dairy products on a daily basis. Similar findings have been seen elsewhere (Doyle-Lucas *et*



al. 2010). While this number is relatively small, failure to ingest adequate amounts of dairy products or substitutes—a major source of calcium—could lead to insufficient calcium in the diet (Warren *et al.* 1991). As calcium has been shown to increase bone mineral density, sufficient dietary calcium is particularly important for female dancers and all vegetarians with sub-optimal diets. Notably, 26% of our respondents smoked. These results contrast with earlier research where 33% reported to be smokers (Wilmerding *et al.* 2002). Reasons for this difference could lie in recent changes in anti-smoking regulations in many countries, or that only select respondents felt comfortable answering this question. However, health professionals have attributed poor cardiovascular health, diminished stamina, and increased fatigue levels to this lifestyle habit (Brinson and Dick 1996).

In conclusion, the present study highlighted dietary and lifestyle patterns internationally. As with most dietary and lifestyle research, our study was limited to self-reported data, thus actual patterns may prove different. Finally, results from this study could update valuable work done by dietetic and nutrition educators, nutrition and dance scientists, and physicians working with dancers to implement educational programs with a more research-based perspective.

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Thursday  
29 August 2013



Symposium:  
Insights into sound practice:  
A national study of Australian  
orchestral musicians



# Physical characteristics of professional orchestral musicians: Results from a national survey and physical evaluation research project

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Professional orchestral musicians have been reported as having unacceptably high injury rates in a large number of international studies. It is concerning that these relatively consistent high rates of injury have been maintained despite several decades of research, perhaps related to a lack of injury prevention or health intervention studies. The Sound Practice Project answered the call from the government-commissioned Strong report (2005) for the development and implementation of the first-ever national injury surveillance scheme and occupational health and safety initiatives to develop improved policies and practices for orchestral musicians. The starting point for this project was to administer a comprehensive physical and psychological health survey as well as conduct a physical assessment on participating musicians. The physical cross-sectional data revealed high levels of injury across instrumental groups that were not correlated with dysfunction as recorded using traditional physical examination procedures. The findings nonetheless set baseline physical goals that can be useful for rehabilitation, and the reported injury regions have guided the implementation of a series of targeted interventions.

*Keywords:* orchestral musicians; performance-related musculoskeletal disorders; physical examination; muscle control; electromyography

Professional musicians perform highly complex repetitive skills for many hours on a daily basis and are widely reported to suffer high rates of injury as a consequence. Moreover, these relatively consistent high rates of injury have been maintained despite this problem being highlighted since the mid-1980s (Fry 1986, Fishbein *et al.* 1988). The majority of these injuries was reported

to relate to disorders of the musculoskeletal system, loosely defined as over-use or misuse syndromes, and were aggravated by playing their instrument. Since this time, studies globally continue to report a dire situation for musicians' health with few recommendations emerging to date for effective interventions or preventative measures. In 2005, a report on the orchestras of Australia led by James Strong identified soaring workers compensation insurance premiums due to the burden of injury, and one of his key recommendations was for the government to provide funding to research strategies to improve their occupational health. This funding, along with a substantial funding amount secured from the Australia Research Council, allowed the authors of this paper to establish the Sound Practice Project to address these orchestral occupational health issues.

To develop interventions to reduce the risk of playing-related injuries occurring, it is important first to understand the pain characteristics and physical profiles across instrument groups. In this project, the researchers wanted to identify typical physical profiles of musicians and highlight any areas of concern that would form the basis for intervention projects.

The aims of the baseline physical assessments were to (1) to use a standardized physical examination protocol to comprehensively assess strength, flexibility, and muscle control, particularly for the spine and upper limbs; (2) to gather self-report data including demographic information, orchestral requirements, and other playing loads, exposures to potential risk factors, presence, and location of past or current injury, and recovery rates from past injuries; and (3) to investigate whether any relationships were evident between the two.

## METHOD

### Materials

Professional orchestral musicians ( $N=377$ ) completed a purpose-designed questionnaire before undergoing a series of physical examination procedures. The examination protocol was developed employing both commonly used clinical tests (with acceptable ratings of sensitivity and specificity) and a criteria document for evaluating work-related spinal and upper limb disorders (Driscoll and Ackermann 2012). A team of physiotherapists was trained to implement the selected tests and good inter-rater reliability was shown during testing occasions.



## Procedure

A research team conducted testing procedures at each orchestra location, taking approximately two hours per musician: one hour for the survey and one for the physical examination. For the physical examination, a protocol was developed using a range of procedures to test strength, range of motion, neural sensitivity, and fine motor control (Driscoll and Ackermann 2012). All testers attended a protocol-training day and were given a detailed booklet to optimize consistency, and inter-rater reliability tests were conducted on several occasions.

## RESULTS

In Australian professional orchestral musicians, 84% had a past history of playing-related pain, and 49% of the 377 musicians reported pain lasting longer than a week at the time of the survey. For half of these players, pain had been present for longer than three months. Full recovery from previous injuries was reported in less than 50% of cases, with poorest recovery rates in the upper limbs reported for the shoulder.

Overall, injuries were most commonly reported in the spine and shoulders but varied in relation to instrumental groups. For example, pain in the right elbow and forearm was more common for woodwind players than all other instrumental groups, and pain occurring in shoulders was significantly more common ( $z=2.00$ ,  $p<0.05$ ) on the left in trombonists and on the right in cellists. The pain results have been published previously in detail (Ackermann *et al.* 2012), but an example of right neck and arm pain differences between broad instrumentalist categories is shown in Table 1.

Physical tests showed expected differences between genders, with males generally being stronger and females generally rating better for flexibility measures. The results revealed some instrument-specific differences in range of motion and strength; e.g. significantly greater forearm supination ( $F_{4,384}=3.92$ ,  $p<0.004$ ) in upper string players and a wider hand span in the left hand ( $F_{4,391}=3.30$ ,  $p<0.02$ ) but not the right hand of lower string players. Despite half the musicians suffering from performance-related musculoskeletal disorders (PRMDs), normal physical measurements were found in nearly all cases and were not significantly correlated to pain. In testing of fine motor skills of the hand (the Purdue peg board), scores were highly significantly related to sex (women scoring higher than men;  $t_{390}=5.28$ ,  $p<0.001$ ) and also significantly related to instrument ( $F_{4,390}=2.49$ ,  $p<0.05$ ), with woodwind players scoring highest.

*Table 1.* Percentage of musicians from each instrumental category reporting pain in the listed regions of the right upper extremity.

	<i>Brass</i> ( <i>n=58</i> )	<i>Woodwind</i> ( <i>n=67</i> )	<i>Lower strings</i> ( <i>n=68</i> )	<i>Upper strings</i> ( <i>n=169</i> )	<i>Percussion</i> ( <i>n=12</i> )
Shoulder/upper arm	10.3	10.4	11.8	10.1	16.77
Elbow/forearm	3.5	11.9	4.4	6.5	-
Wrist/hand	1.7	1.5	2.9	4.1	-
Fingers	-	3.0	-	-	-
Thumb	-	4.5	4.4	-	8.3

*Note.* Three harpists were not included as they were felt to be too easily identifiable and were not considered to belong to the other groups.

## DISCUSSION

The cross-sectional data from the Sound Practice baseline testing revealed that injuries are common in Australia orchestral musicians and that these injury rates have changed little since the 1980s (Fry 1986). The location of these injuries appeared to reflect specific increased demands associated with playing an instrument in terms of static postural loading (e.g. in the left shoulder of trombonists) and/or dynamic movement challenges (e.g. in the right shoulder of cellists).

Physical examination procedures established a range of baseline measures for musicians and also highlighted instrument-specific adaptations (Driscoll and Ackermann 2012). Pain patterns were not reflected by a poorer score in the physical assessment findings; in fact as seen above, woodwind players had the best Purdue pegboard fine motor control scores and yet also some of the highest rates of injury in the forearms, hand, fingers, and thumbs. Given the instrument-specific nature of reported pain patterns and their lack of correlation to typical physical examination procedures, it would appear that better tools for evaluating playing posture and music performance biomechanics are needed. The challenges with assessing these variables hamper the ability to identify and define interventions that may be important in both injury prevention and management for musicians.

The wide range of traditional physical tests used for this study were chosen because of their sensitivity, specificity, and clinical utility, and yet they proved to be limited in assessing musicians' injuries. It is worth contemplating that many of these tests have been based on measurements of physical characteristics in "normal" populations and in injured or disabled popula-

tions. According to the measurements obtained, musicians, if anything, seem to show physical attributes above the normal benchmarks as may be expected in an elite or “hyper functioning” population. However, the results provide a useful guide to identify goals for rehabilitation of the injured musician based on a large cohort of professional orchestral performers.

### **Acknowledgments**

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# Psychological wellbeing in professional orchestral musicians in Australia

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We report the major findings from the psychosocial questionnaire component of a cross-sectional population survey of the musicians in Australia's eight full-time professional symphonic and pit orchestras. The response rate was 70% (n=377). Female musicians reported significantly more trait anxiety, music performance anxiety (MPA), social anxiety, and other forms of anxiety and depression than male musicians. The youngest musicians (<30 years) were significantly more anxious compared with the oldest musicians (51+). The youngest female musicians were most affected by MPA. Music performance anxiety was lowest for the older musicians (51+ years). Thirty-three percent (33%) of musicians may meet criteria for a diagnosis of social phobia. Twenty-two percent (22%) answered in the affirmative to a question screening for post-traumatic stress disorder. Thirty-two percent (32%) returned a positive depression screen; this subgroup had higher scores on the anxiety measures. Linear regression analysis identified STAI-T, SPIN, ADD, and age as independent predictors of music performance anxiety severity. Significant numbers of musicians (14%) drank alcohol in a manner outside the NHMRC alcohol guidelines (2009); only 6% were current smokers. This study has identified a significant pattern of anxiety, depression, and health behaviors that require attention in occupational health and safety policies and programs for this workforce.

*Keywords:* professional orchestral musicians; psychosocial well-being; music performance anxiety; depression; anxiety

The act of playing music professionally is a complex undertaking, similar to many elite sports, requiring a high level of physical and psychological skill to

succeed; yet there have been few health or psychological services to support this population, in great contrast to the sporting population (Tubiana 2000).

The mental health of professional musicians is not well understood; hence, their mental health needs are often poorly managed (Kenny 2010). Psychosocial health including health behaviors, such as substance and alcohol use, have not been systematically studied and this needs to occur in order that health prevention programs target the appropriate health behaviors for the appropriate subgroups if these are identified.

In 2005, a comprehensive review was conducted of the Orchestras of Australia. This review noted soaring insurance premiums related to health issues and, inter alia, issued a key recommendation to study and develop specific occupational guidelines for orchestral musicians (Strong 2005). In a unique research effort, a national collaborative team was funded to address these major health concerns in this population. The team includes researchers from the University of Sydney (the authors) and the eight major symphony and pit orchestras of Australia with funding support from two Australian government agencies: The Australia Council for the Arts and the Australia Research Council.

The first major phase of the study was a cross-sectional survey of the musicians. The survey involved a detailed questionnaire and administration of standardized psychological tests. This paper reports on the major findings from the psychological component of the questionnaire, including psychological tests. We assessed the prevalence and reported causes of music performance anxiety within this population, identified comorbidity profiles, and provide some normative data on a range of psychological screening tests for professional musicians.

## METHOD

### Participants

Participants were musicians (184 males [49%] and 192 females [51%]) from the eight state orchestras of Australia ( $n=377$ , 70% response rate). The mean age of the musicians was 42.1 years ( $SD=10.3$ ; range=18-68 years).

### Materials

The inventories used were the: *Kenny Music Performance Anxiety Inventory* (revised) (K-MPAI; Kenny 2011); *Trait questionnaire of the State-Trait Anxiety Inventory* (STAI-T; Spielberger 1983); *Anxiety Sensitivity Index* (ASI; Reiss et al. 2008); *Social Phobia Inventory* (SPIN; Connor et al. 2000);

*PRIME-MD Patient Health Questionnaire; Anxiety and Depression Detector (ADD; Means-Christensen et al. 2006); Core Self-Evaluations (CSE; Judge et al. 2003); and the Alcohol Use Disorders Identification Kit (AUDIT; Babor et al. 2001). Descriptive measures designed by the first author for the study were the performance anxiety in different performance settings rating scale, perceived causes of music performance anxiety checklist, and self-management of music performance anxiety rating scale (for details of measure construction, see Kenny et al. 2011).*

## **Procedure**

All musician members from the eight orchestras were invited to participate. Those who agreed to participate (n=377) completed a self-report survey containing a demographic questionnaire and all of the above measures.

## **RESULTS**

K-MPAI, SPIN, ASI, STAI-T, and ADD were highly inter-correlated and significantly negatively correlated with CSE, indicating that low CSE predicted higher scores on the anxiety measures (SPIN  $r=-0.53$ ; STAI-T  $r=-0.75$ ; K-MPAI  $r=-0.71$ ; ADD  $r=-0.50$ ). Female musicians reported significantly higher trait anxiety ( $F=8.46$ ,  $p=0.004$ ), music performance anxiety, social anxiety, and depression than males. The youngest musicians (<30 years) were significantly more anxious than the oldest musicians (51+;  $F=2.87$ ,  $p=0.04$ ). For K-MPAI, the sex by age interaction was significant ( $F=2.94$ ,  $p=0.033$ ). For K-MPAI, male musicians' scores remained stable across the four age categories, but female scores did not. The youngest female musicians were most affected by music performance anxiety (mean=104.5), followed by females in the 41-50 year age group (mean=99.7). Music performance anxiety was lowest for the older musicians (>51 years) for both males (mean=78.6) and females (mean=78.3). There were no significant differences in K-MPAI, STAI-T, SPIN, or ADD by instrument group. Eighty-four (n=84; 22%) musicians answered in the affirmative to the question on PTSD in ADD.

Musicians were asked to review and then select from a list of 22 items those which they identified as causal factors in their music performance anxiety. From their self-generated list, musicians were then asked to rank order the item in terms of its importance as a factor causing their music performance anxiety. Results are presented in Table 1.

Table 2 presents musician ratings of the degree to which they experienced performance anxiety in a variety of musical performance and other situations (such as making an oral presentation or sitting an examination). The non-

musical situations were used as benchmark comparisons for the level of anxiety reported in musical settings. Ratings were made on a scale from 0 to 10 where 0=not at all anxious and 10=extremely anxious.

Significant percentages of musicians engaged in adaptive strategies to manage MPA such as increasing their practice time before stressful concerts and practicing relaxation techniques. Musicians also used medications to manage their MPA, most commonly beta blockers (31%), but also alcohol (12%), anxiolytics (5%), and antidepressants (4%).

*Table 1.* Numbers, percentages and first ranked causes among 22 causes of music performance anxiety in orchestral musicians (n=377).

<i>All ranked causes of music performance anxiety</i>	<i>N</i>	<i>%</i>	<i>% Rank 1</i>
Pressure from self	320	88.6	28.8
Excessive physical arousal prior to, or during performance	278	78.3	24.4
Inadequate preparation for performance	220	63.0	18.8
Health issues	159	45.0	16.8
Tendency to be anxious in general, not just in performance	131	37.3	15.3
Negative thoughts/worry about performing	270	76.3	13.6
Not knowing how to manage physical arousal	165	48.1	13.6
Lack of confidence in yourself as a musician	175	51.5	11.8
Attempting repertoire that is too difficult	216	61.4	9.8
Inadequate support from people close to you	92	27.3	9.7
Concern about audience reaction/fear of negative evaluation	243	67.5	9.6
Bad performance experience	277	78.0	9.6
Concern about reliability of memory	202	57.5	9.0
Generally low self-esteem	122	36.0	8.7
Pressure from conductor or section leader	151	43.4	8.5
Pressure from/competing with peers, other musicians	212	60.7	8.2
Technical flaws that cause uncertainty	255	72.2	8.1
General lack of self-confidence	192	59.1	8.0
Not knowing how to manage negative thoughts/worry about performing	161	47.4	7.6
Pressure from parents	41	12.2	6.3
Generally high level of self-consciousness	191	55.5	4.4
Negative performance feedback	113	33.6	3.3



*Table 2.* Mean ratings (0-10) of degree of MPA in different musical settings.

<i>Performance setting</i>	<i>Severity of MPA</i>			<i>Impact of MPA</i>	
	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
Audition	334	8.44	2.07	-1.73	2.89
Solo performance	333	7.30	2.31	-0.53	2.86
Oral presentation	328	5.82	3.03	-1.16	2.35
Chamber music performance	335	5.82	3.03	-1.16	2.35
Orchestral concert performance	366	4.85	2.80	-0.12	1.93
Lesson or master class	297	4.30	2.94	-0.49	1.94
Written exam	290	3.63	2.85	-0.12	1.93
Orchestral rehearsal	366	3.01	2.32	0.01	1.98
Practicing alone	365	0.62	1.21	0.12	1.71

Using the SPIN cutoff score of 19 to diagnose social anxiety disorder, 128 (34%) orchestral musicians in this sample (Males=56 [30.4%]; females=72 [36.9%]) may meet criteria for a diagnosis. There were no sex or age group differences.

32% (n=118) of musicians responded in the affirmative to either the first (12.8%) or second (1.9%) question only or to both questions on the PRIME-MD (n=64, 17.4%), indicating that further screening for depression should occur. Univariate ANOVAs indicated that more severe depression was associated with more severe MPA ( $F=40.84$ ,  $p=0.001$ ), trait ( $F=74.02$ ,  $p=0.001$ ), and social ( $F=21.03$ ,  $p=0.001$ ) anxiety.

K-MPAI was predicted by STAI-T, SPIN, ADD, and age ( $F_{4,343}=155.73$ ,  $p<0.001$ ) in regression analyses; the model explained 65% of MPA variance.

## DISCUSSION

The K-MPAI was sensitive to the age and sex differences observed in most measures of anxiety. Significant correlations with each of the anxiety measures used in this study provide early evidence for the convergent validity of K-MPAI, STAI-T, SPIN, and ADD, which contributed unique variance to the prediction of K-MPAI scores, in addition to age. The results suggest that tests of PTSD and depression need to be included in assessments of musicians presenting with problematic MPA; assessments of medication use are also warranted, given the high usage in this population. This paper has cast a bright light on the extent of underlying psychological difficulties, which must

be addressed as a needed first step in enhancing the psychological well-being of this valued profession.

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# Surveillance of musculoskeletal disorders and risk factors in orchestral musicians

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A surveillance system for musculoskeletal injury and associated possible risk factors in orchestral musicians in Australia was developed as part of the Sound Practice Project. Participants were members of any of the eight main professional orchestras in Australia. Three approaches to surveillance were developed: one paper-based and two web-based. All three essentially asked the same questions. The second web-based system has addressed some of the issues with the earlier two systems and allows regular individual feedback to the participants in order to encourage on-going participation.

*Keywords:* surveillance; orchestra; musculoskeletal; injury; epidemiology

Professional orchestral musicians perform at the elite level, placing high physical demands on their bodies. However, there is a lack of prospective longitudinal data on the incidence of musculoskeletal injury and associated risk factors. This limits the ability to reliably identify priority risk factors to address in injury prevention strategies for this population. The Sound Practice Project is a longitudinal study of the eight main professional orchestras in Australia. The project investigates the health of musicians and trials various health-focused programs and interventions.

In Australia and elsewhere there is little or no systematic collection of data on injury or on exposure to potentially important injury risk factors. One arm of the Sound Practice Project (Ackermann *et al.* 2012, Driscoll and Ackermann 2012, Kenny *et al.* 2012) was to attempt to establish a surveillance system to collect prospective information on exposure to potential risk factors and on the occurrence of musculoskeletal disorders.

The aim of this article is to provide an overview of experiences in developing a surveillance system for musculoskeletal injury and associated possible risk factors in orchestral musicians in Australia.

## **METHOD**

### **Participants**

Participants were members of the eight main professional orchestras in Australia. They participated for varying lengths of time and in one or more of the three approaches used (see below).

### **Materials**

Three approaches to surveillance were developed: one paper-based and two web-based. All three essentially asked the same questions.

The data collection instrument covers data on exposure (playing and non-playing activities), psychological parameters, and on relevant outcomes (pain and injury). In terms of playing, separate information is collected on rehearsal and performance. This is collected separately for orchestral music, chamber music, popular/commercial/cross-over playing for the orchestra, solo performance, and playing in non-orchestra situations. Information on personal practice and on non-playing workload (such as teaching) is also collected. There is a single question on overall level of exertion and four questions on mental health. The pain/injury questions relate to the site of pain/injury, various characteristics of the pain, and to the pain/injury's perceived relationship to, and interference with, playing.

## **RESULTS**

The paper-based system was implemented with the intention of musicians completing the two-page form on a regular basis before or after scheduled rehearsals. Based on discussions with orchestra management and musicians, it was expected this would maximize participation. However, the trial implementation identified several important issues, including allocating time for the form completion around the orchestra rehearsal schedule, balancing the frequency of data collection with the proportion of musicians who completed the forms, the level of detail of information collected, the areas covered by the data collection; the format of the form, and the musicians' perceptions of the usefulness of the information collected.

A majority of musicians subsequently requested a web-based system, with varying opinions as to how frequently the data needed to be entered (weekly,

fortnightly, or four-weekly). The first web-based system allowed the musician to choose the frequency of data entry. Uptake was better with the original web-based system (the paper-based system was continued for those who wanted it) but still low. The main issues identified were difficulties maintaining regular email contact (due to changing email addresses and firewall issues), developing a workable system of reminders, making the entry of data on anatomical site and symptoms simple, and maintaining interest among the musicians. The key areas of improvements were determined to be the need for automatic regular feedback to musicians regarding the data they had entered previously and the ability to extract data easily for analysis purposes. A new surveillance system, developed in cooperation with the Dancer Wellness Project, which has an operating model for dance, has been developed. This new version of the online system allows the participant to click on a picture to identify the area of injury, initially broadly and then more specifically. The online data collection is menu-driven as much as possible, but the system does allow text entry in some areas. It incorporates regular reminders and provides feedback to allow the individual to compare their exposure data with others who play the same instrument and overall. This system is being trialed in 2013. Initial results from this trial, and the lessons learned from this and previous approaches will be presented.

## **DISCUSSION**

Useful surveillance is difficult to establish and maintain; must be developed taking particular account of the needs, interests, and attitudes of musicians; and is probably most likely to be effective with inclusion of regular and timely feedback to participants of their own results and the broader findings of the surveillance program.

### **Acknowledgments**

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# Noise exposure and attitudes to hearing protection in orchestral brass musicians

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Among professional orchestral musicians, brass players are exposed to the highest continuous levels of sound in the workplace. Although much of their working life is spent in private practice, little is known about sound level exposure during this activity or the hearing health and hearing conservation practices of this group in particular, making exposure estimation and development of appropriate hearing conservation approaches very difficult. The current study aimed to assess practice room exposure levels, self-reported hearing health, and hearing conservation practices of this group. Ten professional musicians practicing comparable musical material were assessed for sound exposure and questionnaires were distributed to brass players of eight professional orchestras. Findings indicated brass instrumentalists are likely to exceed acknowledged "safe" sound exposure limits in under an hour of private practice and that, of brass players surveyed (N=65), 50% of those under the age of 50 self-report a hearing loss of some kind while 95% reported the use of hearing protection while playing to be difficult or impossible. Improvements to personal protective devices together with enhanced education for musicians and their teachers, managers, and audiologists is essential to further safeguard the hearing of those in the field and those training to enter it.

*Keywords:* orchestras; hearing; noise; exposure; musicians

Orchestral brass players (players of the trombone, tuba, trumpet, and French horn) are exposed to the highest continuous levels of sound in the orchestral workplace and, as such, are at risk of permanent damage to their hearing (Schmidt *et al.* 2011). This risk is likely to be significantly greater once exposure in individual practice rooms (where these musicians hone their craft) has been taken into account. There are a range of administrative and engineered

mechanisms for reducing sound exposure to these musicians; however, even with the most rigorous strategies in place there is inevitably a need for the use of devices such as earplugs (O'Brien *et al.* 2012).

There are no data available on practice room sound exposure for these musicians and existing reports indicate rates of earplug usage generally to be poor, with a range of reasons for non-compliance, including earplugs interfering with these musicians' abilities to perform, rehearse, or practice in a productive and musically useful way (Laitinen and Poulsen 2008, Zander *et al.* 2008).

This study aimed to assess the noise exposure of professional brass players during private practice and determine approaches and attitudes to hearing conservation to help develop solutions to this on-going problem.

## METHOD

### Participants

A questionnaire was distributed to brass musicians in eight professional orchestras across Australia. Additionally, ten full-time tenured brass players from a professional orchestra volunteered to participate in the practice room noise exposure trial component of this study.

### Materials

Musicians were assessed in a room (54 m<sup>3</sup>) built and acoustically treated for individual instrumental practice (see Figure 1). Three Type I Sound Level Meters were used, calibrated prior to and at the conclusion of each measurement using a matching calibrator. Participants also completed a short questionnaire on practice habits.

The broader questionnaire collected data on playing history, perceived hearing health, perceived risk of noise-induced hearing loss (NIHL), ease of use of earplugs, motivation and history of earplug use, type of earplugs used, and difficulties experienced while wearing earplugs.

### Procedure

To determine exposure, sound levels were recorded simultaneously within 5-10 cm of each ear and 1.5 m in front of the musician. The assessment consisted of three main elements: a warm up, where participants played A=440Hz (or its nearest comfortable octave equivalent) for 10-15 seconds at various dynamic levels (soft, moderately loud, loud, and very loud) with a short break after each note; five minutes of technical work (scales, arpeggios,



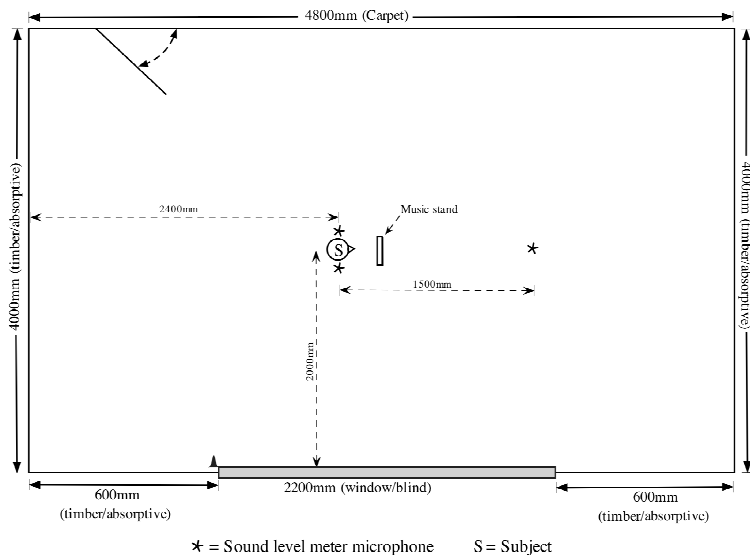


Figure 1. Testing room layout.

etc.) of own choice; and fifteen minutes practice of their instrument's first-chair part for *Don Quixote* (Richard Strauss). Results were analyzed using software associated with the sound level meters, at which point the overall exposure for each assessment was assessed as well as the various elements of each assessment. Within the results, dBA  $L_{eq}$  refers to the equivalent steady state sound level required to replicate the expended energy of the actual (fluctuating) exposure as measured. Analysis of the broader questionnaire data was undertaken using *Stata* and *SAS* statistical software.

## RESULTS

### Practice room exposure data

The most exposed individual musician (trumpeter) was exposed to 98.6 dBA  $L_{eq}$  (left ear) over the duration of the assessment (equivalent to 94% of the allowable daily noise dose or 286% if exposed to this level for one hour). Inter-aural differences were highest for the horn and tuba players and levels in front of the musicians (dBA  $L_{eq}$  Ctr) were consistently lower than at either ear (see Table 1).

*Table 1.* Exposure for whole assessment by instrument; projected percentage of allowable daily noise dose (where 85 dBA  $L_{eq}$  over 8 hours=100%, 3 dB exchange) and interaural difference (where bold type indicates right ear louder). Where  $n>1$  mean arithmetic average of multiple assessments is given with range indicated.

<i>Instrument (n)</i>	<i>dBA <math>L_{eq}</math> (range)</i>			<i>Projected dose after 1 hour (%)</i>	<i>dBA <math>L_{eq}</math> inter-aural difference</i>
	<i>Left ear</i>	<i>Right ear</i>	<i>Ctr</i>		
Trombone (2)	96.1 (0.4)	95.7 (4.4)	94.0 (1.1)	161	0.4
Bass tromb (1)	95.8 (-)	96.1 (-)	93.8 (-)	161	<b>0.3</b>
Trumpet (3)	95.8 (4.4)	94.6 (4.8)	92.8 (6.0)	150	1.2
Horn (3)	92.2 (2.9)	95.2 (2.5)	90.0 (2.9)	131	<b>3.0</b>
Tuba (1)	94.7 (-)	92.2 (-)	87.8 (-)	117	2.5

*Table 2.* Exposure at fortissimo, Don Quixote, and technical work (dBA  $L_{eq}$ ).

<i>Instrument (n)</i>	<i>dBA <math>L_{eq}</math> at ff (range)</i>		<i>Don Quixote dBA <math>L_{eq}</math> (range)</i>		<i>Technical work dBA <math>L_{eq}</math> (range)</i>	
	<i>Left ear</i>	<i>Right ear</i>	<i>Left ear</i>	<i>Right ear</i>	<i>Left ear</i>	<i>Right ear</i>
Trumpet (3)	102.3 (4.9)	100.8 (5.2)	96.5 (4.8)	95.3 (2.6)	95.2 (2.6)	94.3 (3.2)
Horn (3)	98.4 (4.4)	100.7 (2.1)	93.1 (2.0)	96.1 (2.6)	90.0 (5.2)	93.1 (3.2)
Trombone (2)	104.1 (5.1)	101.7 (4.8)	96.5 (1.8)	96.4 (5.4)	94.0 (2.7)	93.8 (0.7)
Bass tromb (1)	102.4 (-)	104.1 (-)	96.5 (-)	96.8 (-)	95.1 (-)	95.3 (-)
Tuba (1)	102.3 (-)	97.9 (-)	95.5 (-)	93.2 (-)	93.1 (-)	90.6 (-)

The individual with the highest exposure during the *fortissimo* section of the assessment alone (not including all other parts of the assessment) was a trombonist, registering 106.6 dBA  $L_{eq}$  in the left ear while playing at this dynamic. At this level the player would risk NIHL after around 3 minutes and fifteen seconds. Exposure during three sections of the assessment is detailed in Table 2. Practice sessions of 1.9 h per day, 5.8 days a week (mean average) were reported.

### Questionnaire data

Of all respondents ( $N=65$ ; 29 horns, 14 trumpeters, 17 trombonists, and 5 tubists; mean age approximately 41 y [24-61 y]; 78% male), 83% reported a risk of NIHL in the orchestra, while 32% reported risk of NIHL during private

practice. Fifty-one percent used earplugs at least some of the time and 6% used earplugs all the time or very frequently. Of earplug users, 70% used them in response to pain, while 67% did not use earplugs when they thought they were necessary. None reported earplug use during private practice and none reported use during performances. Ninety-five percent of respondents reported earplug use to be difficult or impossible, with no correlation between history of earplug use or of earplug type and ability with earplugs. Overall, the most commonly identified problems were: hearing other players while wearing earplugs (91%), being unable to hear themselves (75%), difficulties with balance (66%), and intonation problems (63%).

Of those  $\leq 50$  years of age ( $n=48$ ), 50% reported hearing loss, with brass players significantly more likely to report a hearing loss than other instrumental sections ( $p=0.042$ ). By instrument type, 62.5% of trumpets and 54% of horns  $\leq 50$  years reported a hearing loss.

## DISCUSSION

Private practice is a major contributor brass players' daily sound exposure. The incidence of reported hearing loss among this group is high, and while most are aware of the risks they face in ensemble, fewer acknowledge the risks posed in private practice. Almost all experience difficulty using currently available personal protective devices.

Should orchestral rehearsal time (often 5 to 6 hours per day) be included, all brass players would be at high risk of NIHL in the course of their daily musical activities unless measures were taken to limit their exposure. The variability in exposure noted between players may be due to practice habits, technique, and position (principal or a section player). This is an indication that practice habits may be an effective tool to reduce daily sound exposure and this requires further investigation.

Age-related hearing loss typically takes effect around 50 years of age (Sataloff and Sataloff 2006). With 50% of those  $\leq 50$  years of age reporting a hearing loss it appears brass players are much more likely to consider themselves to have a hearing loss than the general population (Shield 2006). It is also evident from difficulties reported that current earplugs available (including the custom-moulded variety) are inadequate to ensure broad acceptance by this group of musicians. Problems with custom-molded plugs may include molds being too shallow and not adequately reducing occlusion (Chasin 2009) and results of this study indicate that over-attenuation is a significant problem. It is for these reasons that it is essential audiologists

ensure properly made, correctly fitting molds and consider prescribing lower levels of attenuation (9 or 10 dB instead of 15 dB) in order to increase usage.

This study took no audiological data, relying upon perceptions of hearing health only. Further study should further investigate this together with alternatives to currently available personal hearing protection (including recently released level-dependent earplugs) and methods to improve the dissemination of broader research findings.

It is essential that a viable solution be found that has minimal impact on the art these musicians create on a daily basis. Only when this has been achieved will we be able to ensure these musicians have long and fruitful careers free of significant hearing pathologies.

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# Can experienced observers detect postural changes in professional musicians after interventions?

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Postural dysfunction is reported to increase the likelihood of developing performance-related musculoskeletal disorders in musicians. Both Exercise Therapy and Alexander Technique (AT) use methods that are suggested to assist with improving posture. This study aimed to investigate whether experienced observers were able to detect postural changes in professional orchestral musicians following a 10-week intervention program. 57 musicians volunteered for either a program of Exercise or AT. Standardized series of photographs were taken of each participant before and after participating in an intervention program. Photographs were then randomized by (1) time taken and (2) intervention type. These were evaluated by five experienced musician health professionals and four specialist music educators who had training in AT or Body Mapping. Observers were asked to identify the better posture using anterior and lateral photographic views of each musician. All participants reported an improvement in playing posture post-intervention. Health professionals and music educators identified the true post-intervention photograph as having better posture significantly more frequently than chance (50%). Observers were better able to identify this in the AT group photographs compared to the Exercise group, however this was not statistically significant. Our findings suggest that while experienced observers were able to detect postural changes post-intervention using photographs, further studies could aim to improve findings by increased training and incorporation of video footage.

*Keywords:* Alexander Technique; exercise; performance-related musculoskeletal disorders; photographs; professional orchestral musicians

Poor posture is frequently cited as a problem for musicians with performance-related musculoskeletal disorders. Several interventions that have

been suggested in the literature to improve posture are strengthening exercises and Alexander Technique (AT). However, it is unknown whether there are postural changes that occur through these interventions that can be observed. One method of evaluating postural change is through the use of photographs; a cost-effective and convenient method that has been validated by numerous investigators (Fortin *et al.* 2011).

Upper limb and trunk strengthening exercise programs have been shown to increase trunk and shoulder muscle strength as well as improve self-reported levels of exertion, fatigue, and pain during instrumental playing (Ackermann *et al.* 2002, Kava *et al.* 2010). Further, increased trunk and shoulder muscle strength and control have been positively correlated with better posture (Emery *et al.* 2010, Kibler *et al.* 2006). Hence, a musician-specific exercise program combining these two elements of exercise may improve playing posture.

AT uses touch and verbal cues to address maladaptive postures and provide instruction on proper alignment and balance during every day and work-related activities (Schlinger 2006). Music educators increasingly train in this method of teaching to aid with these problems during instrumental playing. There is recent evidence to suggest that AT may be effective in facilitating postural relearning (Woodman and Moore 2012).

The aim of this study was to investigate whether experienced observers were able to detect postural changes, using photographs, in professional orchestral musicians following 10-week intervention programs.

## METHOD

### Participants

Email invitations were sent out to health professionals and Alexander or Body Mapping music educators with experience in working with musicians. In addition, volunteers were recruited at the annual 2012 Performing Arts Medicine Association Conference in Colorado, USA. Exercise and AT intervention programs were offered to all musicians employed in the eight premier symphony orchestras of Australia. A total of 57 professional orchestral musicians (37 females) volunteered and completed at least 80% of an intervention program, and were included in the final analysis (see Table 1).

### Interventions

Participants undertook 16 sessions of either an Exercise or AT program over a ten-week timeframe. The exercise program used was specifically designed to

*Table 1.* Summary of demographics and instruments played by participants.

	<i>Exercise (n=30)</i>	<i>Alexander (n=27)</i>
Females	21	15
Age (SD)	43 (10.1)	44 (11.8)
Violin, viola (upper strings)	20	16
Cello, double bass (lower strings)	3	7
Flute, clarinet, oboe, bassoon (woodwind)	5	4
Timpani (percussion)	1	0

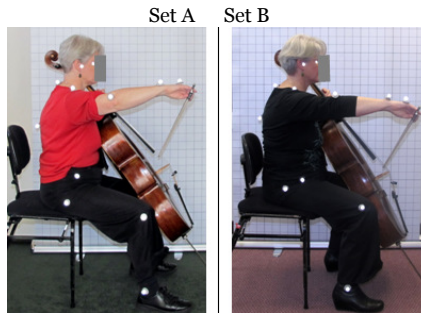
target musculoskeletal problems of professional orchestral musicians (Chan *et al.* 2013). Group sessions included warm-ups, cool-downs, and a series of five different exercises targeting the neck, shoulder, abdominal, lower back, and hip regions. The AT program was tailored to include the core principles, procedures, and additional applications for orchestral musicians and was delivered in a comparable group format rather than the usual one-to-one format (Davies 2012).

## **Procedure**

Posture was recorded by a series of anterior and lateral photographs taken of each musician during instrumental playing before and after an intervention program. Woodwind and brass players were asked to play a series of low and high pitched notes with different dynamics, string players were asked to play low and high notes at the tip and heel of the bow across the strings, and percussionists were asked to play notes with different dynamic levels and speeds.

Circular retro-reflective markers were placed bilaterally on standard facial, spinal, pelvic, and lower limb bony landmarks, as well as the lateral epicondyle of the elbow, radial styloid process, and the base of the fifth metacarpal. A 2.1 m x 1.2 m pull-up banner with 5 x 5 cm gridlines was placed posterior to the musician to assist as a point of reference. All musicians were provided with an adjustable orchestral chair or stool and given a standardized instruction to “sit as you normally would during rehearsal and performances adjusting the chair/stool as necessary.” The camera was mounted on a tripod that was then set to the level of shoulder height of the performer.

Photographs of the musician playing the same note in the same position were randomized for intervention type and before and after intervention, and then presented in two columns (Set A and Set B). This was made into a color booklet for postural analysis by the observers (see Figure 1). The booklet was presented to five healthcare professionals (two physical therapists, two phy-



*Figure 1.* A sample of pre- and post-intervention photographs; a cellist playing on the A string at the tip of the bow. (See full color version at [www.performance-science.org](http://www.performance-science.org).)

sicians, and one osteopath) and four music educators with additional training (two in Body Mapping and two in AT) to perform the photograph evaluation. These observers all had experience managing musician musculoskeletal issues with an average of 24 years (SD 8.3) in their respective profession. The observers had ten seconds to compare the two sets of photographs on each page and recorded whether Set A or Set B was the better posture or no difference. A binomial proportional model with logistic regression was performed on the observer's responses. Participants were also asked whether they perceived a change in their playing posture post-intervention using a five-point ordinal scale (-1=negative effect to 3=large effect).

## RESULTS

63% of the time the observers identified the true post-intervention photograph as better posture (see Table 2). In contrast, the Exercise and AT participants reported moderate to large improvements in their playing posture immediately after interventions: 2.0 (SD=0.8) and 2.5 (SD=0.8) respectively.

The healthcare observers were more likely to identify the true post-intervention photographs having better posture than music educators, but this was not significantly different (95% C.I.=-1.1% to 9.9%,  $p=0.113$ ). The observers were more likely to identify the true post-intervention photographs of the AT intervention than the Exercise, but this was not significantly different (95% C.I.=0.4% to 10.8%,  $p=0.07$ ; see Table 2).

## DISCUSSION

Experienced observers were able to identify postural changes after Exercise and Alexander Technique interventions in two thirds of the professional or-



Table 2. Summary of responses according to the judges and intervention, and probability of selecting the true post-intervention photo as having improved posture.

	Observer		Intervention		Observers & Intervention (n=990)
	Healthcare (n=550)	Music Educator (n=440)	Exercise (n=504)	Alexander (n=486)	
In favor <sup>1</sup> (%)	67	47	51	54	52
Against <sup>2</sup> (%)	30	31	34	28	31
No difference (%)	13	22	15	18	17
<i>Probability of Post-Intervention Photo Selected</i>					
Point estimate (%)	65	60	60	66	63
95% C.I.	61-70	55-65	55-65	61-71	60-66
p-value	<0.001	0.002	<0.001	<0.001	<0.001

Note. <sup>1</sup>=post- and <sup>2</sup>=pre-intervention photograph selected as having better posture.

chestral musicians. Healthcare professionals were slightly better at detecting these changes. These results suggest that the ability to identify changes in posture after an Exercise or AT program using this method is better than chance.

Using a method of observation by photographs alone was chosen to ascertain whether changes could be detected by a group of independent observers. The discrepancy between perceived improvements in posture by the musicians and the observers may have reflected the limited ability to evaluate dynamic postural change during playing movements using static photographs alone. It may be the case that only small differences are likely to occur in an elite sample of musicians, and that these are below the level of being easily detectable in a clinical setting. Another important factor influencing the results is the individual interpretation of what constitutes better posture can vary between observers. While large scale abnormal skeletal postures, such as spinal deviations or forward head postures, can be relatively straightforward to identify for experienced observers, recognizing “good” or “better” posture remains difficult (O’Sullivan *et al.* 2012). The observer’s own clinical and practical experiences, musical training, or health background can confound the interpretation of optimal playing posture. Finally, perceived improvements of the musicians may have been influenced by changes in factors other than posture, such as reductions in muscle tension, playing exertion, stress, and anxiety that would not be perceptible using photography.

Limitations of this study include the small sample size of observers and the lack of a gold standard for the ideal playing posture against which to compare the participant's post-intervention and pre-intervention photographs. Future research could employ definitions of postural change to facilitate agreement and provide movement analysis training for observers, as well as trial the use of video-footage together with photographs to compare pre- and post-intervention postural change.

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# Depression and music performance anxiety are associated with severity of performance related musculoskeletal pain in professional orchestral musicians

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We examined self-reported frequency and severity of performance related musculoskeletal pain (PRMD), trigger point pain (TPP) and depression, social phobia (SPIN), and music performance anxiety (MPA; Kenny Music Performance Anxiety Inventory, K-MPAI) in a cross-sectional survey of 377 professional orchestral musicians. Most (84%) musicians had experienced performance impairing pain; 50% reported current pain. Females reported more performance-impairing pain and more current pain than males. Cluster analysis indicated a complex relationship between depression and PRMD severity. Three clusters showed the hypothesized relationship (i.e. more depression, more pain). Musicians in the fourth cluster denied depression but reported the most severe pain, suggesting a group who somatize their psychological distress. Cluster analysis also revealed a strong relationship between PRMD severity and MPA. Clusters with higher scores on K-MPAI reported higher scores on PRMD severity. TPP was not associated with self-reported PRMD frequency or severity. There was a significant linear relationship between TPP and MPA for females, but males scoring the highest MPA reported lower TPP than those with milder MPA. Neither SPIN nor beta blocker use were associated with PRMD frequency or severity. The complex relationships identified between PRMD, TPP, depression, and MPA may have important implications for PRMD management in professional musicians.

*Keywords:* performance related musculoskeletal pain; depression; music performance anxiety; trigger point; professional musicians

Pain arising from performance related musculoskeletal disorders (PRMD) occurs frequently in professional musicians (Kaufman-Cohen and Ratzon 2011). The cause of musculoskeletal disorders and pain is multi-factorial, with occupational, environmental, biomechanical, psychosocial, and psychological factors contributing (Wu 2007). However, the impact of psychological factors, such as music performance anxiety, depression, and tendency to somatize (i.e. to express psychological distress through somatic symptoms), on the presence of musculoskeletal symptoms is unclear. Although relationships between pain and stress, anxiety, and depression have been explored in different pain populations, few studies have examined these relationships in professional musicians. Thus, this study assessed these relationships. Unlike the majority of studies assessing pain in musicians, we included both subjective (self-report) and objective measures of pain (i.e. trigger point pain, TPP), which have been used extensively in work settings to assess pain related to acute overload and overwork fatigue (Simons *et al.* 1999).

## METHOD

### Participants

Participants comprised professional orchestral musicians from each of the eight professional state orchestras in Australia.

### Materials

Materials included:

- Psychosocial measures: *Kenny Music Performance Anxiety Inventory (Revised)* (K-MPAI; Kenny 2011); *Trait questionnaire of the State-Trait Anxiety Inventory* (STAI-T; Spielberger 1983); *Social Phobia Inventory* (SPIN; Connor *et al.* 2000); *PRIME-MD Patient Health Questionnaire* (PRIME-MD PHQ); and *Core Self Evaluation Scale* (CSE; Judge *et al.* 2003).
- Pain measures: pain frequency and pain severity scales were developed using 11-point numerical rating scales with endpoints 0="never" and 10="constantly" (frequency) and 0="no pain" to 10="worst imaginable pain" (severity).
- Physical examination of right and left upper trapezius triggers points.

### Procedure

Information sheets, consent forms, and invitations were posted to all musician members of the participating orchestras. Those who agreed to participate

(N=377; 70% response rate) were sent a self-report survey, which they mailed in self-addressed, stamped return envelopes provided by the researchers. This method ensured confidentiality and anonymity of the musicians to all parties except the researchers, who had to match questionnaire data with results from the trigger point examination.

## RESULTS

Three hundred and eighteen musicians (n=318, 84%; mean age=42 years, SD=10.2) reported having experienced pain that interfered with their performance. Ninety-one musicians (24%) reported experiencing PRMD pain constantly; 21% (n=75) reported that the severity of the pain was the “worst imaginable.” There was a highly significant relationship between the frequency of reported pain and its severity, with those reporting higher frequency much more likely to report higher pain severity ( $X^2=304.84$ ,  $p=0.001$ ). Half the musicians (50%) reported current pain during performances; females had significantly higher reports of pain that interfered with their performance, and more occasions of such pain ( $X^2=5.62$ ,  $p=0.018$ ).

Using the general linear model, the effects of sex and age group (<=30; 31-30; 41-40; 51+) on reported PRMD pain frequency and severity were assessed. There were significant main effects for both sex and age but the sex\*age interaction was not significant. Table 1 summarizes the findings.

PRMD severity (but not frequency) was significantly associated with depression ( $F=3.90$ ,  $p=0.02$ ). Linear regression analyses tested the hypothesis that PRMD severity could be predicted by psychological distress as assessed by the K-MPAI, STAI-T, SPIN, CSE, and the depression screen. The K-MPAI was the only factor that contributed significantly to the prediction (Beta=0.17,  $t=3.23$ ,  $p=0.001$ ). However, the model's ability to explain the variation in the PRMD pain severity was poor (R square=0.029). Cluster analysis was conducted to identify the cause of the nonlinearity in the regression findings and to test the possible presence of a somatizing group of musicians. A two-step cluster analyses was conducted using the K-MPAI with severity ratings of PRMD pain as inputs. The cluster quality was good (Average silhouette=0.7) and four distinct clusters were obtained with approximately equal proportions in each cluster. A significant association between pain severity and MPA severity was observed; as reported PRMD pain became more severe, mean scores on music performance anxiety increased. When the depression variable and severity of PRMD-related pain were used as the inputs to define the clusters, the cluster quality was good (Average silhouette=0.6) and again, four clusters were identified as shown in Table 2. Two clusters reported no de-

Table 1. Relationships between sex, age, and PRMD frequency and severity.

		<i>F</i>	<i>Sig.</i>	<i>Observed Power</i>
Sex	PRMD frequency	7.27	0.007	0.77
	PRMD pain severity	4.19	0.041	0.53
Age group	PRMD frequency	5.38	0.001	0.93
	PRMD pain severity	3.20	0.024	0.74
Sex*Age group	PRMD frequency	0.25	0.863	0.10
	PRMD pain severity	0.55	0.651	0.16

Table 2. Cluster analysis of PRIME-MD (Depression) using pain severity.

<i>Cluster 1</i>	<i>Cluster 2</i>	<i>Cluster 3</i>	<i>Cluster 4</i>
No Depression	No Depression	Yes to 1Q	Yes to 2Q
N=148 (42.9%)	N=86 (24.9%)	N=51 (14.8%)	N=60 (17.4%)
PRMD(S)=1.61	PRMD(S)=6.65	PRMD(S)=4.21	PRMD (S)=4.52

pression. The first group reported minimal PRMD severity (mean=1.61; 43% musicians); the second group (25% musicians) reported the highest PRMD severity (PRMD(S); mean=6.65) of all the clusters, including those in clusters 3 and 4 who replied in the affirmative to one or both of the depression questions, respectively.

The other psychosocial measures did not yield significant findings. With respect to trigger points, there were no significant correlations between the right trigger point with PRMD frequency ( $p=0.07$ ) or PRMD severity ( $p=0.08$ ) or the left trigger point with PRMD frequency ( $p=0.17$ ) or PRMD severity ( $p=0.14$ ). There was a significant sex difference for pain reports for both right ( $F_{1,3}=8.31$ ,  $p=0.004$ ) and left trigger points ( $F_{1,3}=10.31$ ,  $p=0.001$ ) for musicians reporting the highest scores on the K-MPAI. Scores for females increased as MPA scores increased, while males in the highest MPA group showed a decrease in report of pain from the trigger points. On pain ratings for the right ( $F_{1,6}=2.6$ ,  $p=0.02$ ) and left ( $F_{1,6}=2.54$ ,  $p=0.05$ ) trigger points, those reporting high MPA and affirmative responses to both depression questions had higher trigger point pain ratings than subgroups with lower ratings of MPA.

## DISCUSSION

Most (84%) elite professional musicians in this study reported having experienced PRMD pain severe enough to interfere with their performance; 50% reported current pain; 24% reported constant pain; 21% reported their pain as the “worst imaginable,” with a further 29% reporting moderately severe pain. Higher proportions of females reported both more severe performance impairing pain and more frequent occasions during which they experienced pain of this severity. Cluster analyses of PRMD severity and music performance anxiety severity showed that increasing PRMD severity ratings mapped linearly onto increasing mean K-MPAI scores across the four clusters identified in the analysis. Univariate analyses revealed a significant relationship between PRMD severity and depression, but not between pain frequency and depression. Cluster analysis further assessing this relationship between PRMD severity and depression is of considerable clinical and theoretical interest. Cluster 2, 25% sample, reported no depression while simultaneously returning the highest ratings for PRMD pain severity. Similar discordances have been observed in studies of anxiety and physiological arousal, but no comparable study has examined this phenomenon for depression or in musicians. Cluster 2 represent possible “somatizers,” that is, individuals who express their psychological distress in physical systems, while denying their emotional distress. Findings such as these highlight the short-comings of self-report measures over clinical assessment. One of the key reasons that standard self-report measures are limited in this way is that the relevant psychological processes may be implicit, that is, they are not available to awareness and thus, cannot be directly reported upon. Musician “somatizers” need closer study using measures devised to tap into implicit processes in order to further our understanding of this vulnerable group and to assist in the management of their pain. There were no significant relationships between right or left trigger points and PRMD frequency or severity. In contrast to the study by Rickert *et al.* (2012) where a specific instrumental group with high neck and shoulder loads during performance was studied, this study evaluated a wide range of instrumentalists, which may have required more trigger points to be assessed to reflect the specific mechanical loading of the different instruments. The use of trigger points in only one region of the body may have reduced the association between the reported PRMD frequency and severity and trigger point sensitivity as most reported associations of trigger point sensitivity and pain are located within the region of pain (Freeman *et al.* 2009). However, trigger points do seem to be sensitive to psychological phenomena. In our study, there were significant sex differences for both right

and left trigger points for musicians in the K-MPAI's highest score category (125+). The results suggest that PRMD may not be able to be treated effectively without considering its relationships to depression and MPA.

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**Thematic session:  
Performance practice**



# A microstructural investigation into jazz syncopation: The effects of selected musical variables on note dynamics

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The purpose of this study was to empirically determine what selected musical factors affect the acoustical properties (i.e. note dynamics) of eighth notes in jazz performance. Eighth notes (N=231) were sampled from four unaccompanied solos performed by American saxophonist Chris Potter. Note dynamics were simultaneously regressed on metrical beat placement, melodic character, intervals, articulation, range, underlying harmony, and tempo. The omnibus test was statistically significant, and the predictor variables combined to account for 22.3% of the variance in note dynamics. Tempo was found to have a statistically significant effect on note dynamics.

*Keywords:* dynamics; expression; jazz; microstructure; syncopation

One of the most fundamental elements in jazz performance is swing rhythm (Berliner 1994, Collier and Collier 1996, Friberg and Sundström 2002, Schuller 1968). However, it is one of the least discussed elements in jazz education because of its elusive nature. Syncopation is a defining construct of swing rhythm and serves as an expressive tool underscored in the most prevalent sub-tactus metrical level in jazz: the eighth note (Liebman 1997). A jazz performer's subtle manipulation of note dynamics, or the acoustical loudness of a given eighth note, engages the listener in the feeling of tension and release, rest, and unrest. Perceptually, syncopation is responsible for the forward moving, rhythmic drive described in jazz performance (Hodier 1956).

A problem, however, lies in the lack of ability to describe, capture, and notate expressive qualities in music performance. Therefore, the rich variety of nuance found in jazz has traditionally been taught through performance practice and learned aurally. Pedagogically, the aural imitation approach to learning jazz nuance engages the learner in a manner where perception and

conceptualization is freed from the limitations of categories. A strict aural approach to teaching the nuances inherent in jazz rhythm, however, inhibits important instructional dialogue pertaining to prescriptive, preventative, and aesthetic aspects of the educational process. Previous empirical studies have investigated the role of jazz rhythm in terms of eighth note length and ensemble synchronicity (Benadon 2006, Busse 2002, Cholakis and Parsons 1995, Collier and Collier 1996, Collier and Collier 2002, Povel 1977, Reinholdsson 1987, Rose 1989). However, no empirical studies have investigated the effects of musical factors on the acoustical properties of jazz syncopation.

The aim of this study was to empirically determine the musical factors that affect eighth note dynamics in jazz performance. A more complete understanding of the microstructural elements of jazz syncopation is necessary for the improved pedagogy of jazz rhythm. More importantly, it can provide a more fundamental understanding of the underlying structure in jazz performance. The empirical testing of jazz syncopation may provide valuable insight into identifying, diagnosing, and prescribing solutions to problems pertaining jazz phrasing and time-feel.

## METHOD

### Participants

Eighth notes (N=231) were sampled from four unaccompanied solos performed by American saxophonist Chris Potter (*Confirmation, 26-2, It Could Happen to You, Rhythm Changes*). Chris Potter was selected as an exemplar because his performance of eighth note lines is performed in a clear manner in all registers of the saxophone and his performances are based upon a strong rhythmical foundation rooted in the jazz tradition.

### Materials

The data designated by the variables of note duration, tempo, and beat emphasis were analyzed using MATLAB, created by Mathworks, with the utilization of MIRtoolbox 1.3.3 (Lartillot *et al.* 2008). The data was analyzed by utilizing reliability, correlation, and regression sub-routines in the Statistical Package for Social Sciences (SPSS).

### Procedure

Upon examination of jazz research literature, musical variables effecting syncopation (i.e. individual eighth note dynamics) were identified. The variables were examined for redundancy, appropriateness, and testing feasibility. The

identified variables included (1) articulation, (2) interval preceding, (3) interval succeeding, (4) interval direction preceding, (5) interval direction succeeding, (6) metrical placement, (7) instrument range, (8) tempo, and (9) underlying harmonic character. An a priori power analysis was conducted in order to calculate the appropriate sample size with the desired power of 0.80 and an alpha level of 0.05. The data indicated that 211 units of analysis were needed. The relative signal energy for each individual eighth note performed was calculated utilizing *MIRtoolbox's mirrms* (root square mean) function.

## RESULTS

Note dynamics ( $N=231$ ) were simultaneously regressed on metrical beat placement, melodic character, intervals, articulation, range, underlying harmony, and tempo (See Table 1). The omnibus test was statistically significant ( $R^2=0.223$ ,  $F_{9,221}=7.06$ ,  $p<0.001$ ). The independent variables combined to account for 22.3% of the variance in note dynamics. Tempo ( $\beta=0.408$ ,  $t_6=427$ ,  $p<0.001$ ) was found to have a statistically significant effect on note dynamics. All of the inter-correlations were non-significant beyond  $p=0.05$ .

## DISCUSSION

The results indicate that, acoustically, only tempo has an effect on the examined eighth notes. Therefore, it can be argued that the perception of jazz syncopation may play more of an important role than the acoustical occurrences of syncopation in a jazz listening experience. By using an acoustical under-

Table 1. Summary of the simultaneous regression analyses.

<i>Variable</i>	<i>b</i>	<i>SE</i>	$\beta$	<i>p</i>	<i>VIF</i>
Variables predicting note dynamics					
Range	.012	.006	.145	.029	1.241
Metrical placement	-.001	.002	.042	.500	1.082
Underlying harmony	-.007	.006	.082	.201	1.163
Interval preceding	.002	.002	.063	.355	1.322
Interval succeeding	.005	.002	.002	.974	1.096
Melodic character preceding	.004	.006	.053	.450	1.383
Melodic character succeeding	.010	.006	.105	.090	1.085
Articulation	.002	.008	.014	.829	1.144
Tempo	.002	.000	.437	.000	1.177

Note.  $R^2=0.223$  ( $p<0.001$ ).

standing as a foundation, further investigation into the relationships between listeners' perceptions and the true acoustics of a jazz performance may broaden our perceptual, pedagogical, and theoretical understanding of jazz rhythm.

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# Doing without thinking? Aspects of musical decision-making revisited

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This paper explores how performance decisions are made through an analysis of interviews conducted with 18 Baroque violinists and cellists about their interpretation of solo works by J. S. Bach. Using Interpretative Phenomenological Analysis (IPA), broad themes were found relating to influences on musical decisions and processes of decision-making. Influences were grouped into seven super-ordinate themes: harmony, analysis, physical/technical, historical information, performance context, specific experiences, and repertoire and scores. Many of these themes revealed how performers learn and communicate their knowledge about style. For example, interviewees compared pieces with other Baroque repertoire, referred to historical treatises and different editions, drew on influential performance experiences, and talked about being familiar with the possibilities afforded by the bow and instrument. In the category processes of musical decision-making, most themes related to the meaning, nature, and role of what could be termed intuitive or deliberate processes. Intuitive processes were experienced as a “feeling,” “recognition,” or “sense” based on accumulated experience and knowledge. Deliberate decision-making was discussed in terms of having an awareness and control over a performance, leading to consistency and discipline in executing musical choices. This paper links themes from the interviews to literature on Baroque performance and recent psychological research on judgment and decision-making.

*Keywords:* music performance; interpretation; decision-making; intuition; phenomenology

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# Dialogue and collective interaction: Informants upon the collaborative interpretation of Baroque performance practice

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Baroque composers frequently notated critical aspects of performance practice in minimal fashion, leaving to the performer's discretion interpretive characteristics that were considered mandatory knowledge for musicians of the time. Yet modern editions often present a diverse variance of scholarly rigor with respect to the interpretation of ornamentation, articulation, tempo, and dynamic inflections. Many of the twenty-first-century practitioners surveyed in this study reported limited formalized theoretical and practical training in Baroque performance practice, with skills instead honed through personal interaction within early professional contexts. Scholars reported upon interpretive guidelines relating to Baroque music as collaborative and artistic mechanisms fundamental to well-versed rehearsal and performance techniques. In light of these scenarios, this qualitative research study reflects upon musicians' collective interaction. The findings consider the decisive roles played by collaborative discourse and critical listening as procedures inherent to research processes and to rehearsal and performance environs. Furthermore, this paper suggests co-operative dialogue and analytical listening procedures as integral to effective pedagogical settings. Such techniques assist the twenty-first-century musician in engaging with, and adapting to, the enigmatic nature of performance practice within Baroque music.

*Keywords:* interpretation; collaboration; Baroque; performance; pedagogy

Composers of the Baroque period (c. 1600-1760) regularly gave scant written indication of their intentions concerning critical aspects of performance

practice, including ornamentation, articulatory inflections, and the nuances of dynamics and tempo. These interpretive components were considered mandatory knowledge for musicians of the time, and were commonly left to the performers' discretion (Cyr 1992, Hill 2005). Yet the interpretation of these aspects of performance practice evident within some modern editions of Baroque works frequently displays an eclectic variance of scholarly rigor. For example, the critical edition of Handel's *Messiah* by Burrows (1987) presents a stark contrast with the problematic edition by Chrysander (1902). Many of the twenty-first-century practitioners surveyed in this study described the absence of theoretical study and a dearth of tuition in applied contexts within formalized academic environments, with the acquisition of skills in performance practice through collaborative scenarios within professional settings a resultant consequence.

This paper reflects upon collective interaction as an intrinsic phenomenon underpinning the preparatory phases and the performance of Baroque music. It examines the decisive, collaborative roles played by dialogue and analytical listening processes within practical, pedagogical, and music research contexts. The research outlined within this paper concurs with scholarly views upon the historical awareness of performance parameters when applying "musicological evidence" to Baroque music (Donington 1982, p. 3). Established within the literature as integral components of learning (Waghid 2006), this paper confirms the relevance of dialogue and collective interaction to the effective interpretation of Baroque performance practice. It also underlines the interpretive procedures relating to Baroque music as collaborative and artistic mechanisms fundamental to well-versed rehearsal and performance techniques (Donington 1982), and as informants to scholastic and applied perspectives upon Baroque performance practice.

## METHOD

### Participants

The research sample comprised professional instrumental and vocal performers, vocal coaches, teachers, and conductors considered eminent in the field. In accordance with ethical protocols, the desire for anonymity of those interviewed has been observed in the reporting of the research findings.

### Procedure

This paper adheres to a qualitative research paradigm, employing rigorous procedures of data collection including semi-structured interviews and refer-

ences to documented literature (Denzin and Lincoln 2000). The investigator's coding of the transcripts, critical reading, and reflection upon the codes produced generalized concepts within the data. Through the grouping of concepts into categories (Richards 2005), reflection, and analytical questioning, the critical narrative that has been constructed offers rich descriptions of the data.

## RESULTS

Revealing three principal analytical themes, this paper comments upon aspects of collaborative discourse, listening processes, and person-to-person contact as fundamental elements of pedagogy and research, and as conventions associated with the preparation and performance of Baroque music (see Table 1).

## DISCUSSION

*Theme 1.* Person-to-person interaction formed milestones in the sampled practitioners' conception of Baroque performance practice. Several interviewees described the desire to develop their views of performance practice within particular works, and to openly discuss their reading with instrumental colleagues and the music director. Highlighting inter-personal skills as an indispensable component of collaboration and dialogue, another practitioner emphasized the value of one's innate inclination to explore innovative concepts, coupled with openness towards the views and skills of other musicians. Person-to-person interaction while learning "on the job" and playing the keyboard continuo with the *Bournemouth Sinfonietta* and the *English Baroque Soloists* was described by one practitioner as crucial to her development of interpretive skills and to the applied knowledge of Baroque performance practice.

In the artistic working environment, unambiguous dialogue between the performers promotes a vibrant interpretive setting through the mutual exchange of ideas. This type of artistic and pedagogical milieu stimulates creativity and the extension of existing knowledge through the critical examination of assumptions and ideals (Waghid 2006). Elements of the research literature link the interpersonal skills established within collaborative activity to dialogue, to the fulfillment of collective purposes, and to conflict resolution (Younker and Burnard 2004). Consequently, the dialogic aspects of collaborative practices interchange well within musicians' learning procedures.

*Table 1.* A summary of the data codes, categories, and analytical outlines pertaining to dialogue and critical listening processes as informants upon the collaborative interpretation of Baroque performance practice (BPP).

<i>Codes</i>	<i>Categories</i>	<i>Analytical reflection</i>
<b><i>Theme 1:</i></b> Discourse and analytical listening processes inherent within person-to-person contact in professional scenarios frequently influences performers' interpretations of BPP.		
Person-to-person contact	Dialogue	Transparent dialogue in the observation, discussion, and application of concepts in BPP ignites the musician's learning process.
Critical listening	Dialogue	Critical listening and dialogue are procedural components of learning.
<b><i>Theme 2:</i></b> Teacher-student discourse and systematic listening processes associated with live and recorded music are active components in the pedagogy of BPP.		
Specialist coaches; vocal /instrumental teachers; musicologists	Dialogue; critical analysis	Specialist pedagogues may promote critical dialogue upon the interpretive components of BPP.
Recordings and evaluative listening	Critical analysis	Active listening and critical reflection upon dialogic processes, recordings, and live performances open pedagogical conduits to facets of BPP.
<b><i>Theme 3:</i></b> Dialogue and critical listening within collaborative rehearsal processes may stimulate the process of research.		
Collaboration	Dialogue	Research through practitioner collaboration develops conceptual cross-fertilization and philosophical discourse.
Recordings and evaluative listening	Critical analysis	Critical listening contextualized through the analysis of primary sources develops research and interpretive skills.

*Theme 2.* Several interviewees revealed dialogue with specialist coaches as crucial elements of their training, while the pedagogic role undertaken by such performer-teachers offered students direct contact with leading early music specialists. Reflecting upon their early professional careers, some interviewees described their palpable willingness to accept direction from experienced players and conductors within specialist period instrument groups.

Other practitioners explained a life-long fascination with recordings as a key element in the formulation of interpretive knowledge, and as a contributing mechanism to pedagogic processes within higher education. Some of the surveyed musicians teaching in tertiary institutions employed recordings as a means of demonstrating elements of performance practice. This research suggests that a balanced mixture of recordings and the experience of live performance are vital components of scholarship pertaining to Baroque performance practice.

Learning transpires within a multi-layered process, such as the interactive and evaluative assessment that occurs through listening encounters with recorded music and live performance (Blair 2009). Directed listening (Kassner 1998) and listening to stimulate the imagination (Cobbs 2005) also play their role in the training of musicians. This paper indicates that active pedagogy promotes constructive dialogue between musicians. It also encourages discourse, evaluative listening, and reflection upon the application of performance practice in recordings and within live performances.

*Theme 3.* Analysis of the data identified the collaborative element of person-to-person contact as a component within research practice. The surveyed practitioners frequently approached their research through a co-operative dialogue that creates interpretive concepts based upon the exchange of individual elements of scholarship and shared ideals. Several interviewees credited critical listening and dialogic processes in collaborative interaction with musicologists as a stimulus to performers' research procedures.

Some specialists interviewed within this study advocated analytical listening practices in relation to recordings as significant processes within their research methodologies. The ready access to high-quality performances through digital media is useful in forming an awareness of the interpretive realm of Baroque performance practice. Critical reflection also establishes the significance of collaborative research practices. The literature underlines the critical role of discourse and reflexivity within rigorous data collection and analysis procedures (Freire 1998), while Rekrut (1997) highlights the fundamental role of dialogue within collective enquiry. Research methodologies incorporated through personal interaction therefore allow the pedagogic environment to define and promote the practical implementation of research skills.

In summary, this paper encapsulates findings based on the analytical interpretation of empirical data. Through person-to-person contact in professional environments, dialogue and critical listening processes emerged as fundamental informants upon the interpretation of Baroque performance practice. Elements of discourse, systematic listening, and critical analysis

facilitate the input of specialist pedagogues and recordings within higher music education frameworks. The collaborative aspects of rehearsal methods and the analytical listening procedures associated with recordings may also serve to stimulate research practices. This study therefore promotes constructive dialogue, systematic listening, and critical evaluation as key interpretive resources assisting the endeavors of twenty-first-century musicians performing together, engaging with, and adapting to the enigmatic nature of Baroque performance practice.

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**Thematic session:  
Performing together I**



# Speaking with one voice? Ensemble members' audiovisual perceptions of each other's performances

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Successful ensemble performances require a mutual agreement on expressive characteristics of the music. The correspondence between the musicians' expressive intentions should be manifest in the acoustic and/or visual information conveyed. This study investigated auditory and visual interactions within a string quartet by asking the musicians to play an active role both as performers and in the research. They were filmed during a public performance of Vaughan Williams' first string quartet in G minor. Some months after the performance, each member of the quartet evaluated the expressiveness of their own and fellow musicians' performances separately with continuous response ratings for an excerpt from the first movement. Results indicate a general cross-modal agreement on their expressive performance, yet reveal limits to self-other perception and mutual understanding when focusing on each member of the quartet individually. Grand average expressiveness judgments of the music were related to acoustical measures of intensity. Consequences for ensembles without a conductor are discussed.

*Keywords:* string quartet; self-other perception; musical interactions; continuous response; time series analysis

If performances of string quartets are conversations of four people, as Goethe put it, then the question arises whether individual musicians know what they are telling each other. When performing together, musicians need to express their intentions in a way that is decipherable by others so that they can modify their playing during the course of a performance. This study analyzed how members of a string quartet perceived their expressive performances continuously in self-other judgments.

Research on string quartets provides insights in creative musical collaboration, social roles in a team, and strategies of rehearsal and performance coordination without a conductor. Davidson and Good (2002) identified complex interactions and social roles within a student string quartet. Typical social roles were also identified by King (2006) for student quartets of various musical instruments. Quartets with a clear leadership structure were seen as being more effective. Seddon and Biasutti (2009) described verbal and nonverbal communication patterns in a professional string quartet. Of particular importance were “empathic attunements” (p. 127) with fellow members of the quartet during performance, which enabled spontaneous reactions to their musical ideas. Taken together, these studies highlight the contribution of individual members and their social roles for quartet success. It is not entirely known yet in what ways musicians react to each other on a moment-to-moment basis and how they perceive the expressive intentions conveyed by each individual member.

It can be assumed that quartet members are particularly skilled in perceiving their fellow musicians’ intentions. The basis for this assumption lies in their action competence (see Schütz-Bosbach and Prinz 2007, Novembre *et al.* 2012), which enables them to take the perspective of other musicians and to internally “feel” their performance movements. Support for this claim has been provided in a study that addressed the impact of motor competence on a music-specific perception task (Wöllner and Cañal-Bruland 2010). In order to investigate the perception of individual quartet members’ intentions and the mutual agreement within the quartet, the current study analyzed the conveyance and perception of musical expressiveness, which can be defined as the intensity in which emotions are communicated. Highly expressive moments, for instance, occur in musical passages in which emotions are strongly communicated, without the need for specifying the valence dimension. Regarding the arousal dimension of emotions, research has evidenced relations with increasing loudness (Schubert 2004), a psychoacoustic correlate of dynamic intensity.

Within musical ensembles, successful interactions should be manifest in a high correspondence between the visual and/or auditory perception of one’s own expressions and the perception of one’s expressions by other individuals. In this study it was assumed (1) that individual musician’s expressive intentions are related to expressiveness perceptions by fellow members of the quartet (self-other perception), and (2) that expressiveness judgments of the music correspond to acoustical measures of intensity.

## METHOD

### Participants

An advanced student string quartet of a major conservatoire was video recorded. At the time of the study, quartet members (20 and 21 years old, all female) had studied their current or further musical instruments for at least 13 years (max. 17 years). Each of them had played in musical ensembles for 11 years or more, and the current quartet had been formed four years prior to the study. This research was approved by the institution's Ethics Committee.

### Procedure

The quartet performed Vaughan Williams' first string quartet in G minor to a small audience. For the recording, two identical digital video cameras (Panasonic NV-GS280) were positioned in front of the quartet. An excerpt from the first movement was chosen for this study, which spanned measures 48-97 (62 seconds). Three to four months after the performance, members of the quartet took part in individual experimental sessions. They were first presented with four visual-only video sequences of the selected excerpt, in which each member of the quartet was shown individually including the one who was watching the sequences. Second, each member of the quartet was presented with an auditory-only excerpt. Third, they watched audio-visual versions showing individual members of the quartet again with sound. While watching the sequences, they indicated continuously the level of expressiveness in the performances. Purpose-written computer software played back the videos and simultaneously recorded continuous responses with a sample rate of 10 Hz.

### Data analysis

The first six measures were excluded from analysis, allowing for adjustment time in continuous responses (Bachorik *et al.* 2009). In order to reduce random noise in the time series, all continuous profiles were smoothed by aggregating successive response values, resulting in a new sample rate of 1 Hz. Grand expressiveness profiles were calculated by averaging individual profiles. Since serial positions in data may confound correlation coefficients (Schubert 2004), all continuous responses were first-order differenced before being subjected to correlation analysis. Following Kolmogorov-Smirnov tests, Spearman correlations were calculated between expressiveness profiles across experimental conditions and between individual members of the

quartet. Mean intensity values (sample rate: 1 Hz) were analyzed with Praat (Boersma and Weenink 2010).

## RESULTS

Grand average profiles of the quartet's continuous expressiveness responses largely corresponded across modalities (see Figure 1), with the correlation between visual and auditory profiles being statistically significant ( $r_{54}=0.34$ ,  $p<0.05$ ). The combined information in audio-visual sequences resulted in deviating perceptions of expressiveness in some parts and was not significantly related to other profiles. The quartet's average response profile for the auditory sequence correlated significantly with intensity ( $r_{54}=0.29$ ,  $p<0.05$ ), indicating that quartet musicians played with higher dynamic intensity in expressive moments as intended and evaluated by themselves.

The visual transmission of each individual musician's expressiveness to fellow quartet members was analyzed. Continuous self-evaluations were correlated with averaged responses of the three other members. For the visual sequences, positive correlations were obtained for each member, yet self-other perceptions were only significant for the cellist ( $r_{54}=0.31$ ,  $p<0.05$ ). For the audiovisual sequences, all self-other correlations were positive, reaching significance levels for the first violinist ( $r_{54}=0.27$ ,  $p<0.05$ ) and the violist ( $r_{54}=0.42$ ,  $p<0.01$ ). Contributions of each musician's auditory expressiveness judgments to the quartet's average profile of the auditory sequence were analyzed. The profile of the first violinist explained 26.5% of variance in correlations, the one of the violist 53.3%, and of the cellist 8.0%. The second violinist, on the other hand, may have had a different perception of the musical expressiveness for this excerpt, which was not equally well perceived by other quartet members. This outcome is also reflected in the visual and audiovisual self-other correlations above.

## DISCUSSION

Results of this study indicate positive but only partially significant relations between individual musicians' expressive intentions and corresponding perceptions by fellow musicians. Grand average profiles, on the other hand, resulted in significant correlations between visual-only and auditory-only conditions, the latter also being related to acoustic intensity. Since visual sequences were presented first and continuous evaluations took place several months after the recording, these results suggest that musicians' overall bodily expressiveness matched their musical intentions.

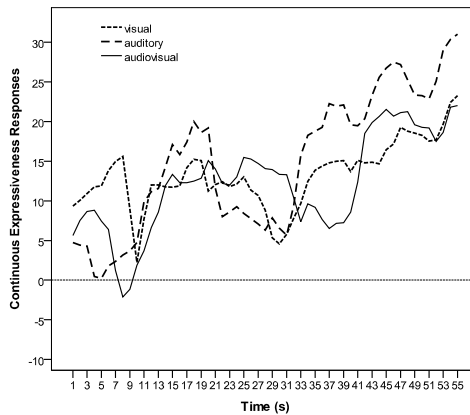


Figure 1. Mean continuous response profiles of the string quartet for visual-only, auditory-only, and audio-visual presentations of the performance.

The ability to decode expressive intentions plays a key role in musical ensemble performance. Based on research analyzing interactions and social roles in quartets (Davidson and Good 2002, King 2006, Seddon and Biasutti 2009) it can be assumed that mutual understanding of each others' visual performance cues may be as important as auditory cues in spontaneous music making. Alternative options for reaching ensemble coherence can be observed in exhaustive rehearsal processes, where members negotiate expressive performance characteristics in meticulous detail that may not leave much scope for variation during live performances, or otherwise in distinct leadership. Since these approaches are clearly goal-directed and always involve negotiation, they are particularly interesting to study in small musical ensembles. In this regard, Gilboa and Tal-Shmotkin (2012) recently found that string quartets develop self-managing strategies that resemble teamwork behavior in the business sector. The finding that not all quartet members in the current study perceived their fellow musicians' intentions in an unambiguous way calls for more research that may compare rehearsal and performance strategies in relation to social roles and level of professionalism.

If musicians are not only led by one person and react spontaneously to each other during live performance, then the level of accomplishment in small musical ensembles and successful interactions could hypothetically be related to empathy (see Newman-Norlund *et al.* 2009, for a study on verbal interactions). Accomplished musicians should be more proficient at estimating the musical intentions of others, and empathy as seen from perception-action

models may play a key role. There is also preliminary evidence (Wöllner 2012) that empathy in relation to music's inherent gestural quality influences the appreciation of music, and that musicians may develop specific forms of empathy based on their action competence.

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# Investigating the relationship between expressivity and synchronization in ensemble performance: An exploratory study

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We present an exploratory study on ensemble expressive performance based on the analysis of string quartet recordings. We recorded a piece with three expressive intentions: mechanical, normal, and exaggerated. We made use of bowing gesture data (bow velocity and force) acquired through a motion tracking system to devise a precise score performance alignment. Individual contact microphone audio signals allowed extraction of a set of audio descriptors for each musician and each note. We show how tempo and loudness on a macro-scale changed across expressive intentions and score sections. The score is also taken into account in the analysis by extracting contextual attributes for each note. We show that micro-deviations were affected by note contextual attributes, whereas the effect of expressive intention varied across sections. We find sections that exhibited a lower entrainment, where individual parts tended to be freer and presented more asynchronies.

*Keywords:* expressive timing; synchronization; ensemble performance; entrainment; motion capture

In ensemble performance the need for introducing expressive deviations and the need to maintain the dictated relationships among individual parts are in continuous competition (Keller 2008). Two types of deviations have been considered in the literature and have often been modeled separately (Widmer and Goebel 2004). The first includes modulation of tempo and dynamics happening at phrase level (macro-scale). The second (micro-scale) includes note lengthening/shortening and local loudness accentuation, which do not affect the macro-scale. In ensemble performance macro-scale deviations are collective since the musicians need to share a common reference for tempo and

dynamics whereas micro-scale deviations are related to individual contributions of each musician.

One of the main methodological issues of research in music performance is separating the signal from random fluctuations (Palmer 1997). In an attempt to address this we extract contextual attributes that can explain the measured variability in different groups of notes. We are interested in studying how the synchronization among performers interacts with the micro-scale expressive deviations. In a preliminary study (Marchini *et al.* 2012) it was shown that musicians tend to introduce more micro-timing deviations when playing together than when playing alone. This supports the idea that micro-timing deviations interact with the synchronization mechanism. Here, we look for clues on how synchronization interacts with the expressive deviations in different sections of the score when musicians render the performance with different levels of expressive intentions.

## METHOD

### Participants and materials

We recorded a professional string quartet performing the last movement of Beethoven's *Quartet No. 4 in C minor* (Op. 19 No. 4, *allegro-prestissimo*). After the quartet had played their first version ("normal") we asked for a "mechanical" and an "exaggerated" execution. The three executions were each around five minutes long. The piece is in the classical *rondo* form and thus its sections follow a structure ABACABA. With the assistance of a professional musicologist, sections were further segmented into phrases, leading to phrases of around four bars.

### Procedure: Data acquisition

For each musician, we used a contact microphone (bridge pickup) and sensors of a motion capture system (EMF, see Maestre 2009) to acquire data. Processing of motion data corresponding to the instrument's body and bow trajectories allow us to compute a number of bowing descriptors, such as bow velocity and bow force (Marchini *et al.* 2011).

We used bow velocity, bow force, audio signal intensity (RMS), and pitch to set up a score-to-performance alignment algorithm based on dynamic programming, from which we automatically segmented the performance into notes (onset/offset list) and matched it to score notes. The alignment was revised by manual inspection.

We described loudness and timing at the two temporal scales (micro and macro). For loudness, we first computed the peak intensity within each note (in dB). Then, for each musician, we obtained the *macro-scale loudness excursion* on windows of four bars by computing the difference in peak intensity between the loudest note and the softest note within the window. *Micro-scale loudness fluctuations* were computed as deviations (in dB) of each note's loudness from the weighted average peak intensity of surrounding notes in a window of four seconds.

*Macro-scale timing* is described as ensemble tempo fluctuations: by jointly processing note onsets and offsets of concurrent notes in the score, a phrase arc tempo curve is devised. We applied the same procedure used for loudness to compute the excursion on the tempo curve, this time also dividing it by the average tempo on the surrounding 32-bar window.

The *micro-scale timing description* provided us with three features to work with: *note duration ratio*, *participatory asynchrony* and *asynchronies among musicians*. Note duration ratio was computed as the ratio between real duration of the note in seconds and expected duration of the note in respect to the estimated local tempo. Participatory asynchrony was computed as the deviation of the onset from the macro-scale timing in beats and is defined for every note in the score. Asynchronies among musicians were instead defined only on groups of at least two simultaneous notes as the standard deviation of their onset times (in ms).

### **Note contextual attributes**

From the symbolic information available from analysis of the score, we computed six contextual attributes for each of the notes in the performance: metrical strength quantized to three levels, melodic charge, harmonic charge quantized to two levels, Narmour group (Narmour 1990), and pairwise melodic charge: a boolean set to “yes” if the note presented the highest value among concurrent notes.

### **Analysis**

Macro-scale analysis was carried out by studying the excursion of dynamics (loudness) and tempo fluctuations along the different sections of the three piece executions. Micro-scale analysis was performed by means of n-way ANOVA tests on loudness deviation, duration ratio, and participatory asynchrony. Factors studied in these tests were the six note contextual attributes previously described, and the expressive intention (normal, mechanical, exaggerated). We restricted the analysis to quaver notes to avoid bias on dura-

tion. This restriction left us with 2946 notes (495 from violin 1, 861 from violin 2, 861 from viola, and 729 from cello) for the ANOVA.

We complemented the analysis by looking at the average asynchrony among musicians per section. Finally we also computed an interdependence measure over participatory asynchronies using mutual information. The method was the same as reported in Papiotis *et al.* (2012) except mutual information was computed over participatory asynchronies.

## RESULTS

The results can be summarized in three points. First, expressive intention affected macro-scale. Second, the micro-scale deviations were not noise, since they can be explained from contextual attributes. Third, the effect of expressive intentions on *duration ratio* and *participatory asynchrony* varied in relation with mean asynchrony of each section.

Tempo excursion (in percentage respect to section mean tempo) and loudness excursion (in dB) are shown in Table 1. A one-way ANOVA on the three expressive cases shows that the difference is significant ( $p < 0.05$ ). After the ANOVA analysis of micro-scale deviations, we found that all six score attributes affected the loudness; analogously, we also found that five out of six affected the duration ratio; finally, three out of six affected participatory asynchrony. This confirms that the introduced deviations are not noise but are rather related to contextual attributes.

We then looked at the effect of the expressive intention factor separately on each section. We found an inverse relation between the p-values of the duration ratio and p-values of participatory asynchrony as depicted in Figure 1. This means in general that when one of the two was affected the other was not and vice-versa. Although one can point out that such an inverse relation could depend on how the asynchrony and duration ratio are computed from segmented performances, we tested for correlation among the two and found a small (-0.18) correlation, which does not seem to explain this behavior. From section A to section B the mean asynchrony among musicians rose from

Table 1. Means (and standard deviations) of collective performance parameters on the three expressive cases.

	<i>Mechanical</i>	<i>Normal</i>	<i>Exaggerated</i>
Tempo excursion (percentage)	7.14 (2.11)	8.45 (2.05)	9.59 (2.95)
Loudness excursion (decibel)	15.31 (2.26)	17.67 (2.69)	23.43 (3.97)

19 to 24 ms ( $p < 0.01$ ) and then went back to 19 in section A' and section C. Correspondingly, the interdependence between asynchronies of musician pairs tended to diminish (see Figure 2). Both measures mirror the result on the effect of expressive intentions on micro-timing.

## DISCUSSION

Different expressive intentions were realized modulating macro-scale tempo and loudness with different levels of excursion. We found correlations between the contextual attributes and micro-timing deviations. Our findings on synchronization and micro-timing suggest that in section B musicians were less bound one with each other and thus executed their part with more freedom in terms of timing. This supports the idea that entrainment forces the musician to shape their timing deviations differently depending on the global

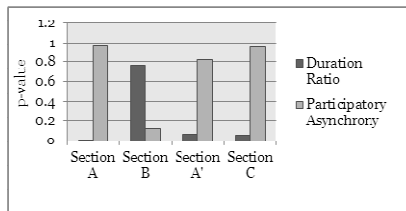


Figure 1. P-values of the factor expressive case for duration ratio and participatory asynchrony on four sections of the piece.

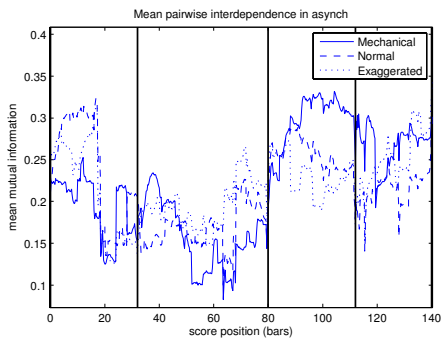


Figure 2. Interdependence among musicians in terms of asynchrony for the three expressive cases. The vertical lines mark the boundaries of score parts A, B, A', and C. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

intention. By looking at the score with the musicologist we also found that in section A the main theme is given to first violin whereas in part B all the musicians contribute more equally to shape the melodic line. This aspect might also be the cause of the different entraining levels.

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# Behavioral coordination among chamber musicians: A study of visual synchrony and communication in two string quartets

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In ensemble performances, group members may use particular behaviors as a sort of “language” to supplement the lack of verbal communication. These behaviors can be classified into several categories: music regulators, musical expression behaviors, personal needs behaviors, and preparatory and instrumental needs. This study focuses on music regulators, which are defined as signs to the other group members for coordinating the performance: eye contact, smiles, and body movement for attacks and feedback. To understand how regulators are used by ensemble players, video recordings of two string quartet performances were analyzed. Two conditions were considered: a low stress performance (LSP) represented by an ensemble rehearsal, and a high stress performance (HSP) represented by a concert. Findings demonstrated that, during musical performance, eye contact has two important functions: communication between ensemble members and monitoring individual and group performance. It appears strictly related to the score, as it is used to support synchronization, especially in critical technical or rhythmical passages. Movements connected with attacks seem influenced by stressful conditions and by the presence of the audience, conveying both communicative and expressive meanings.

*Keywords:* music regulators; behavioral coordination; eye contact; video analysis; string quartets

There is a growing interest in research that considers gesture and behavioral coordination among musicians during music performance (Biasutti 2013,

Davidson and Correia 2002, Davidson and King 2004, Overholt 2009, Seddon and Biasutti, 2009a, 2009b, Thompson and Luck 2011, Williamon and Davidson 2002). It is a research field focused on particular behaviors that group members may use during musical performance, as a sort of “language” to supplement the lack of verbal communication. These body movements take on different meanings. According to their specific functions, behaviors can be classified into several categories such as music regulators, musical expression, personal needs, and preparatory and instrumental needs. Davidson and Correia (2002) and Davidson and King (2004) identified three main functions of gestures and body movements in musical performance: sound production with instrumental technique, musical expression, and non-verbal communication with co-performers and audiences. Musical expression includes gestures used to promote musical expressiveness and those which are visual, externally oriented representations of mental and physical intentions. There are three main kinds of externally oriented gestures: “illustrators” (self-explanatory gestures of emphasis), “emblems” (gestural symbols, with cultural and social meanings), and “regulators” (gestures used to mark entrances and exits). Non-verbal communication includes adaptive self-regulatory gestures related to inner states or characteristics of the performer (e.g. touching his/her own face, caressing the body, and so on).

Williamon and Davidson (2002) examined communication between pianist’s co-performers. An increase in gestures and eye contact was found that connected with the process of familiarization with the musical pieces. Participants played their musical role in coordinating among individual performances and shared musical meanings as the process of learning occurred in practice settings. Thompson and Luck (2011) examined differences in movements, timing, and dynamics of pianists during four conditions: normal performance, performance with a reduced level of expressiveness, performance with the highest level of expressiveness, and performance with the least body movement. The findings provided evidence that more expressiveness is connected with larger body movements. In the reviewed literature, several aspects of gesture and behavioral coordination among chamber musicians were reported. However, little research has been carried out considering combined music regulators, such as eye contact and body movement for attacks, examining how they vary in different performance conditions.

## METHOD

The current study focused on music regulators, defined as signs to the other group members for communicating and coordinating the performance: eye



contact, smiles, and body movement for attacks and feedback. The aim of the project was to analyze non-verbal communication between co-performers, focusing on musical specific regulators: eye contact and attacks. Moreover, some quantitative differences in the amount of eye contact and levels of attack emphasis were hypothesized between rehearsals (low stress performance, LSP) and concert performances (high stress performance, HSP).

### **Participants and procedure**

Two young professional string quartets participated in this project: the French *Quatour Girard* and the British *Wu Quartet*. Both groups completed their musical education with famous string quartet performers and reported high-ranking positions in many international competitions. For both quartets, one polished run-through of a set program in a typical rehearsal space and the concert performance of the same program were video-recorded. The recordings regarded two different moments: a rehearsal condition (LSP), and the concert (HSP).

### **Data analysis**

In order to analyze the video recordings, the constant comparative method (CCM)—an inductive method based on grounded theory—was used. Then a quantitative time analysis was performed considering attacks and eye contacts. To determine the performance attacks, observers watched the video recordings several times to develop confidence in the players' performance style and a definition of attack. In a follow-up meeting with an expert, attack was defined as a pre-determined intentional gesture acted by one performer and addressed to the other members with the aim of synchronizing the performance. The observers came back to the video recordings independently to identify the total number of attacks using the above definition. To determine the total eye contacts, two observers analyzed the video recordings independently. To decide what movements could be considered eye contact the following definition was developed: eye contact is intentional eye movement towards one or more performers with the aim of checking aspects of the performance, such as synchronizing bow movements, intensity, or gesture. Eye contact was measured for each performer. For the Girard quartet a video recording of the first movement (*moderato*) of Bartók's *Op. 17 No. 2 for Two Violins, Viola, and Cello* (1915-1917) was considered (duration=10'06" for LSP condition, 11'00" for HSP condition), while for the Wu ensemble video recordings of the first and fourth movements (*allegro moderato* and *finale*

*presto*) of Haydn's *Op. 77 No. 1 for Two Violins, Viola, and Cello* (1791) were examined (total duration=9'39" for LSP condition, 10'17" for HSP condition).

## RESULTS

For the Girard quartet, 15 attacks were recognized by both researchers in both LSP and HSP conditions, while 3 attacks were identified by only one of the observers. In order to verify the consistency of the attacks, the score was used to confirm if it was an effective attack or an expressive performer gesture. In a follow-up meeting the two observers discussed with another expert the consistency of the attacks. Finally, the agreed total number of attacks was 17. For the Wu quartet's first movement, 4 attacks were recognized by both researchers in both conditions, while 6 attacks were identified by only one of them; for the fourth movement 6 attacks were the same for both observers, while 3 attacks were not the same. In order to verify the consistency of the attacks, the score was again used to confirm if it was an effective attack or an expressive performer gesture; in some cases, to identify an attack, the behaviors of other members were also considered. The two observers discussed with another expert the consistency of the attacks and determined a total number of 9 attacks for the first movement and 8 attacks for the fourth movement. In a follow-up analysis two observers independently evaluated the emphasis of the attacks, which was defined as the confidence, amplitude of gesture, and global body involvement in performing the attack. The judgment variability for the emphasis of attacks was calculated with Pearson's  $r$  correlation coefficient; for Girard group's analysis  $r=0.57$  ( $p<0.01$ ), while for Wu group's  $r=0.69$  ( $p<0.01$ ). Because the  $r$  coefficient was statistically significant in both cases, it can be assumed that there was an acceptable level of agreement between the observers.

Considering eye contacts in video recordings of the Girard ensemble, 35 eye contacts were recognized by both the observers in the LSP, while 46 were identified by only one. For the HSP, 23 eye contacts were the same for the two observers, while 61 were not the same. The two observers discussed with another expert the consistency of the eye contacts, checking for doubtful cases on the video recordings and defining 67 eye contacts for LSP and 70 for HSP. In the Wu quartet's fourth movement, 17 eye contacts were recognized by both observers in the LSP while 13 were identified by only one. For the HSP, 25 eye contacts were recognized by both observers, while 16 were identified by only one. At this point the two observers again discussed the consistency of the eye contacts with another expert, checking for doubtful cases on the video

recordings. At the end of this process 31 eye contacts for LSP and 41 eye contacts for HSP were recognized and agreed upon by the researchers.

In order to contrast LSP and HSP conditions, t-test comparisons were conducted using SPSS. With regard to the Girard quartet, a significant difference was found for attack emphasis in LSP and HSP conditions ( $t_{16}=3.77$ ,  $p<0.01$ ), while no significant differences were found for number of eye contacts. Considering the Wu quartet, a significant difference emerged for attack emphasis in LSP and HSP conditions ( $t_{16}=5.46$ ,  $p<0.01$ ), with no significant differences concerning eye contact. Despite the absence of significant differences for eye contacts, members who assumed a leading role (e.g. the first violinists) in both ensembles showed an increase in eye contact from the rehearsal to the concert (8 versus 10 eye contacts for Girard's first violin; 15 versus 21 and 6 versus 13 for Wu's first violin in the first and fourth movements respectively).

## DISCUSSION

The findings of the current study demonstrated a difference in the attack emphasis between LSP and HSP conditions and are in agreement with Thompson and Luck's (2011) results, which found that music expressiveness is connected with the amplitude of body movements. For the string quartets here considered, the concert is a situation which required more expressive behaviors in order to extend musical communication from inside the ensemble to the outside context, i.e. the audience. A double role for movement attacks, as both expressive and communicative movements, may be hypothesized (Davidson and Correia 2002, Davidson and King 2004). For both ensembles the first violin increased the amount of visual contact with other quartet members during the HSP, though group differences between performance conditions were not significant. This behavioral pattern is consistent with research concerning the role of ensemble leaders, supporting King's (2006) evidence of recognition of the first violin as leader by all string quartet members.

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**Thematic session:  
Career perspectives**



# Constructing an artistic identity two careers at a time: Dance and the career lifecycle

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The attraction and retention of highly skilled labor is one of the most challenging issues of our time, so much so that labor shortages in many Western nations have fuelled a “war for talent” that increasingly targets retention over initial recruitment. One of the difficulties of retention is that younger workers are increasingly mobile and demonstrate what appears to be a lack of employer loyalty. Not surprisingly, this has prompted calls for a much better understanding of the attraction and retention drivers of young people. Recognizing that, the inclusion of outlier cases has the potential to reveal perspectives not found in more putative cases. This largely theoretical paper contributes insights from research with dancers-in-training. The findings suggest marked differences in the quality of career preview developed by industry-based students and those in higher education. They also suggest that the passion and focus of students may not be an impediment to developing broad views of work and career. The implications for educators center on the need to encourage students to consider possible roles throughout the whole career lifecycle.

*Keywords:* career; attraction; preview; dance; education

In many developed countries declining labor force participation and an ageing population are critical economic issues with significant implications for employers and educators. As older workers retire, and there is an increasing reliance on younger workers, the attraction and retention of highly skilled labor is set to become more important. Increasingly mobile younger workers, however, demonstrate what appears to be a lack of employer loyalty (Sonlet and Kralj 2010).

Traditionally, careers have been perceived in terms of linear progression, with promotion awarded on the basis of seniority and experience. The current trend is towards careers that are non-linear, unpredictable, and less likely to

feature standard forms of employment and regular working hours. Workers increasingly link periods of work with periods of new learning. Moreover, they encounter movement and/or promotion based on transferability of competencies and internal work values (Clarke 2008). These trends bear many of the hallmarks of careers within the arts, which are often complex, self-driven, precarious, and low paid (Throsby 2012).

The nature of arts work has resulted in a workforce with characteristics that would be the envy of many other sectors. Despite the more difficult aspects of careers in the arts, for example, workers tend to be highly committed to their arts work. Similarly, the concept of lifelong learning, which has become a human resources catch cry, has long been a reality in the arts. As such, arts workers present an extreme and highly useful case for exploring the drivers of motivation and attraction.

The commitment of dancers is higher than that experienced in many other sectors. In addition to passion or calling, it is necessary to devote significant amounts of time and energy to highly specialized training if there is any hope of a professional career. This can include full-time dance training while still at secondary school.

Despite the length of time it takes to become a professional dancer, most dancers retire from their physical dance practice in their thirties (Bennett 2009). The majority of dance graduates work as independent artists, who juggle forward-planning with the demands of existing projects and other work. Work of this type requires competencies beyond performance and beyond dance, and it demands these competencies at graduation. Recognition that graduates are rarely so well-equipped has led to multiple calls for broader initial training together with appropriate professional learning opportunities (Burns and Harrison 2009). The questions explored in this paper include how students define careers in dance, whether and how they think about life after dance, and what this might mean for educators.

## METHOD

### Participants

In order to explore potential differences between students training within industry and those within higher education institutions, the study sought two distinct cohorts. The first cohort was comprised of secondary school students (N=8), aged 14–17 years, who were enrolled in full-time professional dance programs while completing school via distance learning programs. The second cohort consisted of dance students (N=25) who were enrolled in an undergraduate dance program at a university.



## **Materials**

The research design for this study employed the possible-selves construct (Markus and Nurius 1986), which links the construction of identity with the consideration of possible futures. The construct was deemed useful because it relates to formative career choice and aspirations, and also to work-specific attraction and retention.

## **Procedure**

The participants responded to questions that explored possible fears or concerns, aspirations, and the possible characteristics of participants' future dance careers. Focus groups were employed with cohort 1, because it is an appropriate method for obtaining data from children (Stewart *et al.* 2007). Cohort 2 participants responded to a survey that contained open and closed questions. Participants were invited to the study via email and/or a request made by their lecturer, and they were free to withdraw at any time. Parental consent was obtained for participants under the age of eighteen. The research was explained to the students at the commencement of the project, and their confidentiality was assured.

Textual data were transcribed, coded and analyzed using a thematic rather than a content analysis approach. Each researcher independently conducted the initial coding, after which coding was compared and refinements applied. Quasi-quantification was applied to survey responses as appropriate, and these were included with the quantitative material in an SPSS database for analysis. Interviews were recorded and transcribed utilizing the qualitative research software package NVivo.

## **RESULTS**

This section presents a snapshot of the findings for each of the two cohorts within the two themes of career preview and career post-view.

### **Theme 1: Career preview**

When asked what prompted them to study ballet so intensively participants in cohort 1 noted the physical and emotional challenges of dance. A major theme was a "passion" for dance. This was driven by an intrinsic sense of self and identity, reflecting what the students wanted to do and the enjoyment they hoped to gain from it.

The participants in cohort 1 trained six days per week, with study breaks for academic classes. Dance classes often extended until 8pm. Students regu-

larly participated in rehearsals and performances for professional productions and they attended extra-curricular workshops with professional dancers. They expressed a realistic view of how long a physical career in dance might be sustainable. They also appeared to accept the possibility of leaving dance due to physical limitations such as the impact of ageing or injury, or for child bearing. At this formative career stage there was no mention of a proactive decision to leave dance in favor of increased income or job status. Similarly, the issue of work-life balance was not linked to workplace flexibility or conditions of employment. Cohort 1 was acutely aware of the nature of dance careers, and participants indicated that a work-life balance was not achievable. Both male and female participants reported that they would make the choice to begin a family even if this meant curtailing their dance careers.

Cohort 2 also recognized the realities of starting a family: “I imagine [the career] will impact decisions to have children, and I expect to do a lot in the industry before children. Of course, I’m male, so I could continue a while after” (male). The majority (84%) of cohort 2 participants reported having made early decisions to commit to dance. However, this cohort appeared less accepting of the realities of dance careers: “I didn’t comprehend that I would constantly live not knowing what I would be doing in six months’ time” (female). Interestingly, none of the cohort 2 participants identified injury as a concern, whereas it was a common theme in cohort 1. While cohort 2 indicated satisfaction with their undergraduate dance training, a number of them requested greater diversity and expressed a need for guest lecturers, mentors, or coaches who could better prepare them for life as a dancer.

### **Theme 2: Career post-view**

A number of cohort 1 participants described themselves within alternative careers after their future transition from dance. Many indicated a desire to stay in the arts, but others were planning to follow another career path. Surprisingly, these second careers were often fairly well thought-out in terms of both the requisite education and training, and the potential to fit with family responsibilities. The students appeared to be managing the risks they faced as dancers by planning alternative careers, even when their passion for dance was intense. A greater majority of cohort 2 participants had considered careers after dance. Unlike cohort 1, however, none of them indicated interest in specific second careers.

## DISCUSSION

Transitions into, through, and from post-secondary study are attracting increasing attention. This comes at the same time as concern that education institutions and employers fail to adequately prepare young people for their future work and careers (Coffey 2012). The majority of participants in this study had already developed not only a preview of dance careers, but a post-view: i.e. a view beyond their physical dance careers to second careers identified as possible future career paths. This suggests a realistic view of the short-term nature of careers in dance, and also flexibility and forethought in contingency and future planning. However, the quality of career preview differed markedly between the two cohorts.

Cohort 1, whose training was oriented within professional practice, noted that realistic job previews were provided early in their training and were reinforced as training progressed. Significant actors included dance teachers, educators, guest artists, and practicing dancers. The sharing of negative experiences as part of this process aligns with research undertaken by Pickard and Bailey (2009), who linked realistic previews, preparedness, and resilience. Indeed, Coffey's (2012) study of early career dance graduates reinforced the high level of congruence between dancers' industry-based training, career advice, expectations, and career realities.

To some extent the benefits of a broader education and the award of a degree are offset by less contact with the sector and the delay of full-time training until after secondary school. In contrast with cohort 1, cohort 2 articulated a need for a more realistic preview of being an artist in the "real world" and how to survive once there. It is likely that more accurate and realistic career information, short-term placements, guest speakers, and work integrated learning would lead to better alignment between career expectations and reality, reduce training costs, and lead to higher retention.

The findings suggest that the passion and focus of arts students does not form an impediment to developing broad views of future work and careers. This is a natural result of exploring many possible selves, and this is most effective when it involves interactions and experiences within and beyond the arts. Introducing students to the concept of a career lifecycle over which they have control, and within which they can be free to investigate many possible selves, is central to the development of salient identity, resilience, and independence. These issues all warrant further exploration.

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# Life after performance: The subjective experience of musicians who undergo career transition

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This study examines the subjective experience of musicians who “closed shop” and moved on to another career. Direct, open-ended, experientially oriented data were collected through interviewing 10 former musicians. The data were systematically analyzed in accordance with the tenets of the grounded theory method and revealed two main groups of participants: “natural” and “ambivalent” musicians. The former group was further subdivided into “injured” and “non-injured” musicians. The core category of the representative model was *Finding Self, Losing Self: Quest for Areté*—a category that illustrates the importance of realizing one’s selfhood through the quest for personal excellence. Subsumed under the core category were four major themes: (1) Unfolding Self: The Making of an Artist; (2) Turning Point: On a Crossroad; (3) Making the Decision; and (4) Looking Ahead: Consequences of Transition. These themes were further divided into subcategories and their properties. Overall, the model presents a holistic perspective of the process of career transition experienced by musicians who retired from the concert stage. In addition, the findings delineate participants’ psychological responses related to identity issues, depending on the specific group of musicians. The model and the findings of the study are discussed within the framework of the organismic valuing theory of growth through adversity.

*Keywords:* performing artists; musicians; career transition; grounded theory; human science

Music, from the performing artist’s viewpoint, is an intimate, passionate and intense long term relationship involving challenges, struggles, sacrifices, victories, and defeats. It also involves interaction with composers, teachers, colleagues, and most of all audiences. Regardless of these intense and passionate

relationships, a musician may occasionally decide (or be forced) to abandon the concert stage and undergo a career transition to a second career which may or may not be related to his or her former occupation.

Surprisingly, the issue of mid-career change among musicians has not been addressed in the social science field or in the more specialized field of music psychology. This is likely because the transition from an artist to a former artist often severs the connection with the artistic world, and because research on issues faced by musicians tends to focus on artists who are active in the profession. Due to the lack of anecdotal or empirical research if one wished to examine this issue empirically, the lack of a theoretical base is very limiting. Consequently, and consistent with this author's own philosophical conviction, it is proposed that the appropriate methodological approach to this particular study requires a qualitative inquiry adhering to the human science approach to research.

## **METHOD**

### **Participants**

The participants were ten classical musicians: nine were professional musicians who had earned their living by performing and teaching, and one had been a music student training in performance and teaching. All but one made a career transition to a non-performing art profession.

Two groups were targeted. The first group consisted of four former artists who were forced to make a career transition as a result of an injury which prevented them from performing. The second group consisted of six former musicians who left the profession for reasons other than injuries: they were unable to maintain financial independence, they did not enjoy the highly competitive nature of the profession, or they developed other interests.

### **Materials**

Two instruments were used to collect data from the participants: A personal history questionnaire (i.e. demographics, vocational status and performance history) and a non-structured and non-directive interview. Each interview was audio taped and subsequently transcribed. The analysis of the transcripts served as the primary source of data for the study.

### **Procedure**

The ten transcripts were analyzed following the Grounded Theory Method (Charmaz 2006, Glaser and Strauss 1967). In the first stage of data analysis

three models were constructed. These were later collapsed into a hierarchical general model which encompassed all aspects of the phenomenon.

## RESULTS

The analysis revealed two main groups of participants: “natural” and “ambivalent” musicians. The latter group was subdivided into “injured” and “non-injured” musicians. The core category of the hierarchical general model was *Finding Self, Losing Self: Quest for Areté* which illustrates the importance of realizing one’s selfhood through the quest for personal excellence. Subsumed under the core category were the following four major themes: (1) “Unfolding self: The Making of an Artist” which consists of material related to the process by which participants became professional musicians; (2) “Turning Point: On a Crossroad” entails participants’ realization they had reached a major crossroad, which could lead them to consider an alternative route; (3) “Making the Decision” which consists of the decision to terminate one’s career and the choice of an alternate career; and (4) “Looking Ahead: Consequences of Transition” which consists of identity issues emanating from participants’ career transitions. All of these themes were further divided into subcategories and their properties (see Table 1).

Most participants acquired their new direction through a return to school and re-education in a different field. All ten stopped performing professionally and nine switched to a second career. Some participants were able to form an immediate closure whereas others took a longer route to disengagement or were never fully disengaged. The ambivalent and injured musicians (but one) seemed to be the most successful in their attempts to achieve closure with the ambivalent musicians being more successful in this endeavor. The injured musicians realized that they had no choice but to give up their careers and the non-injured musicians, although able to develop what one can consider to be a very successful second career, were still, many years later, experiencing ongoing regret and grief.

## DISCUSSION

Career transitioning processes of former performing artists can be explored and understood within the context of vocational identity theories (e.g. Abend 1974, Super 1957), life transition (e.g. Schlossberg 1981), and adaptation to disability (e.g. Livneh and Antonak 2005). The present discussion will focus on a different perspective related to the organismic valuing theory of growth through adversity (Joseph and Linley 2005). This theory, which builds on the work of earlier humanistic-existential theorists, postulates that individuals

*Table 1. Finding self, losing self: Quest for Areté.*

Unfolding self: The making of an artist	A. Formative years	- Discovery of talent
	B. Identity formation	- Investment - Unfolding identity - Forced identity
	C. Career path	- Goals and aspirations - Career development
Turning point: On a crossroad	A. Onset of injury	- Encounters with health professionals - Reaction to injury
	B. Discord	- Disenchantment - Realizing own limitations - Acknowledging the dissonance
	C. Encountering alternatives	- Serendipity - Weighing one's options
Making the decision	A. The pivotal point	
	B. Suspending the dream or disengagement	
	C. The chosen alternative	- Investment in second career - Qualities of the second profession - Gains and losses
Looking ahead: Consequences of transition	A. Evolving self	
	B. Realization of self	- The "true" self - Looking back
	C. Split self	- The overt and covert self - Losing the key

possess the intrinsic motivation towards positive growth following adversity and after accommodating such adversity they will end up with positive changes and increased psychological well-being.

The organismic valuing theory of growth proposes three possible outcomes to adversity. An individual who "assimilates" traumatic experience by integrating it to a pre-existing world view can recover emotionally but does not grow psychologically and remains vulnerable to future stressors. An indi-



vidual who negatively “accommodates” the event might experience feelings of hopelessness with a higher likelihood of developing depression. Lastly, individuals who positively accommodate the trauma and appropriately modify their prior worldview will experience psychological growth defined as enhanced personal relationships, greater sense of personal resiliency including acceptance of vulnerabilities and limitations, and changes in life philosophy (Joseph and Linley 2005).

There is no doubt that musicians who have spent most of their lives preparing for a performing art career (often to the exclusion of other activities) and then have to grapple with the realization that they will not be able to fulfill their passion initially experience sense of loss and grief as they are not able to live in accordance with their organismic valuing process. Their ability then to process this trauma depends on their reaction to this adversity. The injured musicians not only were able to keep their musician’s identity intact, they were also able at the same time to “expand” their identity and develop an alternate identity or self. By coming to terms with their disabilities they were able to proceed with a fulfilling second career; in other words these individuals seemed to have been able to accommodate their life adversity in a positive way by modifying their world view accordingly.

The non-injured musicians, who seemingly terminated their career volitionally, appeared to be “stuck” even though all were able to develop a very successful second career. From an emotional perspective they have been unable to move forward and achieve closure, still harboring the hope that someday they will be able to return to the concert stage. It can be argued that members of this group have accommodated their experience in a negative way which resulted in periods of despair and unresolved grief accompanied by feelings that they have not been living in accordance with their organismic valuing process. The ambivalent musicians followed an opposite route. They experienced a contradiction between their organismic valuing process and the performance career they chose and only by leaving the profession they achieved their desired growth and fulfillment.

Interestingly, regardless of the reaction and adaptation (whether positive or negative) to leaving the profession, the quest for personal best was present with all participants. This quest for all inclusive excellence is indeed in line with the ancient Greek ideal of *Areté*. It is argued here that embedded in the artistic profession (or for that matter, any profession that requires skilled performance) is the passion for excellence. Performers continuously strive to improve their art and to push the limits of their abilities. Previously studied and performed musical compositions are rarely considered by performers to be “finished products,” because it is understood that much more could always

be achieved. If pursuit of excellence is indeed a fundamental characteristic of artistic professions, and given that most musicians are introduced to the profession in their early lives, it follows that striving for excellence does become an integral part of their personality makeup. Thus, it appears that mastery in one field compels mastery in other fields.

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# Occupational health and wellbeing in the UK conservatoire sector: Staff perspectives

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Occupational health and wellbeing for musicians has not historically been a core consideration or component of education within the conservatoire sector. This is, however, beginning to change, and current research acknowledges that educational environments should become increasingly focused on providing students with the tools to sustain lengthy professional careers. The UK conservatoire sector in particular represents a highly competitive set of institutions that have developed unique and distinctive identities and individual approaches to occupational health and wellbeing training and resources. Through a series of semi-structured interviews with 22 staff members from 8 UK conservatories, this research has examined the existing occupational health and wellbeing provisions, activities, and resources and explored the possible future of the topic. The resulting data have revealed wide-ranging and complex occupational health and wellbeing provisions, with each individual describing differing aspects of and purposes for the topic. Institution-wide policy ranged from the highly formalized to the personal and *ad hoc*, even within one institution. When questioned about the future all described a desire for development, but identified several barriers. Many stressed a need for an improved culture where health and wellbeing was incorporated into everyday conservatoire life and was supported and contributed to by all members of staff.

*Keywords:* conservatoire; health; wellbeing; provisions; policy

The research output of music medicine practitioners and performance scientists has grown immeasurably over the last three decades, with the body of data now clearly demonstrating the specific nuances of occupational health and wellbeing for musicians. Pivotal projects have explored both the prevalence (Fishbein *et al.* 1988) and prevention (Spaulding 1988) of the specific

musculoskeletal problems associated with musical performance and have sparked wide-ranging investigations into all aspects of music performance. It is, however, only in the last 10 years (Chesky *et al.* 2006) that specialist musical educational institutions have really begun to recognise the importance of placing these topics at the core of their business, with one researcher stating:

It is now time for all music schools and universities to demand the resources to invest in the health of their most valuable assets, their students, all of whom have the potential to become physically and psychologically healthy cultural ambassadors of the future.... It is now that institutions should be advocating the establishment of psychological and physical interdisciplinary programs and courses in the curriculum as important aspects of health music programs (Nagel 2009).

Recent literature (Williamon and Thompson 2006) has clearly demonstrated how UK conservatoires have begun to bring occupational health and wellbeing into their policy, strategy, and curriculum (Manchester 2007). But how do members of staff working in UK conservatoires engage with and feel about these provisions? This paper will report some of the key findings of an interview-based study which consulted staff from across the UK conservatoire sector on their views and opinions of both current and future occupational health and wellbeing activities.

## **METHOD**

### **Participants**

A total of 22 participants from 8 UK conservatoires took part in semi-structured interviews on the topic of occupational health and wellbeing. Purposeful sampling was utilized to recruit participants working within the roles of student services managers, student welfare practitioners, one-to-one instrumental teachers, heads of faculty, and heads of program.

### **Materials**

Semi-structured interviews were carried out with 18 of the participants individually and 4 in pairs. An interview schedule was utilized and began by asking each participant to describe their role in the conservatoire, how this related to occupational health and wellbeing, and to give a brief description of any services, initiatives, or resources that they were aware of relating to the topic. The interview went on to investigate participants' personal views of

these provisions and explore possible futures for health and wellbeing within their role and their organization. The interview concluded by exploring the notion of commonality and investigating how this might function in the UK conservatoire sector. The interviews were recorded and later transcribed verbatim for analysis.

### **Procedure**

A thematic analysis was carried out, with the results from each role being compared with those in similar roles as well as with the whole group. The data were categorized into 5 areas: description of role, identification of existing resources, views of the future, perceived student opinion, and participant opinion. A further set of subcategories identified overarching views and key issues relating to the creation and promotion of developed occupational health and wellbeing provisions which included: individuality and complexity, the one-to-one teaching environment, and changing culture.

## **RESULTS**

### **Individuality and complexity**

Each interview demonstrated high levels of individuality, with participants from each institution providing a wide variety of descriptions and opinions of how they approach occupational health and wellbeing. All participants did, however, share a positive view of the subject, and demonstrated the importance of the topic within their lives, citing statements such as:

“Playing any musical instrument is such a physical activity that feeling passionately about health and wellbeing is clearly core.... You have to have a working body and mind in order to be able to play music, so it seems a bit of a no-brainer really to not think about it” (BD) and “everyone has their own little health hobby horse, don’t they” (TJ).

Despite participants being able to easily identify their personal connection to existing practices, policies, and resources relating to occupational health and wellbeing, the complexity of the topic within each conservatoire was identified. As one participant stated, “encapsulating kind of where it’s happening is really difficult” (HM). Many had little or no knowledge of conservatoire-wide initiatives, with, for example, a one-to-one teacher and the head of student services within the same institution denying and confirming, respectively, the existence of an in-house counselor. One participant correctly

stated “as I’m talking to you it’s interesting to see how pretty chaotic the approach here overall sounds, and I would imagine if I was doing your research I would find comparisons quite interesting between differing institutions as to levels of awareness and formality of provision” (RS).

A wide spectrum of approaches to occupational health and wellbeing were noted, sometimes even within one institution. Some participants described a carefully considered strategy, while others, such as in the quotation below, defined their approach as *ad hoc*:

We don’t have a structured Police Force to deal with occupational health and wellbeing but we do have vigilantes...a network of people and staff across the institution that are in a sense silently monitoring what’s going on and checking things are happening (GA).

### **The one-to-one teaching environment**

Participants from all roles have clearly demonstrated how the one-to-one teaching environment plays a central role in conservatoire education and in the delivery of occupational health and wellbeing. One teacher stated “I think we naturally approach health and wellbeing issues in every lesson” (RS), while those looking from the outside stated “I know that teachers are often the first port of call for students with health problems as I sometimes have teachers who are a bit unsure of what to do” (LA).

All stated problems in communication were between institution and one-to-one teaching staff, with one participant stating that “there’re about 200 members of part-time staff, and you may just come in and do a one-hour lesson and leave...and they have very limited contact with the student and how the place works” (AN). Another reported that “when you’re in for such a short amount of time you never really get the hang of the machinery, as it were” (GB).

Many felt that developing the role of health and wellbeing in this setting would be challenging, with one participant stating:

You know, I have a lot of stuff to prepare just for their playing and their instrument lessons are taken up with that...there just isn’t the time.... It probably would be good for me to know more about the health stuff...and it probably would be a good idea for them to communicate with me more...but then it would be up to me to read it [LAUGHS] and that takes time.... You know we all get tonnes of paperwork through our door every week and do we read it all carefully? Of course we don’t (BD).

## Changing the culture

All participants explored how their health and wellbeing provisions might be improved, with a variety of practical outcomes ranging from the introduction of in-house alternative therapies to increased daily living advice being suggested.

A more significant vision for the future proposed that, in order to create and maintain a healthy working environment, an adjustment in institutional culture was needed to ensure that the topic was embedded within the core of the organisation. Ten participants spoke about their personal visions of how this might look and be implemented, with the words of one participant encapsulating the main points:

It's an area which needs kind of total war...in the sense that you want to be in an almost entirely utopian world, you want good services...to make sure that the implied curriculum is promoting good health...both physical and mental.... In other words, that each and every teacher has an understanding of what...is healthy practice in their area, healthy both physically and mentally and can guide their students towards that" (BS).

Several expressed their apathy towards developing health and wellbeing in the future, with one participant stating that "it's not at the forefront of what we do because the forefront of what we do is teach them to play music" (AM) and others stating that "if we started showing pictures of internal organs and diaphragm and everything...I think that there could be a danger of a kind of over-analysis and for creativity to be lost" (PJ).

## DISCUSSION

This research has demonstrated that all members of staff, from within all conservatoire roles studied, are aware of and are in some way connected to current health and wellbeing practices. Despite diverse personal opinions all were keen to explore ways of developing provisions with the aim of sending their students out into the professional world with the equipment to have long and successful careers, as well as the skills to pass on their knowledge of healthy practice to the next generation.

A complex and somewhat confused picture of current practices was revealed with participants demonstrating little knowledge of how occupational health and wellbeing fits into an overarching, conservatoire-wide strategy and policy. Personal knowledge of provisions was limited to their individual experiences, and few were able to identify provisions outside of their own depart-

ment, demonstrating a need for improved communication and institutional cohesion of provisions.

Participants identified a wide range of barriers to the development of occupational health and wellbeing, with issues ranging from funding to staff retraining and from lack of support to time and space in existing programs.

Many felt that developing common approaches across the UK conservatoire sector might be a good idea, and felt that communication and sharing of best practices could only enhance implementation. However, few could see how provisions might be managed systematically, sector wide, and stressed the importance of keeping the student experience as the focus, with one participant stating:

What I would say about this whole subject is that it's very, very important, and we should all talk about it, but it's very difficult to have a policy because every single student is different (AM).

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Thematic session:  
Performing together II



# Ravel's *Introduction et Allegro*: The issue of pedaling in piano duet performance

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Many authors have discussed the use of pedal in four-hand piano performance, and it is generally understood that the *secondo* player should control it. The main problem when two performers share one instrument is that the player who is handling the pedal must employ it for both himself and his partner, which affects the overall ensemble. In other words, the *secondo* player needs to know both parts thoroughly and listen with extreme care in order to decide how to pedal successfully. Pedal also affects articulation, tone color, clarity of texture, and dynamic nuances. Other important issues include the acoustics of the hall and the quality of the instrument. Both factors vary tremendously, and the pianists should know how to adapt to these conditions prior to their performance. The question of pedaling also has a profound impact on the *primo* player, since performing without operating the pedal affects articulation, attack and release of the keys, and dynamic control. This paper investigates how pedaling should be employed and practiced in Ravel's *Introduction et Allegro*, transcribed for piano duet by Léon Roques, and how it affects the performance.

*Keywords:* Maurice Ravel; *Introduction et Allegro*; pedaling; musical performance; piano duet repertoire

Keyboard instruments provide a rare case in which two performers may play a single instrument at the same time. This very special form of chamber music was cultivated even before the invention of the piano and achieved its zenith through piano duet repertoire during the nineteenth century (Lubin 1976). Collaboration between partners is the prime condition for the success of a chamber music group, and for piano-duet performers this collaboration may achieve a higher degree of refinement, both technically and musically. Performing together involves myriad aspects, from the choice of a partner to

the performing decisions regarding touch, phrasing, articulation, dynamics, and pedaling (Moldenhauer 1950). Many studies have examined pedaling, but very few discuss the use of the pedal in four-hand piano music. Transcriptions for one-piano-four-hands of symphonic, operatic, and chamber music works were common practice during the nineteenth and the beginning of the twentieth centuries. Moreover, they performed a crucial role in the perpetuation of this instrumental medium. Following this tradition, Ravel transcribed for two pianos his original work *Introduction et Allegro* for harp with accompaniment of flute, clarinet, and string quartet. Léon Roques later transcribed this work for piano duet. This piano duet transcription offers the possibility of exploring the particularities of pedaling. Both performers must emulate the sound of the harp, the strings, and the woodwind instruments. Since the use of pedal affects timbre, dynamics, accentuation, phrasing, and articulation, it is crucial that both performers consider several ways to employ pedal until a final decision is made (Banowetz 1985, Katz 2009, Wenger 1992, Wong 1995). This paper will examine the issue of pedaling in the piano duet medium using Ravel's *Introduction et Allegro* as a practical example.

### MAIN CONTRIBUTION

Pedaling is one the most important aspects of piano technique. Walter Gieseking, a distinguished interpreter of Debussy's and Ravel's piano music, was very explicit in the correct use of the pedal: "Just as one learns correct finger technique from the head and not the fingers, so one learns correct pedaling from the dictates of the ear and not the foot" (Banowetz 1985, p. 231). Moreover, music notation conveys only limited instructions about pedal use and it is impossible to notate all of the subtle gradations of pedaling because of constant changes in the acoustics of the concert halls and the quality of the instruments. Indeed, several writers have acknowledged the fact that pedaling varies according to performance conditions (Leimer and Gieseking 1938). Pedaling in piano duet repertoire represents a challenge for both performers. The main problem when two performers share one instrument is that the player who is handling the pedal must employ it for himself, and also pedal for his or her partner, which affects the overall ensemble. In other words, the *secondo* player needs to know both parts thoroughly and listen with extreme care in order to decide how to pedal successfully. The question of pedaling also has a profound impact on the *primo* player, since performing without operating the pedal affects articulation, attack and release of the keys, and dynamic control.

### **Pedaling suggestions in Ravel's *Introduction et Allegro***

Debussy and Ravel amplified the resources of the sustain pedal, creating new sonorities through a refined awareness of timbre. The four-hand piano transcription of Ravel's *Introduction et Allegro* offers a unique opportunity for both performers to explore pedaling as a complement of the tonal canvas and timbre. In the opening measures (see Figure 1) the *primo* player has to emulate the sound of the wind instruments (flute and clarinet), and it is necessary for the *secondo* player to depress the pedal completely before the beginning of the piece in order to engage the full resonance of the instrument. The *primo* player has to voice both hands carefully and a perfect *legato* must be observed in this passage during the change of pedal over the chromatic passing tones to avoid clashing harmonies. A difficult pedal problem occurs for the *secondo* player in measure 4 (see Figure 2). In the first beat there is a pause, but in the *primo* part there is a modulatory passage with octaves and double notes in *legato* that needs pedaling. As a practical suggestion, it would be interesting for the *secondo* player to play this passage alone, prior to deciding on how to pedal, as a means of feeling the tactile sensation of the performance of the *primo* player's part and to be able to react accordingly. The *secondo* player needs to respond to a blend of sound, which will be easier to do if she/he knows both parts and overcomes the strong tendency to pedal only for their own part of the score. Since the *primo* player is not pressing the pedal much more attention must be given to the articulation of the notes, attack, and release of the keys. In this particular passage a smooth *legato*, combined with the use of half pedal, is advisable. One beat later in the same measure both pianists have a harp figuration, and it is important to maintain the sonority by holding the bass line with the pedal, underpinning the harmony above. Tempo, touch, articulation, and pedaling are interrelated and crucial for the construction of the musical discourse and the atmosphere of this introduction.

A passage that could be pedaled by the *primo* player appears in measure 209 (*Très lent*, see Figure 3), where there is a cadenza performed by the harp in the original work. The melodic material of the introduction comes back as a remembrance of the opening measures. Although it is possible for the *secondo* player to use the pedal, it is more comfortable for the *primo* to employ it, since she/he could provide a better synchronization of pedaling with the attack and release of the keys, avoiding an interruption of sound during the several changes of pedal in the repeated double-thirds.

Très lent  $\text{♩} = 40$

PIANO

*pp* *expressif*

*pp*

*mf*

*mf*

*pp* *expressif*

Figure 1. Opening measures of the *primo* part to Ravel's *Introduction et Allegro*, transcription by Léon Roques.

Très lent  $\text{♩} = 40$

PIANO

*pp*

*pp* *expressif*

*mf*

*mf*

Figure 2. Opening measures of the *secondo* part to Ravel's *Introduction et Allegro*.

Très lent

*mf*

*pp*

*mf*

*p*

Figure 3. Measure 209 of the *primo* part to Ravel's *Introduction et Allegro*.

### Texture, articulation, resonance, and color

In measure 104 (see Figures 4 and 5), the section *un peu plus lent* is constructed over an Eb-minor pedal harmony. In Ravel's original version a harp solo is harmonically sustained by the woodwinds in *legato* and accompanied by the strings in *pizzicato*. The duo has to translate this multi-layered texture using different touches and a refined use of pedal. In the rolled-chord harp

figurations the melodic top notes must be brought out and the pedal changes must come on these top notes. The arpeggiation of the chords should start before the beat. The pedal should be used through the entire passage, and non-harmonic notes should be voiced more softly than harmonic ones, even though there are *staccato* markings in the left hand of the *secondo* part (emulating the *pizzicato* of the strings). The performers must control tempo, sonority, dynamics, and pedaling to create an impressionistic frame.

### IMPLICATIONS

In Ravel's *Introduction et Allegro*, the possibility of emulating the sound of different instruments adds another perspective to the use of pedal. Pedaling is one of the essential elements of a piano performance. It is even more complex within the duet medium, where the two performers need to act as one in order to form an ensemble. It is important that each one knows both parts and that they always practice together to achieve balance and coordination. The use of pedal is also affected by tempo, dynamics, articulation, and the acoustics of the hall. The question of pedaling has a profound impact on the *primo* player, since performing without operating the pedal affects the response of the instrument to the attack and release of the keys. The use of pedal in four-hand piano music requires planning and a great deal of practice. Although proper knowledge of pedaling effects and principles are imperative, the ear is always the final judge in the interpretive process. Notwithstanding the fact that much has been written about piano pedaling, few discuss the use of pedal in the piano duet repertoire. Studying factors that affect pedaling may illuminate how the piano duet should conduct their practice routine in order to find solutions for this important aspect of piano performance.



Figure 4. Measures 104-107 of the *primo* part to Ravel's *Introduction et Allegro*.



Figure 5 Measures 104-107 of the *secondo* part to Ravel's *Introduction et Allegro*.

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# How much do jazz players share understanding of their performance? A case study

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To what extent do collaborating musicians need to understand what they are doing in the same way? Two experienced jazz musicians who had never previously played together improvised a jazz standard three times on either side of a visual barrier, and were then interviewed separately about the performances and their musical intentions. Two months later, the performers listened to the recordings and rated the extent to which they endorsed each statement. Performers endorsed statements they themselves had generated more often than statements by their performing partner or an outside expert. The high quality of the performances combined with the disparities in agreement suggest that, at least in this case study, fully shared understanding of what happened is not essential for successful improvisation.

*Keywords:* intersubjectivity; collaboration; improvisation; shared understanding; jazz

When musicians collaborate, they predict, perceive, and react to what their partners do in complex ways (e.g. Clayton 2005, Davidson and King 2004, Goebl and Palmer 2009, Keller and Appel 2010, Kirschner and Tomasello 2009, Luck and Sloboda 2009). To what extent and in what ways do they need to share understanding of what they are doing? There must be at least some intersubjective agreement if musicians are to follow a shared rhythm and create a plausible joint performance, but must everything be agreed upon?

The aim in this case study was to explore the extent to which a pair of experienced jazz musicians understand what they have done together in the same way: whether they spontaneously generate the same descriptions of their performances and intentions, and when they do not, whether they agree

with their partner's characterization of what happened and what was intended. The methodological approach was to collect immediate retrospective accounts by performers after their performances, and then to examine the extent to which either party endorsed the statements made by the other, as well as statements made by an expert listener (e.g. Gottman and Levenson 1985, Ickes *et al.* 1986).

## METHOD

### Participants

The participants were a professional jazz saxophonist and a professional jazz pianist who had never previously met. Both were male and in their 20s; both had graduated from the same jazz conservatory at different times, and both regularly perform in New York City. They were each compensated \$100 for participating on two occasions.

### Materials

*Day of performance.* A list of potential pieces for performance was generated consisting of 9 jazz standards that the performers might feel comfortable improvising with an unfamiliar partner. Tunes were selected in order to be (1) challenging enough to keep the interest of two good players through three interpretations; (2) flexible enough to provide a range of improvisatory options, for example having common alternate chord changes and not traditionally being played in a single standard key; and (3) common enough so that both performers would be likely to be comfortable playing them. The list (*Here's That Rainy Day, Embraceable You, It Could Happen to You, You Stepped Out of a Dream, How Deep is the Ocean, Green Dolphin Street, Day by Day, If I Should Lose You, Old Folks*) was on two sheets of paper, with the instruction "please circle the tunes you know well enough to feel comfortable playing in a duo context with a very good jazz saxophonist" (or "pianist").

Audio recordings of the performances were burned to CD and immediately provided for presentation to the players on a laptop during the interviews.

A set of prompt questions and interviewing suggestions was visible to both interviewer and performer throughout the discussion. One set of prompts was intended to stimulate general discussion from memory about the differences between the performances; these included questions like "how would you describe the differences in the three performances you two just gave?", "were there any moments that you had trouble playing together?",

and “did you feel that someone was in charge, and did this change during your performances?” Another set of prompts was intended to focus commentary while listening (potentially multiple times, with stops and starts controlled by the performer being interviewed) to the recordings that had just been made; these included questions like “what do you think worked and what didn’t?”, “how did you know what to do next?”, and “what did your partner do that struck you as particularly interesting or notable?”

*Retrospective rating.* A questionnaire was constructed consisting of statements made about the performances by the performers themselves in the interviews immediately after the performances (70 by the pianist and 34 by the saxophonist) as well as 64 additional statements made about recordings of the performances by a jazz saxophonist who is a faculty member at a jazz conservatory. Of the collection of statements, 14 could be seen as alternate versions of the same claim made by more than one party, with 4 statements made by all three parties; this resulted in 151 unique statements that could be rated. The statements were anonymized and made consistent so that the original author of the statements could not be ascertained and to point to the moment in the recording that the performer was discussing; for example, “I was playing a bass part” was transformed into “at about 4:08 the sax plays a bass part.” Of the 151 statements, 33 were made about one performance but could in principle apply to any of the three performances (e.g. “the overall performance was standard or ‘vanilla’”), 4 were general statements about the players and performances (e.g. “my partner’s signals were very clear”), and 114 could only apply to one performance (e.g. “just before about 0:28, the sax was waiting for the piano to play the tonic as a cue to start the melody”).

The questionnaire presented each statement to be rated on a five point scale from “Strongly Disagree” (1) to “Strongly Agree” (5). The questionnaire consisted of four parts: (1) general statements about players and performances, (2) statements that could apply to more than one performance, (3) statements that concerned just one performance, and (4) questions about the experience of completing the questionnaire (e.g. “did you find yourself remembering how you felt at the time or thinking about how you feel about things now when listening or a bit of both?”). For statements in (2), the questionnaire asked raters to rate the extent to which they endorsed each statement for each of the three performances, so that the questionnaire ended up requiring 215 separate ratings of the statements about the performances.

The statements in parts (1) and (2) were presented in a random order and the questions in part (3) were presented in the order corresponding to the moments in the recording to which they applied.

## Procedure

*Day of performance.* Throughout the day, the performers never met each other, saw each other, or heard the other speak; they entered and exited and they were briefed and debriefed entirely separately.

After the performers entered the experiment room, which was a New York City performance space at a jazz conservatory, they were seated on either side of a visual barrier (with the piano on one side) and then asked to select (on paper) which standards they would be comfortable performing (see Materials). The experimenter selected *It Could Happen to You* from those on the list that overlapped, and then presented instructions to both performers simultaneously. The performers were asked to improvise three versions of *It Could Happen to You* that should be different from each other and that should each last about 5 minutes and be separated by silence; the performers were never to speak to each other at all, neither before, during, or after the performances. The performances were audio recorded and immediately burned to CD.

Immediately after the performances, each player was interviewed separately by different interviewers about the three performances using the prompts (see Materials), first from memory and then while listening to recordings of the performances. The interviewers' task was to elicit detailed and specific commentary that addressed the target questions, in whatever way seemed appropriate for each performer, eliciting as many statements clearly tied to specific moments in the music as possible. The interviews took about one hour each, and they were audio recorded for subsequent use.

*Retrospective rating.* Two months later, the performers were provided access to the three recordings and paper-and-pencil hardcopies of the questionnaire for them to fill out at their convenience in a quiet place alone, without interruption. They were instructed to listen to each recording at least once with headphones before responding, and that they could listen to each recording, with starts, stops, and rewinds, as often as they liked in order to provide accurate ratings. They were told that we were interested in their responses as they listened to the recordings *now*, and that this was not intended to be a memory test of how they felt at the time of recording. Both performers returned the questionnaires within a week; they reported having taken about an hour each to complete the questionnaires.

## RESULTS

As Figure 1 shows, the performers both endorsed statements they themselves had generated more often than those by the expert or their partner.

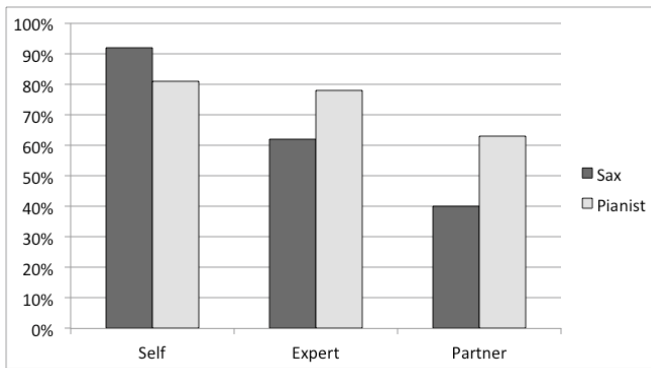


Figure 1. Percent of statements originally made by self, expert, and partner that the pianist and sax endorsed (4 or 5 on the 5-point scale).

At one level of abstraction there was broad agreement between the players. For example, for the 33 statements that could apply to more than one performance, the performers agreed on the rank ordering of the three takes for 11 of them, and for another 16 if we count one party's tied ranking as agreement with the other's distinction.

Closer inspection reveals some surprising discrepancies. Of the 217 separate ratings, players differed by 2 or more rating points on 62 of them (29%), and by 3 or more on 24 (11%). The statements with the most disagreement included not only judgments of quality of one party's performance ("the pianist's opening was excellent;" "the pianist's chord at about 1:23 didn't work") or the ensemble ("this was not the best performance"), but also assessments of the nature of the collaboration ("during these two choruses starting at about 1:22 the sax hears and uses the pianist's substitutions") and even basic facts about what happened ("at about 2:21, the sax started a phrase on B $\flat$ ").

## DISCUSSION

It is of course unclear whether the discrepant ratings reflect true disagreement rather than different interpretations of what the same statement means, or different interpretation of how a statement applies to a particular performance. Nonetheless, the high quality of the performances combined with the disparities in agreement suggest that, at least in this case study, fully shared understanding of what happened is not essential for successful improvisation. Also, the fact that the performers endorsed an expert listener's statements

more than (some of) their partner's suggests that the performers' interpretations may not be privileged relative to an outsider's, at least in some aspects.

### **Acknowledgments**

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# Structural communication in piano duos: Musical compatibility and individual differences in interpretation

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Ensemble performance involves each member contributing to a shared interpretation of the piece. In commercial recordings of piano duo performances, this study examined how individual differences in interpretation between each duo affect the rating of salience of particular events (accents), as well as the continuous ratings of phrasing and tension. An example comparing performances of Mozart's Sonata K. 448 Mvt. 3 and Sonata K. 521 Mvt. 2 by duos Argerich/Kissin and Haebler/Hoffman is shown, looking at significant differences in the ratings of events between the two. Differences were more evident between ratings of particular events in the K. 448 extract, which may serve to explain some of the variance seen between the average phrasing profiles.

*Keywords:* piano; ensemble; expression; structure; perception

In ensemble rehearsal all members contribute to a shared interpretation of the music by developing shared performance goals and landmarks, which are then used in performance (Keller and Appel 2010, Ginsborg *et al.* 2006). This study examined how these shared interpretations are perceived by audience members, focusing on musical compatibility among ensemble components and on differences in interpretation between ensembles. This project addressed compatibility among pianists in piano duos based on individual emphasis on score events (accents). Individual differences in the performance styles of piano duos were explored by analyzing the structural features characterizing each performance and the extent to which eminent piano duos agreed on segmentation of musical phrases and selection and emphasis of accents.

## METHOD

### Participants

12 participants (all trained musicians) were recruited from the University of Graz and the Conservatory of Southern Switzerland via email.

### Materials

Excerpts were taken from 8 contrasting commercial recordings of two Mozart pieces for piano duo (Sonata K. 448 Mvt. 3) and four hands (Sonata K. 521 Mvt. 2). For each piece, accent analysis was performed identifying immanent accents in metric, melodic, and harmonic categories. These defined locations were used as stimuli for stage two of the procedure. The instants of occurrence of these events have been derived in a separate sub-project according to Parncutt's theory of accents (Parncutt 2003, Bisesi and Parncutt 2011, Bisesi *et al.* 2012).

### Procedure

The method used for a pilot study involving solo piano performances of Chopin Preludes (Bisesi *et al.* 2012) was extended here to analyze the perception of phrasing and local event emphasis in 8 contrasting commercial recordings of two Mozart pieces for piano duo. This method is a dual-stage data collection process, first gathering responses on the continuous phrasing and tension of each performance and secondly on ratings for particular salient events (accents). For the first stage, for each piece, participants were presented the performances in random order, first listening to all performances of Sonata K. 448 and then to Sonata K. 521. While listening to these performances they were asked to use a vertical slider to continuously indicate the phrasing as shaped by the performer, the bottom point of the slider indicating phrase boundaries and the top point being reserved for the point of highest tension within each phrase. This data was collected through the Presentation 16.0 software. The participants were given a practice trial, including one of the test pieces, to (1) familiarize themselves with the music and (2) practice the task. Once they were familiar with the piece and the task the participants continued to the real trials. For the real trials the task was repeated again immediately for the same performance so that each one was rated twice.

In a separate session, stage two required the participants to rate the salience of selected notes corresponding to melodic, harmonic, and metrical events using a scale from 1 (not very salient) to 4 (very salient). The audio wave of each performance was presented using Sonic Visualiser 2.0 to allow



repeated listenings of user-selected excerpts according to the event locations. Target events were presented as vertical red lines on top of the audio wave, which itself had been transformed so that envelope information was no longer available. Participants then entered their ratings for each event using the data editor.

## RESULTS

Results presented here represent an example of two contrasting performances taken from the two sonatas. The first performance duo was Martha Argerich and Evengy Kissin (AK) and the second was Ingrid Haebler and Ludwig Hoffmann (HH). Each performance will be referred to by their duo acronym and the sonata's K. number (e.g. AK 448). For each duo and for each piece, the mean and standard deviations of the accent ratings were calculated. These are shown in Figures 1-4. Bonferroni adjusted t-tests (alpha level=0.05) showed significant differences between the performances of the K. 448 sonata extract (see Figures 1 and 2) for accent MH in bar 11 ( $t_{11}=3.62$ ,  $p<0.005$ ) between HH 448 ( $M=1.58$ ,  $SD=0.51$ ) and AK 448 ( $M=2.75$ ,  $SD=0.75$ ), for accent MC in bar 12 ( $t_{11}=4.48$ ,  $p<0.001$ ) between HH 448 ( $M=1.58$ ,  $SD=0.67$ ) and AK 448 ( $M=2.83$ ,  $SD=1.27$ ), and for accent MC in bar 54 ( $t_{11}=-3.77$ ,  $p<0.005$ ) between HH 448 ( $M=3.17$ ,  $SD=0.94$ ) and AK 448 ( $M=2.08$ ,  $SD=0.90$ ). However, no significant differences were found between accent ratings of the Sonata K. 521 extract performed by AK and HH (see Figures 3 and 4).

The positions of these accents were then plotted against the average continuous phrasing and tension responses from the first stage of data collection. Figures 5 and 6 show the plots for the two performances of Sonata K. 448, 3<sup>rd</sup> movement as these showed significant differences in the accent ratings.

## DISCUSSION

Although the majority of accents between performances were rated similarly, certain locations showed significant differences, which may reflect idiosyncrasies in each piano duo's interpretation. Results will contribute to Parncutt, Biseisi, and Friberg's formulation of a computational model of immanent accent salience in *Director Musices*, a software package for automatic rendering of expressive performance.

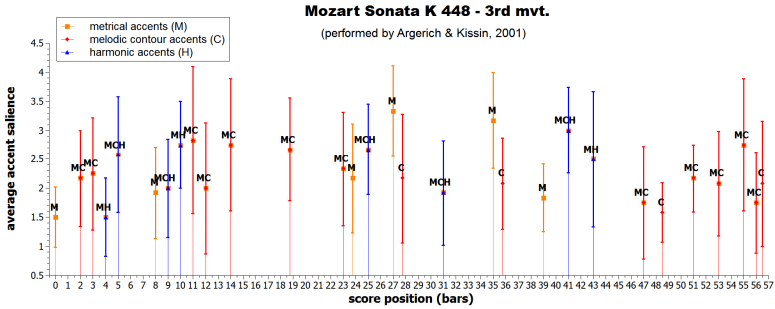


Figure 1. Means and standard deviations of accent ratings for Sonata K. 448, 3<sup>rd</sup> movement, performed by Martha Argerich and Evgeny Kissin.

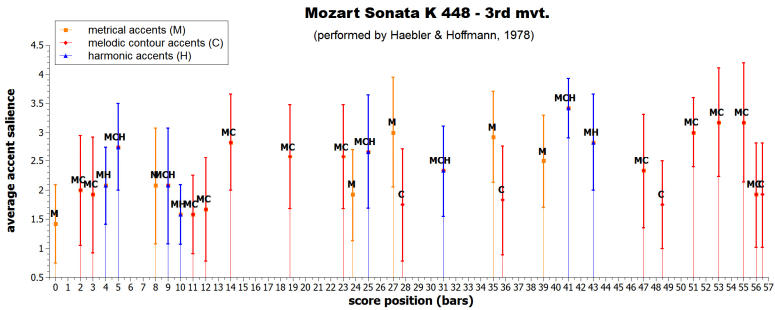


Figure 2. Means and standard deviations of accent ratings for Sonata K. 448, 3<sup>rd</sup> movement, performed by Ingrid Haebler and Ludwig Hoffman.

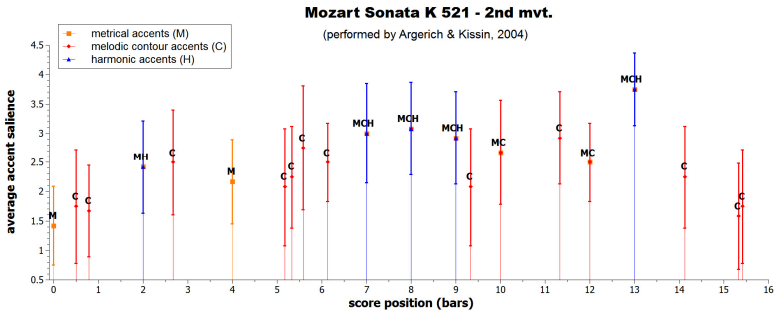


Figure 3. Means and standard deviations of accent ratings for Sonata K. 521, 2<sup>nd</sup> movement, performed by Martha Argerich and Evgeny Kissin. (See full color versions at [www.performancescience.org](http://www.performancescience.org).)

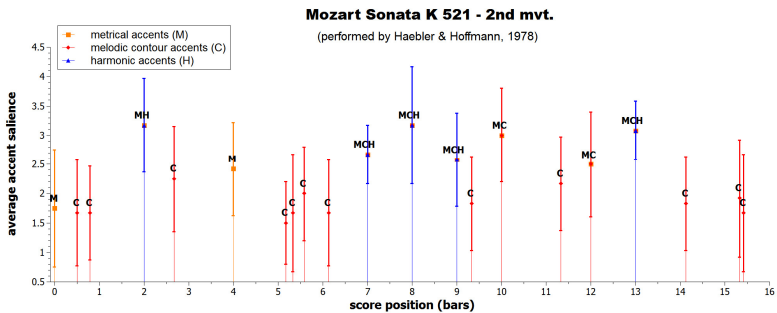


Figure 4. Means and standard deviations of accent ratings for Sonata K. 521, 2<sup>nd</sup> movement, performed by Ingrid Haebler and Ludwig Hoffman.

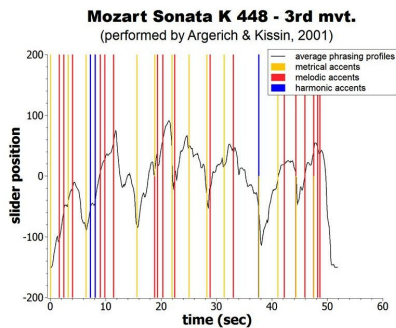


Figure 5. Plot of average phrasing profile across all 12 participants for performance AK 448. Vertical lines represent the position of the metrical, melodic, and harmonic accents taken from the score analysis.

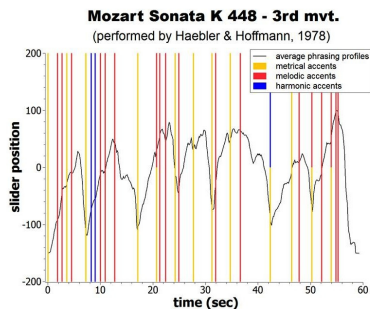


Figure 6. Plot of average phrasing profile across all 12 participants for performance HH 448. (See full color versions at [www.performancescience.org](http://www.performancescience.org).)

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Keynote paper



# Musical ensemble performance: A theoretical framework and empirical findings on interpersonal coordination

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Musical ensemble performance requires precise yet flexible interpersonal coordination. The former Max Planck Research Group on Music Cognition and Action investigated the psychological processes and brain mechanisms that enable such coordination. This paper provides an overview of the group's research on factors that determine the quality of ensemble cohesion. First, the theoretical framework and empirical approach that guided our work are outlined, and then key findings are described. These findings address the role of individual differences in cognitive-motor ensemble skills (anticipation, attention, and adaptation), social-psychological factors (personality), and the performer's knowledge about the music and familiarity with co-performers. The paper ends with a discussion of the implications of our research for pedagogical practice aimed at fostering excellence as an ensemble musician.

*Keywords:* ensemble; coordination; timing; skill; individual differences

Musical ensemble performance can be viewed as a pristine social art form that places exceptional demands upon the cognitive-motor capacities of co-performers. A particularly remarkable feature of ensemble performance is the exquisite balance that individuals are able to achieve between temporal precision and flexibility in interpersonal coordination. Such coordination is typically a highly creative affair involving diverse body parts, a variety of complementary roles played by different individuals, and adaptability to changing cognitive, motor, affective, and social demands that arise during performance. Yet competent co-performers are able to synchronize their actions with consistently high levels of accuracy. Investigating the psychological processes and neurophysiological mechanisms that enable a balance between precision and flexibility is essential to understanding human collaborative

music making. The current paper provides a glimpse into the research conducted on this topic by members of the Max Planck Research Group on Music Cognition and Action, which was active at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany, from 2007 until 2012. There are, of course, researchers elsewhere doing excellent work on ensemble performance, but that work is not reviewed here.

### MAIN CONTRIBUTION

The broad aim of the Leipzig Music Cognition and Action (MCA) group was to investigate the behavioral and brain bases of human interaction in musical contexts. The research agenda pursued by the group was guided by a theoretical framework addressing how basic temporal coordination between co-performers is supported by a set of core cognitive-motor ensemble skills. This framework was explored using an empirical research strategy that focused on individual differences in ensemble skills. Our studies employed performers in diverse ensembles—piano duos, choral groups, jazz combos, and gamelan musicians—but our most rigorous research efforts were directed towards ensemble performance in the tradition of western classical chamber music.

The theoretical framework and research strategy were applied chiefly to three topics: (1) online cognitive-motor ensemble skills and their neural correlates, (2) knowledge about musical structure and stylistic expression, (3) social factors that influence ensemble coordination. In the current paper, I will give a brief description of the theoretical framework and the empirical research strategy before highlighting key results pertaining to these three topics.

### Theoretical framework

The theoretical framework (Keller 2008) assumes that three core cognitive-motor skills determine the quality of real-time interpersonal coordination during musical ensemble performance. The first skill relates to anticipatory mechanisms, such as mental imagery, that are involved in planning a performer's own actions and predicting other ensemble members' actions. The second skill concerns the process of dividing attention between one's own actions and those of others while monitoring the overall, integrated ensemble output. The third ensemble skill is based upon adaptive mechanisms that allow performers to react to variations in each other's action timing and other performance parameters (e.g. intensity). The original framework has recently been extended (Keller in press) to address how the three skills interact with one another, as well as with social-psychological factors (e.g. variables related



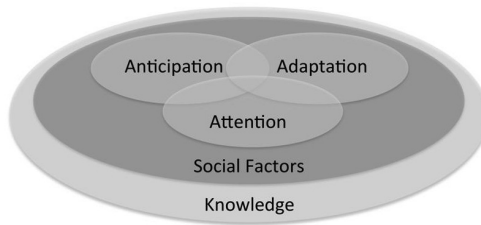


Figure 1. Theoretical framework for musical ensemble performance.

to personality) and the performer's knowledge about the music and familiarity with co-performers (see Figure 1).

### Empirical approach

The empirical approach adopted by the Leipzig MCA group capitalized upon differences in the quality of ensemble coordination that can be observed even among groups of the most assiduously trained musicians. We used this inter-individual variation to gain purchase on the psychological and neurophysiological bases of musical ensemble performance. The fundamental assumption behind our approach is that an individual's ability to coordinate with co-performers in an ensemble is, in large part, determined by his or her abilities related to the three cognitive-motor ensemble skills (anticipation, attention, and adaptation). Based on this assumption, our research program was organized around a set of three empirical goals.

Our first empirical goal was to examine the three ensemble skills using both qualitative and quantitative methods. The qualitative procedures included interviews with internationally renowned ensemble performers (e.g. the Labèque sisters and members of the Chicago Symphony Orchestra; see Keller in press). Our quantitative procedures consisted of a battery of perceptual and motor tasks that yield objective behavioral measures of an individual's anticipation, attention, and adaptation abilities. The functional processes behind these behavioral measures were interrogated through computational modeling and computer simulations, while the brain structures and neurophysiological mechanisms that support these functions were investigated using neuroimaging and brain stimulation techniques.

The group's second empirical goal was to address relationships between individual differences in the three ensemble skills and performance on naturalistic interpersonal coordination tasks. The naturalistic tasks that we employed included real musical ensemble performance (e.g. piano duos) and rudimentary forms of dyadic sensorimotor synchronization (joint finger-tap-

ping). In our studies of ensemble performance, interpersonal coordination was measured at the level of sounds (i.e. audio or digital signals from electronic instruments) and body movements (recorded with motion capture systems). The relationship between ensemble skills and naturalistic task performance was investigated using two strategies. One strategy was correlational: it involved measuring interpersonal coordination under naturalistic conditions and assessing the cognitive-motor ensemble skills within a common sample of individuals, and then calculating the degree to which the interpersonal coordination could be predicted based on ensemble skill estimates. For example, a pilot study (Keller 2008) of a small sample of 14 pianists revealed that the three core cognitive-motor skills, in combination, accounted for over 90% of the variance in the quality of interpersonal coordination when the pianists played in duos. The second strategy entailed assessing ensemble skills, and then testing interpersonal coordination after assigning individuals to pairs based on their level on a given skill (e.g. low skill pairs vs. high skill pairs vs. mixed pairs).

Finally, our third empirical goal targeted factors that potentially mediate the relationship between cognitive-motor ensemble skills and naturalistic interpersonal coordination. Two broad classes of factor were of interest: knowledge representations and social factors. Our methods for addressing the role of knowledge representations included manipulating the degree to which co-performers were familiar with each other's part in ensemble coordination tasks. The impact of social factors was explored by using psychometric instruments to assess social-cognitive variables (e.g. empathy).

### **Key findings: A selection**

In the following, I describe key findings that emerged from the MCA group's empirical research on topics related to musical ensemble performance. I begin by reviewing selected results of our research on cognitive-motor ensemble skills before presenting some work on co-performer knowledge and social factors.

#### *Ensemble skills*

Ensemble performers in the western classical tradition (and indeed many other traditions) invest considerable time into collaborative rehearsal in order to establish shared performance goals, i.e. unified conceptions of the ideal integrated ensemble sound. Shared performance goals ensure that expressive variations in performance parameters—including timing, intensity, articulation, and intonation—are aligned across musicians. Once shared goals are

consolidated, the challenge is to realize them faithfully during performance under the real-time demands and vagaries of live musical interaction. The research described in this section of the present paper is concerned with the cognitive-motor ensemble skills that assist co-performers to meet this challenge by allowing them to anticipate, attend, and adapt to each other's actions in the heat of the moment. I will limit the discussion to temporal aspects of interpersonal coordination, setting aside other expressive parameters (see Keller in press) or affective dimensions associated with joint music making (see Phillips-Silver and Keller 2012).

*Anticipation.* Anticipatory cognitive-motor mechanisms operate in an online manner (during performance) to enable ensemble musicians to plan the production of their own sounds and to generate predictions about the upcoming sounds of co-performers. The MCA group's research into anticipatory mechanisms focused upon the role of covert action simulation in such online prediction. A study that served as a precursor to this work was conducted together with Guenther Knoblich and Bruno Repp (Keller *et al.* 2007). In this study, pianists were asked to record one part from several duets and then, a few months later, to play the complementary part in synchrony with either their own or others' recordings. Synchronization was most precise when the pianists played with their own recordings. We argued that this was the case because pianists predicted the timing of sounds in the recordings by engaging in online simulation of the performances. According to this account, such simulation led to a self-synchronization advantage because the match between simulated event timing and actual timing in a complementary part is best when both are products of the same cognitive-motor system.

At the time when we did this preliminary work on the role of action simulation in predicting others' actions, I was also conducting research on the role of mental imagery in musical action planning (Keller and Koch 2006, 2008, Keller, Dalla Bella, and Koch 2010). The confluence of these lines of research led to the proposal that predictions based on action simulation are experienced as mental images for upcoming sounds and movements (Keller 2008, 2012). This spawned a number of studies that investigated the relationship between mental imagery, temporal prediction, and interpersonal coordination. The first, a study of piano duos (Keller and Appel 2010), found that interpersonal keystroke synchrony (measured with digital pianos) and body sway coordination (measured with a motion capture system) were positively correlated with performance on a separate task designed to measure the vividness of anticipatory auditory imagery in each pianist.

This theme was taken up by Nadine Pecenka, a doctoral student in the MCA group. Her first study (Pecenka and Keller 2009) provided evidence that

auditory imagery facilitates synchronization due to its role in temporal prediction. Auditory imagery ability was assessed using a perceptual judgment task that required participants to mentally continue a tempo change in a short auditory sequence with a gap, and then to judge whether a probe tone occurred early or late relative to the imagined continuation. Prediction tendencies were indexed by a task that required finger tapping with auditory pacing signals that contained tempo changes: Prediction was assumed to be high to the extent that inter-tap intervals matched (rather than lagged behind) pacing signal inter-onset intervals. Positive correlations were found between auditory imagery ability, prediction tendencies, and accuracy on various sensorimotor synchronization tasks. A subsequent study (Pecenka and Keller 2011) showed that these relations have implications for interpersonal coordination. Individuals with high or low prediction tendencies were required to tap (with percussion sounds as auditory feedback) in synchrony with an individual who displayed similar or different tendencies. The results indicated that paired participants' individual temporal prediction abilities accounted for 30% of the variance in the precision of dyadic sensorimotor synchronization.

What are the brain mechanisms that underlie predictions generated via action simulation? Our theoretical framework assumes that the process of action simulation is driven by two types of "internal model" that represent sensorimotor associations between motor commands that issue from the brain and the sensory experience of events in the immediate environment (Keller 2008, 2012). "Forward models" represent links between motor commands (e.g. to lower a finger) and their effects on the body and environment (the tactile sensation of striking a piano key and the auditory sensation of hearing a tone). "Inverse models" represent transformations from intended action outcomes (tones) to the motor commands that produce them. A recent brain imaging study using functional Magnetic Resonance Imaging (fMRI) revealed that temporal prediction during sensorimotor synchronization is supported by a distributed network of cortical areas (including prefrontal cortex, premotor cortex, superior/middle temporal gyrus, and sensorimotor cortex) that may commune with internal models in the cerebellum (a corrugated structure at the lower backend of the brain) (Pecenka *et al.* in press).

Importantly, our framework assumes that separate classes of forward and inverse models are harnessed to simulate one's own and others' actions slightly in advance of their production (Keller 2008). The coupling of "own" and "other" internal models facilitates fluent interpersonal coordination by allowing potential errors in timing to be anticipated and corrected before they occur (van der Steen and Keller 2013). Evidence for two classes of internal

model comes from a transcranial magnetic stimulation (TMS) study run by Giacomo Novembre, a doctoral student in the group (Novembre *et al.* 2012). TMS is a brain stimulation technique that, when coupled with electromyography, can be used to assess the excitability of an individual's motor system. The aim of our study was to investigate how the ensemble musician's brain engages in the simulation of actions associated with the self or another performer. Pianists performed the right-hand part of piano pieces, previously learned bimanually, while the complementary left-hand part was either not executed or (believed to be) performed by a co-performer (an experimenter feigned playing while the participant actually heard a recording). Results indicated a clear self-other distinction in action simulation: Excitability of the motor system was facilitated when simulating the other performer but inhibited when simulating the self. A subsequent study found that using repetitive TMS to disrupt neural activity in brain regions implicated in action simulation interfered with pianists' ability to adapt to tempo changes in recordings, but only when the pianists had themselves practiced the recorded parts beforehand and were hence more likely to simulate them (Novembre *et al.* in press).

*Attention.* Ensemble performance involves concurrently paying attention to one's own actions (high priority) and those of others (lower priority) while monitoring the overall ensemble sound. This form of divided attention, which has been termed "prioritized integrative attending" (Keller 2001), is demanding to the extent that it requires the simultaneous segregation and integration of information from separate auditory streams. It has been proposed that the flexibility required to attend to multiple levels of musical texture is enabled by metric frameworks—hierarchical temporal schema that are yoked to the music's metric structure (Keller 1999, 2008). The dynamics of prioritized integrative attending have been studied using dual-task paradigms that require musicians to memorize or produce one instrumental part while simultaneously memorizing another part or the aggregate structure of multipart rhythm patterns (Keller and Burnham 2005). These dual tasks were designed to capture the demands of music characterized by complex interlocking rhythms, as in Central African music and Balinese gamelan, and work in our group demonstrated that individuals with experience performing such music display relatively good prioritized integrative attending skills (Keller and Schroeder 2010). Recently, an fMRI study conducted by doctoral student Marie Ragert (née Uhlig) identified a fronto-parietal brain network that is involved in regulating the balance between the process of segregating a high-priority part and the process of integrating parts during prioritized integrative attending (Uhlig *et al.* 2013).

*Adaptation.* Adaptive mechanisms control adjustments to the timing of ensemble members' actions so that they maintain synchrony in the face of small random irregularities and expressively motivated deviations in local tempo, as well as larger tempo changes and errors disrupting rhythm. Research in the MCA group focused on two forms of mutual temporal adaptation: assimilative and compensatory (see Nowicki *et al.* 2013). Assimilative adaptive timing involves co-performers automatically copying small fluctuations in the timing of each other's actions. Such mutual temporal assimilation may be a form of non-conscious behavioral mimicry that facilitates ensemble cohesion by making multiple individuals sound collectively as one. Compensatory adaptive timing is driven by error correction mechanisms that enable internal timekeepers—instantiated as oscillations of neural populations in co-performers' brains—to remain entrained (coupled to one another) under conditions where timing is variable.

Two separate mechanisms are assumed to subserve temporal error correction. Phase correction is an automatic process that adjusts the way in which the sequence of pulses generated by an internal timekeeper in one performer is aligned against a sequence of pulses generated by a timekeeper in a co-performer. Period correction involves consciously controlled adjustments to the duration of timekeeper intervals, and is invoked when a performer intentionally adapts to tempo changes produced by a co-performer. While phase correction reduces the variability of asynchronies, thus supporting precision in basic temporal coordination, period correction allows the flexibility that is required for co-performers to accommodate expressively motivated tempo changes.

The degree to which an individual engages in error correction can be estimated by analyzing the time series of asynchronies between finger taps and pacing events in sensorimotor synchronization tasks (e.g. Repp *et al.* 2012). An early study conducted with Bruno Repp showed that a secondary task (mental arithmetic) reduced period correction but not phase correction during synchronization with tempo changes, suggesting that only period correction requires attentional resources (Repp and Keller 2004). However, error correction estimates obtained in experiments employing computer controlled virtual synchronization partners that are programmed to vary in cooperativity (i.e. amount of error correction) have revealed that, while human phase correction remains constant across a range of cooperative virtual partners, its gain can be increased when confronted with uncooperative partners (Repp and Keller 2008). The distinction between automatic and effortful forms of adaptive timing is supported by brain imaging work on sensorimotor synchronization with virtual partners. An fMRI study conducted together with

Merle Fairhurst and Petr Janata found that small shifts in the degree of adaptive timing employed by virtual partners led to large-scale switches in the brain networks activated in participants due to changes in the need for cognitive control (Fairhurst *et al.* in press).

The implications of individual differences in adaptive timing for real interpersonal coordination were borne out in a study of dyadic sensorimotor synchronization (Keller *et al.* 2012). Phase correction was estimated in a sample of individuals who were subsequently paired to form “high-correcting” dyads and “low-correcting” dyads. Each dyad performed a synchronization-continuation task that required both individuals to tap together (with auditory feedback) in time with an auditory pacing sequence and then to continue tapping together when the sequence stopped. Results suggested that, while coordination was generally stable in high-correcting dyads, low-correcting dyads needed to increase the degree of error correction that they employed in order to stabilize their performance during continuation tapping. Such increases are most likely effortful and may have costs in the attentionally demanding arena of musical ensemble performance (e.g. the control of expressive performance parameters may be compromised).

### *Knowledge*

Shared performance goals established during joint rehearsal contain information about musical structure and the expressive intentions and playing styles of ensemble members. Ensemble cohesion is thus constrained to some degree by each performer’s knowledge about the structure of co-performers’ parts and their stylistic tendencies. A study by Marie Ragert suggests that these two varieties of knowledge—structural and personal—serve different functions and can have dissociable effects on ensemble coordination.

In our study (Ragert *et al.* 2013), pairs of unacquainted pianists came to the lab after practicing either one part or both parts of several piano duets at home. The complementary parts of the duets were therefore familiar in one condition and unfamiliar in the other. Pianists’ keystroke timing was recorded on digital pianos and their body movements were tracked with a motion capture system as they played repeat performances across six takes in each condition. Results pointed to a partial dissociation between interpersonal coordination at the level of keystrokes and body sway. Variability in keystroke asynchronies decreased across the takes, and was generally lower in the unfamiliar condition than the familiar condition. This indicates that coordination started out better, and remained so, when pianists had not rehearsed their co-performer’s part. By contrast, body sway coordination (quantified by

estimating “mutual information”) was high throughout the takes in the familiar condition, while it started out low and improved across takes in the unfamiliar condition.

These findings suggest that knowledge affects interpersonal coordination by influencing predictions at different timescales. Familiarity with a co-performer’s part, but not their playing style, engenders predictions about expressive micro-timing variations that are based instead upon one’s own personal playing style, leading to a mismatch between predictions and actual events at short timescales. As knowledge about a co-performer’s stylistic idiosyncrasies is acquired, however, the individual learns—through the calibration of internal models—to simulate the other’s action style. Familiarity with the structure of a co-performer’s part, on the other hand, facilitates predictions at longer timescales related to high-level metric units and musical phrases, and reflected in ancillary body sway movements.

### *Social-psychological factors*

Musical ensemble performance is a social activity to the extent that it involves cooperation and the communication of aesthetic ideas between individuals. The research program of the Leipzig MCA group was concerned with social-psychological factors that potentially affect the dynamics of interpersonal coordination by influencing the core cognitive-motor ensemble skills.

One study (Fairhurst *et al.* 2013) addressed the relationship between temporal adaptation, leader-follower tendencies, and locus of control—an aspect of personality related to the degree to which life events are perceived to be a consequence of one’s own actions. The aim of the study was to identify behavioral strategies and patterns of brain activity that distinguish between individuals with different leader-follower dispositions when they interact with synchronization partners with high or low levels of competence. This was examined in an fMRI experiment that required individuals to synchronize finger taps with sounds produced by virtual partners who varied in terms of competence at maintaining a steady tempo. For performance to be successful, the human participant must assume responsibility for maintaining the tempo when the virtual partner cannot. Results indicated that “leaders” (individuals who attribute the cause of events to their own actions) generally engaged in less adaptive timing than “followers” (who attribute events to external factors). This may reflect a difference in strategy: while followers prioritized the task of synchronizing with their partner (at the expense of maintaining a steady tempo), leaders focused on stabilizing the tempo of their own performance (at the expense of synchrony when the partner was low in com-



petence). Brain regions implicated in evaluating agency (e.g. the precuneus) were activated more strongly in leaders than followers, suggesting greater self-focus in leaders.

Another aspect of personality that may impact upon self-other relations during interpersonal coordination is empathy. Our studies on this topic have identified links between empathy—which is a matter of understanding others’ thoughts and feelings—and anticipatory mechanisms related to action simulation. One of the TMS studies described earlier (Novembre *et al.* 2012) found a positive correlation between the degree to which one pianist represented the other’s part in their own motor system (as indexed by its excitability) and scores on an empathy questionnaire subscale assessing the tendency to adopt others’ perspectives. Furthermore, the degree to which repetitive TMS interfered with tempo adaptation in our follow-up study (Novembre *et al.* in press) was also positively correlated with perspective-taking tendencies. Finally, it was found that perspective-taking is correlated with the degree to which individuals predict event timing during sensorimotor synchronization with tempo-changing pacing sequences (Pecenka and Keller 2011).

## IMPLICATIONS

The mission of the Leipzig MCA group was to shed light on the psychological processes and brain mechanisms that support precise yet flexible interpersonal coordination in musical contexts. Although the group’s research was not geared towards specific applications, some of our findings could potentially inform pedagogical practice aimed at fostering excellence as an ensemble musician. Here I discuss four relevant implications.

An obvious implication of our research is that the enormous amount of experience that is necessary to attain mastery in solo performance needs to be supplemented by a complementary regimen of specialized training dedicated to the development of strategies and skills for ensemble performance. We have identified a suite of cognitive-motor skills that facilitate ensemble cohesion by allowing performers to anticipate, attend, and adapt to the actions of co-performers in real-time. Our results support the hypothesis that individual differences in these cognitive-motor skills constrain the ability of ensemble members to coordinate with one another. It would therefore be beneficial to design techniques for exercising these skills in order to boost each individual’s capacity for precise yet flexible ensemble coordination.

A second implication of our work is related to the fact that interpersonal coordination in ensembles takes place at multiple levels that evolve at different timescales. Sounds triggered by instrumental movements communicate

information about expressive micro timing, while ancillary movements such as body sway communicate expressive information on longer timescales at which musical phrases and higher-order structural units are defined. Our research suggests that interpersonal coordination at these multiple levels relies upon different types of knowledge, with coordination at long timescales benefitting from familiarity with the structure of co-performers' parts, and coordination at short timescales benefitting from familiarity with co-performers' playing styles. It follows that optimal collaborative rehearsal strategies should deliberately encourage the acquisition of both types of knowledge. An additional type of knowledge—one that characterizes partnerships that span decades (e.g. the Labèque sisters)—concerns familiarity with a co-performer's cognitive-motor ensemble skills, that is, how he or she anticipates, attends, and adapts to others. Such knowledge can be considered to be a meta-ensemble skill that allows performers to apply adaptive mechanisms on the basis of anticipated relations between their own and others' actions (van der Steen and Keller 2013).

A third implication of our work is that the impact of social-psychological factors extends beyond influencing the effectiveness of co-performer communication during rehearsal, to affecting the operation of cognitive-motor ensemble skills during performance. Our studies revealed links between empathy and anticipation skills, on one hand, and locus of control and temporal adaptation, on the other. These findings highlight the importance of taking factors such as personality into account when techniques for developing ensemble skills are tailored to individuals. Some young musicians may have personalities that favor the spontaneous development of a complete kit of cognitive-motor ensemble skills, while other individuals may need to invest special effort into training particular skills. Indeed, links between personality and the three skills may predispose individuals towards playing certain roles in ensembles (e.g. soloist versus accompanist; independent versus doubled voice).

Finally, our research findings invite comment on the issue of whether the match between co-performers in terms of their idiosyncratic stylistic tendencies—which may vary as a function of personality and biomechanical factors related to anthropometric characteristics (see Keller in press)—is an important determinant of the quality of ensemble cohesion. Our studies of the self-synchronization advantage and dyadic sensorimotor synchronization suggest that it is not necessarily the match in playing style per se that leads to good coordination, but rather the fact that stylistic similarity allows each performer to anticipate, attend, and adapt to the other's actions effectively. This implies that highly refined ensemble skills may enable co-performers to

transcend their individual musical identities to achieve a group identity, and, with it, a form of expression that arises uniquely through interpersonal coordination in musical contexts.

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**Thematic session:  
Brass and woodwind research**





# Zooming into saxophone performance: Tongue and finger coordination

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On the saxophone, the player has to coordinate articulatory tongue actions with the finger movements at the keys. Finger-key actions are used to modulate the sounding frequency. In contrast to clarinet keys, the saxophone key cushion covers the tonehole completely, so the arrival position of the finger to the key does not influence the sound directly. To investigate finger-key interactions, we improved our existing sensor saxophone setup: additional acceleration sensors track the key movements and a webcam captures the left-hand fingerings of the player. Ten graduate saxophonists played a 24-tone melody in a synchronization-continuation paradigm. We calculated the timing precision of each performance from the reed signal. Detailed examination of the recorded videos showed that the fingering positions differ extremely between subjects. Subjects who covered the key pearl with their fingertips completely achieved better results in timing precision than the average group. Although we assume that the saxophone fingering technique influences the performance, we suspect other playing parameters like tonguing, breathing, and embouchure to have more impact on the overall performance quality.

*Keywords:* saxophone; articulation; fingers; coordination; measurements

In saxophone performance the player has to coordinate articulatory tongue actions with the finger movements at the keys. Depending on the musical phrase, onset timing is controlled by the fingers (legato playing), the tongue and the fingers (portato, staccato playing), or the tongue alone (tone-repetitions; Krautgartner 1982, Liebman 2006). We showed in a previous study that portato playing was more accurate with combined tongue-finger actions

than with only tongued tone repetitions (Hofmann *et al.* 2012). These findings support the theory that temporal stability improves with movements produced by multiple effectors (Ivry *et al.* 2002).

This study focuses on the examination of fingering positions and reports on improvements of the measuring methods for saxophone performance analysis. To clarify observed artifacts in our previous finger-force measurements, we added acceleration sensors to the saxophone keys and mounted a webcam on the bell of the saxophone to capture the motion of the fingers.

## METHOD

### Participants

Four female and six male graduate saxophone students (different from Hofmann *et al.* 2012) from the University of Music and Performing Arts Vienna ( $n=10$ , mean age=23.6 years, range=21-33 years) participated in our study. On average, they were playing the instrument for 11.1 years (range=8-20 years) and were practicing 1.6 hours per day ( $SD=1.06$ ). Four participants played classical music only, four played only jazz/rock/popular music, and two were active in both musical domains. Participants were paid a nominal fee after the experiment.

### Materials

The stimulus material was the 24-tone melody from Hofmann *et al.* (2012). All participants played on an E-flat alto-saxophone, which was equipped with sensors to monitor the saxophone performances: A strain-gauge was glued onto the reed to measure articulatory tongue impulses (Hofmann *et al.* 2013). Force sensors on the key pearls measured left-hand finger force, additional acceleration sensors (Piezotronics: PCB 352C23) tracked key-movements, and a web-cam mounted to the saxophone bell captured the motion of the fingers.

National Instruments (LabView) hardware and software was used for multi-channel recording (sampling rate=11025 Hz).

### Procedure

The participants performed the melody with portato and staccato articulation in three different tempi, timed by a digital metronome on each quarter-note beat. Each trial contained two repetitions of the melody together with the metronome click. After the metronome stopped the players continued to play

according to the introduced tempi (slow=120 bpm, medium=168 bpm, fast=208 bpm). We recorded two trails per tempo condition.

## **Data processing**

### *Reed*

Characteristic landmarks were identified in the sensor reed data: a tongue-reed contact (TRC) occurred when the reed vibrations were stopped by the tongue (note-off). When the player's air-pressure remains constant, a release of the tongue (tongue-reed release, TRR) enables the reed to oscillate again (note-on). A landmark detection function (D11D10D9D8), based on wavelet-decomposition of the reed signal, was used to set TRC and TRR markers automatically in all sensor reed recordings (Hofmann *et al.* 2013).

Additionally a pitch analysis of the reed signal was made (AubioPitch Vamp Plugin to Sonic Visualizer; Brossier 2013) to verify the number of a note in the sequence by its frequency.

### *Keys*

Key movements were extracted by thresholding sub-band (D9) of the acceleration data. The wavelet-decomposition had similar parameters as described in Hofmann *et al.* (2013).

## **RESULTS**

### **Video capture of fingerings**

The artifacts in some subject's force measurements can be explained by inspecting the recorded video: sometimes the saxophone keys were closed by the fingers not covering the key-pearl and thus not triggering the attached force sensor. Figure 1 shows screen-shots of individual players closing all left-hand saxophone keys. Some players (left pictures) cover the key pearl with their fingertips but others (right pictures) only touch a part of it. There seems no direct influence of the fingering position to the sounding outcome, because the key-cushion closes the tone hole independent of the particular properties of the finger action, but we suspect an influence on the timing precision.

### **Fingerings and timing precision**

The time interval between two consecutive TRR landmarks was defined as the interonset interval (IOI). The IOIs during synchronization phase were close to the metronome rates: at slow tempo IOI=249.4 ms (metronome=250 ms);



*Figure 1.* Screen shots of four participants, with fingerings for g' on alto saxophone. Depending on their playing technique, they cover the force sensors (left) or only touch a part of it (right). (See full color version at [www.performance-science.org](http://www.performance-science.org).)

medium IOI=178.3 ms (given=178.6 ms); and fast IOI=147.2 ms (given=144.2 ms), and shows that the players could synchronize well with the metronome.

### *Timing precision*

We computed the variability of the IOIs in the continuation phase, by the coefficient of variation (CV, defined as  $SD_{ioi}/Mean_{ioi}$ ) for each melody phrase and tempo condition. The CV can be seen as a measure of how equally distributed note onsets were played.

Table 1 shows the timing variability of all video recorded subjects. We assume that there is a light influence of the fingering technique on the precision of the performance. The subjects showed in Figure 1, who covered the key pearl completely with their fingertips, achieved a better score in timing precision (CV<8.8) than the average group (CV: M=12.06, SD=2.8).

## **DISCUSSION**

Through video investigations we were able to answer open questions from our previous study and can now better explain the large differences in our finger-force measurements on the key pearls. Our hypothesis that the angle and position of finger-key contact is highly variable among different saxophonists was confirmed by monitoring the fingering video captures.

*Table 1.* Timing precision for new participants (11-20) with video captured performance.

<i>Participant ID</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14*</i>	<i>15*</i>	<i>16</i>	<i>17#</i>	<i>18</i>	<i>19</i>	<i>20#</i>
<i>CV of timing in %</i>	<i>13.12</i>	<i>13.53</i>	<i>11.88</i>	<i>8.8</i>	<i>7.54</i>	<i>10.22</i>	<i>17.27</i>	<i>11.23</i>	<i>14.13</i>	<i>12.85</i>

*Note.* \*Refers to the left pictures in Figure 1; #refers to the right pictures in Figure 1.

Although fingerings might influence the performance quality, we suspect other playing parameters like tonguing, breathing, and embouchure to have more impact on the overall performance quality.

This research is work-in-progress. A detailed examination of all collected data (e.g. acceleration data from the keys, bending signal from the sensor reed) is foreseen.

Multi-sensor investigations of performances on the saxophone deliver valuable insights into the complex interaction of tongue and finger actions and may also be applied to clarinet and other woodwinds.

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# Tonguing on brass instruments: Tempo and endurance

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There are countless notes performed daily on brass instruments by beginners and virtuosi. Articulation on brass instruments has been a subject of many method books for centuries, and subsequently qualitative research on their performances have been studied by different visualization techniques. Maximal tempo and endurance for *single tonguing* and *double tonguing* is musically relevant. Quantitative figures were empirically evaluated in this study for the first time with 121 brass players. Maximal tempi showed high inter-individual variability. The average value for *single tonguing* over two seconds was about 121 bpm and slowed down to 103 bpm within 30 seconds of playing. The fastest player performed 167 bpm (eleven notes per second). With *double-single* the mean values were 173 bpm at the beginning and 136 bpm after 30 seconds. The fastest player performed 238 bpm (sixteen notes per second). The level of experience was more relevant than the instrument. For conclusions regarding gender and mother tongue more participants are necessary.

*Keywords:* brass instruments; tonguing; articulation; tempo; evaluation

A trombone student told me his story; he had a stroke 6 years ago and lost his tongue control. After relearning to swallow and speak he started to play trombone again and continued his trombone studies 4 years later. He wondered how fast he would have to train his tongue for a professional career, but no information about maximum tonguing tempi, neither in research papers nor in study books, could be found. Instruction books from Altenburg (1795) to Arban (2007) hardly explain techniques, let alone tempi, except to always start practicing slowly in order to achieve better regularity.

Budde (2011) documented a good collection of literature and method books on wind instrument articulation. He found very few common facts for brass instrument tonguing beside general principles: “the tongue should create a seal when articulating on brass instruments; as such, the exact amount of tongue contact changes as the jaw is lowered or raised to accommodate the various pitch ranges within a specific instrument” (p. 58).

Hall (1954) and Meidt (1967) have been pioneers in the investigation of wind instrument performance through the use of technology for research. They show that specific vowel formations do not correspond to particular pitches or registers, as stated in different method books since Altenburg (1795). After Hall, the most common oral shape utilized during trumpet performance approximated the position of the tongue and jaw when saying the vowel /v/ as in *pod*, but players tend to assume individualistic positions of the tongue and jaw. Since descriptions of motions and sounds are limited, modern teaching methods include audio-visual material that can be found on YouTube or from specific DVDs (e.g. *Brass Master-Class* by Burba 2006).

More questions rose through discussions with colleagues about how and when to use different playing techniques. While some professionals say they have a slow *single tonguing* but a good control of *double tonguing*, others explain that they are not good in *double* but they have a very fast *single*. This variability is relevant in performing within a brass section where similar attacks and articulations are required. This depends on how fast the player is able to produce each playing technique. This study aimed to find the critical tempi at which individual preferences and abilities influence the interpretation of the brass section.

The evaluation of maximal tempi by brass players of various expertise levels is the objective of this paper and the first part of a larger project on articulation on brass instruments. Follow up studies will focus on the physiological aspects, optimal training techniques, and qualitative sound properties. In a final step the acoustical properties of the instruments will be correlated with articulation characteristics.

## METHOD

### Participants

The presented results are based on 121 participants. Recordings were made in 2012 with professional brass quintets and amateur and professional participants of a brass players' summer camp in 2012 in Samedan (CH), in Linz (A), in Ghent (BE), in Beijing (CH), and at the University of Music in Vienna (A). Mean age was 26.1 years (SD=11.9) and the average playing experience was



15.2 years (SD=10.8). The grouping of the brass players was: female (n=14), male (n=107), amateur (n=59), professional (n=20), student (n=42), trombone (n=27), horn (n=7), trumpet (n=72), tuba (n=9), and other instrument (n=6).

## **Procedure**

All brass players had to perform two tasks, each recorded with available equipment (e.g. laptop with external microphone or cell-phone video). The procedure was documented through a YouTube video for the research partner. Each musician was recorded twice for 30 seconds, playing his or her maximum tempo with single tonguing and double tonguing. With the exception of the fastest players, all participants were assured anonymity. They could choose their preferred natural open note in the middle register. The sound quality and the playing style were not taken into account. They could perform soft or hard attacks, therefore only the onset numbers have been measured when the tongue opens the lip-valve.

The recordings were analyzed semi-automatically with Simon Dixon's audio beat tracking system BeatRoot 0.5.8. The accuracy of discrimination for IOI intervals was about 5-10 milliseconds. Data were analyzed and visualized by self-made Gnu-R statistic scripts. Tempo was measured in the players' typical specification unit, that is to say in beats per minute (bpm) at the quarter note while playing sixteenths. Additionally, the numbers of notes played in 30 seconds, the average (median) values, and standard variations for fifteen two-second sections were calculated.

## **RESULTS**

Preliminary results (N=121) showed a large between-group difference between amateur players/students and professional players and variance within these groups.

In terms of single tonguing, within 30 seconds female musicians played an average of 205 notes (maximum=236), male players an average of 207 notes (maximum=262), amateurs 200, students 219, and professionals 225 notes. A professional trombone player (Gerhard Füssl of Mnozil Brass on his Schagerl Model "Prototype Jubilee 2012") played 262 notes. Fastest players at the start—that is the first two seconds of the task—were a 19 year old trumpet student (Paolo on his Schagerl Model "Vienna") with tempo bpm=167, followed with tempo 150 by a professional trumpet player (Ludwig Wilhelm of Bozen Brass on his customized Spada-Bach) and a beginner (!) (Norbert

Amon, a clarinet player on a Lechner trumpet) who could only play a few notes on the trumpet, but indeed very fast.

Within 30 seconds of the double tonguing exercises female musicians played an average of 250 notes (maximum=304), male players an average of 287 notes (maximum=415), amateurs 257, students 288, and professionals 303 notes. The most notes in 30 seconds (415 notes) were played by a professional trumpet player (Ludwig Wilhalm of Bozen Brass on his Spada-Bach).

Fastest players at the start were a trumpet student (Thomas Liesinger on his Yamaha YTR 6310ZS) with tempo bpm=238, followed by a professional player (Herbert Zimmermann, Munich Philharmonic, on his Schagerl Heavy Hörsdorf trumpet) with tempo bpm=231.

## DISCUSSION

Notable is the fact that the more experienced players tended to start with tempi that they thought they could maintain for longer periods and did not start with absolute maximum tempi. Many advanced players distinguished themselves with increased regularity. Tempo variation is shown in Figure 1.

Astonishing is the fact that individual professionals could reach the same speed on trumpets or tubas, playing 11-13 notes per second (max bpm=240). Comparisons between different groups are shown in Figure 2. Finally, Figure

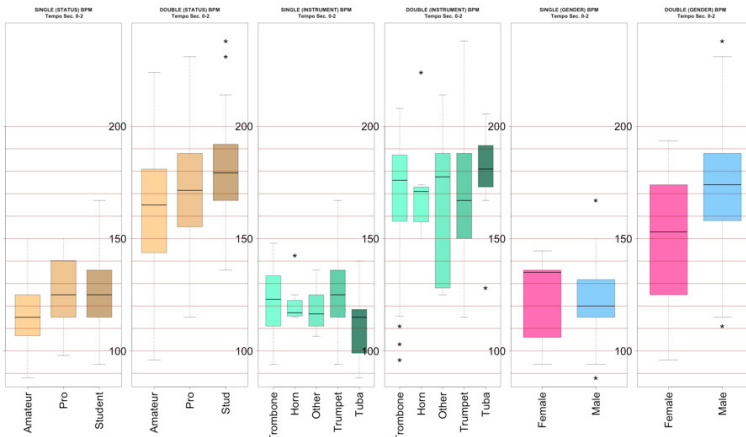
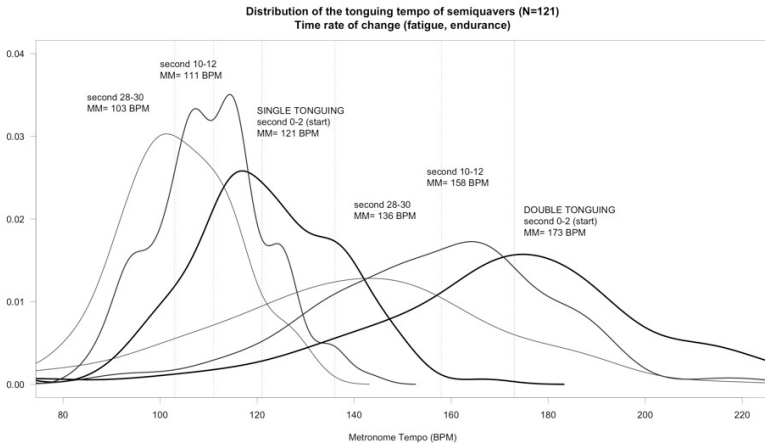
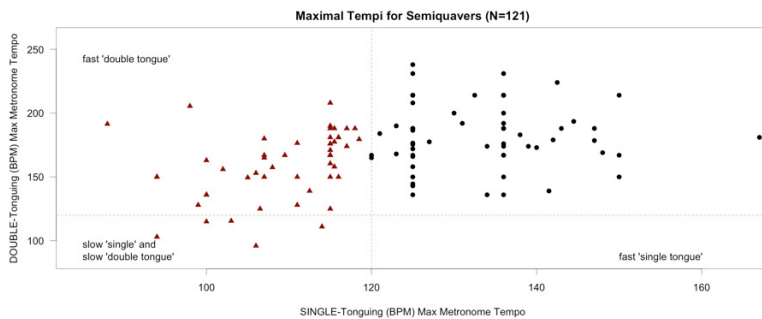


Figure 1. Boxplot comparisons of the maximal tempi played during the first two seconds. Graphics 1, 3, and 5 correspond to *single tonguing*; 2, 4, and 6 correspond to *double tonguing*. 1 and 2 compare the values by status (amateur, professional, student), 3 and 4 by instrument (trombone, horn, other, trumpet, tuba), and 5 and 6 by gender (female, male). (See full color version at [www.performancescience.org](http://www.performancescience.org).)



*Figure 2.* The mean values of the tempi at the beginning (seconds 0-2), after some playing (seconds 10-12), and at the end of the task (seconds 28-30) are shown as density plots over the metronome tempo. The peak values for *double tonguing* slow from 173 bpm to 136 bpm, and for *single* from 121 bpm to 103 bpm. The graph indicates the huge variability for each playing technique.



*Figure 3.* The maximal tempi played during the first two seconds are plotted for each participant in a coordinate system where the maximal *single* corresponds to the x-axis and the values for *double* to the y-axis. Many brass players ( $n=58$ , ▲ symbols) were not able to play *single* faster than 120 bpm; that is they had to play faster tempi with *double*. Other musicians (● symbols) could choose the type of articulation up to 140 bpm and beyond. (See full color version at [www.performance-science.org](http://www.performance-science.org).)

3 shows the individuals' maximum tempi for both articulations and the critical tempo for single tonguing at about bpm=120.

The study will be continued internationally to evaluate the influence of more parameters, including gender and mother tongue. Furthermore, acoustically, physiologically, and pedagogically related parameters will be correlated. Qualitative research is necessary to understand the large inter-individual differences as well as the intra-individual differences including the influence of training effects, instrument acoustics, and preferred sound quality. Further information on the project can be found at [www.drtrumpet.eu/tonguing](http://www.drtrumpet.eu/tonguing).

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# Embouchure problems in professional brass players

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Focal dystonia is a task-specific movement disorder in musicians and has a prevalence rate of 1% to 2% in musicians. In wind players, focal dystonia presents as embouchure dystonia and involves coordination of the embouchure. Data concerning embouchure problems in professional brass players is scarce. Embouchure problems can potentially lead to focal dystonia. The aim of this study was to investigate the frequency of distinct embouchure problems in professional brass players. Professional orchestral musicians (n=585) participated in a cross-sectional study concerning embouchure problems in brass players. A questionnaire was developed evaluating typical signs of embouchure fatigue and embouchure problems. Additionally, practicing habits and coping strategies to overcome the embouchure crisis were collected. Embouchure fatigue was present in 29% of brass players; horn and trumpet players were affected most frequently—33% and 34%, respectively. Embouchure problems were reported by 58% of brass players (64% of trumpet and horn players), and cramping of lips by 13%. The sick leave of musicians suffering from embouchure problems was 16.3%. Mastery of the crisis was claimed by 40% of musicians, whereas 10% reported persisting embouchure problems. The average length of the crisis was 41.33 months. Musicians with embouchure problems were significantly older, played longer in the orchestra, started their instrument later than musicians without embouchure problems, and were used to warming up significantly longer. This study demonstrates the high frequency of embouchure fatigue and embouchure problems in professional brass players. Further studies are warranted to develop screening methods identifying musicians at risk of developing focal dystonia.

*Keywords:* embouchure problems; focal dystonia; brass players; risk factors; coping

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**Thematic session:  
Performance anxiety**





# Maximizing performance potential: The efficacy of a performance psychology program to reduce music performance anxiety and build resilience in adolescents

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Music performance anxiety (MPA) can be distressing for many young people studying music, and may negatively impact their ability to cope with the demands and stressors of music education. This is a randomized wait-list control study of a performance psychology program to reduce MPA and promote resilience delivered to adolescents in a school environment. Fifty-five students (12-16 years of age) split across two groups participated in an eight-week program covering concepts of peak performance, personal strengths, planning and goal setting, motivation, positive self-talk, relaxation and visualization, stress regulation, and recovery after disappointments or setbacks. Assessments immediately pre- and post-program and at a two-month follow-up showed a significant reduction in self-reported MPA that continued to decline two months after participating in the program, accompanied by improved self-belief, planning, persistence, and control over successful outcomes, as well as reduced failure avoidance, self-sabotage and disengagement. This study demonstrates the efficacy of these psychological techniques to reduce performance anxiety and improve motivation, engagement and resilience in adolescent music students.

*Keywords:* music performance anxiety; adolescents; performance psychology; resilience; school

Excessive, debilitating anxiety surrounding music performance in adolescence peaks around 15 years of age (Osborne and Kenny 2005) and is associated with poor performance and educational outcomes in music (Kubzansky and Stewart 1999, Wolfe 1989). In and of itself, anxiety is not a maladaptive

state which needs to be removed in order to enable peak performance. A moderate amount of anxiety enhances performance when an individual's skill level matches the performance demands of the situation (Jackson and Csikszentmihalyi 1999) and the individual interprets that anxiety positively (Jones *et al.* 1993). Indeed, the typical "fight or flight" response in high anxiety states tends to motivate a success oriented student to "fight," that is, to approach a performance situation and undertake the necessary preparation required to achieve optimal performance outcomes (Martin and Marsh 2008). Success-oriented students tend to be optimistic, proactive, and positively orientated to tasks, and respond to setbacks and failure with optimism and energy (Covington 1992).

These success-oriented students demonstrate the psychological characteristics of resilience. In the performance context, resilience refers to the "individual's ability to deal effectively with performance setbacks, stress and pressure" (Martin 2008, p.29), which has received little attention in the performance anxiety literature. Martin and Marsh (2008) found that mathematics anxiety was a powerful factor in explaining academic resilience, such that students with higher levels of anxiety were significantly less resilient, and concluded that anxiety should be a key target for intervention to enhance resilience and academic outcomes. Motivation and engagement are also strong predictors of educational resilience (Martin and Marsh 2006). Motivation is the energy and drive to learn and work hard; engagement is the behavior that reflects this energy and drive. Students who are more academically motivated and engaged report high self-belief, high planning, high control, high persistence, and low anxiety (Martin 2008).

Osborne *et al.* (2007) piloted a cognitive-behavioral program for MPA in elite secondary music school students. All students reported reduced MPA as a result of the intervention, but significant reductions were only reported for actively engaged students. *Thinking Skills for Peak Performance: Unleash your Potential!* (Brandon and Ivens 2009) is a program grounded in performance and positive psychology principles, which encourages participants to achieve performance excellence through recognizing strengths, examining thinking styles, setting goals, overcoming setbacks, and regulating stress. Given that MPA peaks in mid-adolescence and is a common, yet often uncomfortable and sometimes highly distressing and aversive feature of learning a musical instrument, this study evaluated the efficacy of a readily available performance psychology program to both reduce MPA and improve music learning and performance resilience, as measured by motivation and engagement constructs, in a high school setting.

## METHOD

### Participants

Fifty-five students from Grades 7, 8, and 9 (age  $M=13.8$  years;  $SD=0.9$ ) at a private girls catholic college in Melbourne, Australia volunteered to participate. Instruments included piano (26%), woodwind (24%), string (13%), brass (11%), voice (9%), guitar/bass guitar (7%), and percussion (4%), with two girls combining voice with piano and guitar (4%). They had learned their instruments for an average of 3.9 years ( $SD=2.7$ , range 1-10 years).

### Materials

Two questionnaires were used. The *Music Performance Anxiety Inventory - Adolescents* (MPAI-A) is a 15-item a measure of the somatic, cognitive, and behavioral aspects of music performance anxiety in young people, with very high internal consistency and good external validity (Osborne and Kenny 2005). The *Motivation and Engagement Scale - Music* (MES-M) is a 44-item measure of motivation and engagement for music learning and performance activities across six adaptive cognitive and behavioral dimensions, such as self-belief and study management, and five maladaptive cognitive and behavioral dimensions such as failure avoidance and self-sabotage. This measure has very high stability, internal consistency and good external validity (Martin 2008).

### Procedure

Students were randomly allocated to two groups. Group 1 ( $n=27$ ) was the first intervention group who undertook the program during Term 3, 2012. Group 2 ( $n=28$ ) was waitlisted to Term 4, 2012. The program was delivered across eight consecutive weeks after school. Each week a new topic was covered: (1) peak performance and personal strengths, (2) goal setting and motivation, (3) self-talk, (4) performance routines and preparation, (5) mental rehearsal, (6) stress management and wellbeing, (7) focus and flow, and (8) dealing with setbacks. Each session lasted 75 minutes.

## RESULTS

Data were analyzed using 2 (Time)  $\times$  2 (Group) mixed model analyses of variance, with Time 1 as the pre-program measure for both groups (there were no significant differences between groups on any of the outcome measures at Time 1), and post-program measures taken immediately after

treatment (Time 2 for Group 1, Time 3 for Group 2). Two-month follow-up assessments for differences across Time 2 and Time 3 were analyzed for Group 1 only using repeated measures t-tests. Means, standard deviations and significance values are given in Table 1.

Table 1. Dependent variable means (and standard deviations) by group at pre-, post-program, and two-month follow-up (group 1 only). Pre- to post-program significance is denoted after the variable name. Follow-up significance is denoted alongside the statistic. Only significant variables are included.

Variable	Pre Gp1	Pre Gp2	Post Gp1	Post Gp2	Follow-up
MPA***	44.5 (12.9)	42.3 (14.8)	36.4 (14.8)	36.7 (13.1)	28.9 (14.2)**
Self-belief*	87.2 (15)	85.9 (10.5)	92.1 (10.2)	88.7 (13.1)	91.1 (13)
Planning*	57.3 (17.7)	59.2 (13.7)	59.0 (19.0)	68.7 (15.2)	72.4 (16.8)**
Persistence*	76.1 (14.9)	73.3 (17.1)	79.8 (12)	77.7 (14.6)	82.7 (13.7)
Anxiety	65.3 (21.0)	64.3 (20.6)	55.8 (22.2)	66.1 (15.6)	70.4 (15.8)**
Failure avoidance	44.9 (22.9)	48.1 (24.5)	39.8 (22.3)	44.0 (24.9)	25.9 (27.3)**
Uncertain control*	46.2 (19.6)	47.4 (19.4)	37.6 (16.0)	44.1 (22.6)	30.1 (25.9)
Self-sabotage	33.4 (15.0)	34.7 (17.5)	37.2 (20.0)	33.9 (21.7)	28.4 (24.5)**
Disengagement	25.5 (11.6)	24.0 (12.6)	30.2 (18.3)	21.7 (19.8)	18.6 (21.5)***

Note. \*p<0.05, \*\* p<0.01, \*\*\*p<0.001

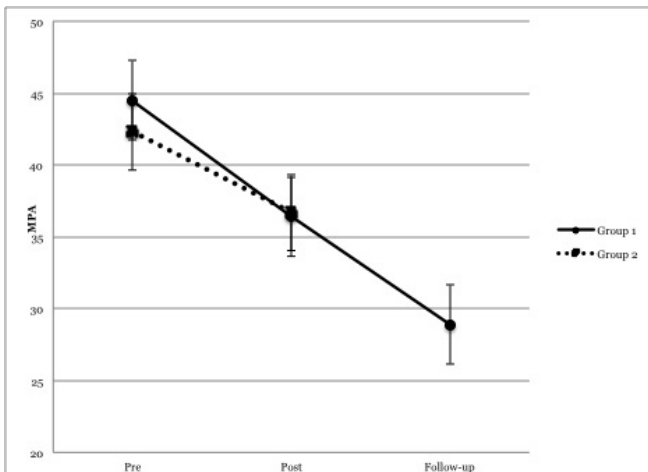


Figure 1. Music performance anxiety by time and group.

## DISCUSSION

This paper provides the first published evidence that adolescent music students who participate in a waitlist control cognitive-behavioral performance psychology intervention delivered within a school setting report significantly reduced MPA immediately after program completion, with further significant reductions in MPA at two-month follow-up. Students were also significantly more optimistic about music learning and performance, held stronger self-beliefs about their abilities in music, were more persistent in the face of difficulty, planned tasks more effectively, and felt more in control and autonomous immediately after completing the program. Students' music learning and performance planning continued to improve two months after completing the program. Two months after completing the program students were significantly less likely to avoid performance due to a fear of failure, and reduced self-sabotaging behaviors such as ineffective preparation and procrastination.

The significant increase for the MES-M anxiety subscale at follow-up is an anomaly. It is inconsistent with the reduction in the other maladaptive subscales of failure avoidance and uncertain control, as well as the MPAAI-A. This could be explained by the MES-M anxiety subscale being a four-item scale with three items focused on worry surrounding performance and one item on not feeling "very good." Alternatively, the MPAAI-A is a larger measure covering the cognitive (worry), behavioral, and somatic dimensions of performance anxiety and is therefore a more valid measure of the MPA construct.

This study has profound implications for the amelioration of MPA in high school students learning music. Students who participated in the *Unleash your Music Potential!* program were more success oriented: they had significantly reduced their performance anxiety, in addition to improving their resilience to setback, stress, and performance pressure. Given that most young people learn a musical instrument or singing at school, an effective school-based performance psychology program holds great promise as a means to reduce debilitating MPA and improve their motivation to rehearse and/or practice longer, more effectively, and ultimately enhance their enjoyment of learning and performing music.

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# Performance psychology information impact on stress and anxiety level of Brazilian music performers

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This work examines the impact of information on music psychology on Brazilian undergraduate and graduate music performance students and its effect on their stress and anxiety levels. It includes an investigation of 15 Brazilian public university curricula based on previous research. The main goals of this study were (1) to investigate how much information on music psychology Brazilian music performance students had access to during their courses and (2) to determinate the impact such information may have on the level of stress and anxiety in the students' performances. Students and teachers from 3 universities of São Paulo State, Brazil were asked to answer three forms: the Kenny Music Performance Anxiety Inventory (K-MPAI), the Inventory of Stress Symptoms LIPP, and an additional form inquiring of the participant's preparation for performance. The study found that information on music psychology is only presented privately at the teacher's discretion. Because there is no formal class on the topic it wasn't possible to infer the results of such a presentation. Just over half of the 191 participants (50.3%) didn't present a stress condition. Almost half of them (49.7%) presented some level of stress.

*Keywords:* performance psychology; performance preparation; performance education; performance anxiety

The theory of music psychology is growing, beginning with the first steps given by Carl Seashore (1967) and incorporating the cognitive sciences with

music performance as shown by the work of Deutsch (1982), Rink (2002), Williamon (2002), Chaffin and Logan (2006), and many others. In discussing the teacher-student relationship, the musician and psychologist Don Greene (2002) raised a common problem: teachers are not psychologists and often don't have the right education and experience in order to help their students with possible psychological issues. This brings into evidence the need for performers to study the so-called "figures of interference," i.e. the positive and negative influences on a musical performance (Ray 2005). Gerald Klickstein (2009, p.155) says that knowing how to deal with psychological aspects is essential for the performer's education, and in particular, to control their level of anxiety and stress. He places mental/emotional preparation as one of the "five facets of performance preparation." Although the significant development in this research field is remarkable, little has been done in Brazilian public universities' performance courses (Ray and Kaminski 2011).

Therefore, the present study aimed (1) to investigate how much access Brazilian music students have to information on music psychology during their courses and (2) to determinate the impact of such information on the levels of stress and anxiety during the students' performances.

## METHOD

### Participants

191 of 636 students and teachers from 3 public universities of São Paulo State (State University of São Paulo [UNESP], University of São Paulo [USP], and University of Campinas [UNICAMP]) that offer under graduate and post-graduate studies in music performance took part. University populations were UNESP=308, USP=97, and UNICAMP=231. These populations included musical performance students and instrumental, vocal, and conducting teachers.

### Materials

The participants answered three questionnaires: the Kenny Music Performance Anxiety Inventory (K-MPAI) translated and validated for the Portuguese language (Rocha *et al.* 2011), based on the validated Portuguese version of the State-Trait Anxiety Inventory (STAI); the Inventory Stress Symptoms LIPP (ISSL); and an additional form examining the participant's preparation for performance. Error estimation was 11%. Data from the K-MPAI inventory were considered as follows: 0-240 points where low=<90 points, moderate=90-138 points, and high=>138 points. These data were associated with



$$n = \frac{\sigma^2 \cdot p \cdot q \cdot N}{E^2(N - 1) + \sigma^2 \cdot p \cdot q}$$

Figure 1. Samples calculus for a finite population.

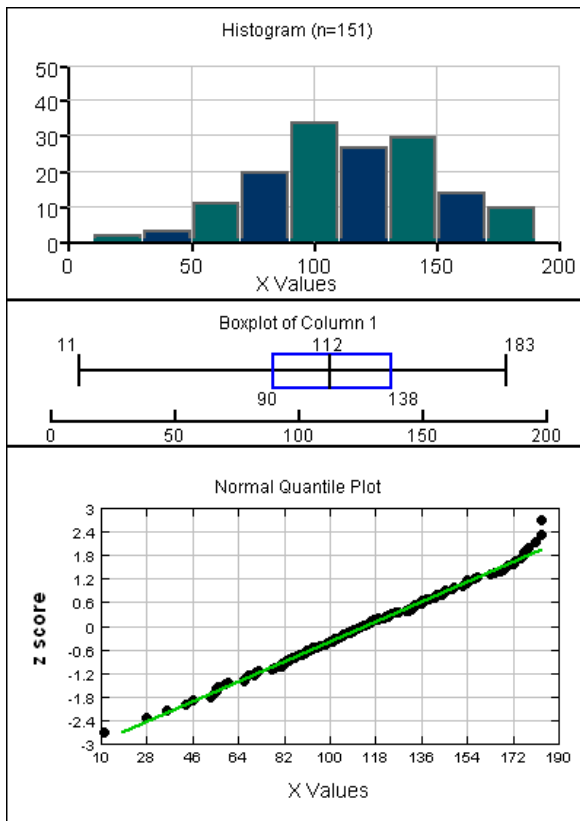


Figure 2. Levels of anxiety for a finite population. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

the levels of stress indicated by the ISSL inventory, which establishes 4 levels of stress: alert phase, resistance phase, almost-exhaustion phase, and exhaustion phase, and the existence (or lack thereof) of information about music psychology during the participant's education.

## Procedure

Participants were introduced to the procedure and questionnaires by a psychologist. For scoring, the samples calculus for a finite population (simple aleatory sample) was used ( $n=191$ ,  $\sigma^2=10\%$ ,  $p=499.74$ ,  $q=96[q=1-p]$  50.26%  $q=100-p$ ,  $E^2=4\%$ ; see Figure 1). The population presented a profile very similar to the population of the studies of the K-MPAI scale validation and translation for Portuguese language (see Figure 2).

## RESULTS

Information on music psychology was only presented when a professor volunteered to discuss the topic privately. Because there were no formal classes on the topic it wasn't possible to infer results on that presentation type. A little more than half of the participants (50.3%) don't show stress conditions (see Figure 3).

Almost half of them (49.7%) presented stress at some level. Of these, 47% were placed into the Resistance level and only 2% were placed into the exhaustion condition (see Figure 4).

## DISCUSSION

The study yields some relationships between high levels of anxiety and stress. Although high levels of anxiety and stress tend to correlate, 17% of the participants without stress reported high levels of anxiety (K-MPAI above 138) which will be closely observed and discussed in the next part of this investigation. Some participants spontaneously declared that they felt less anxious

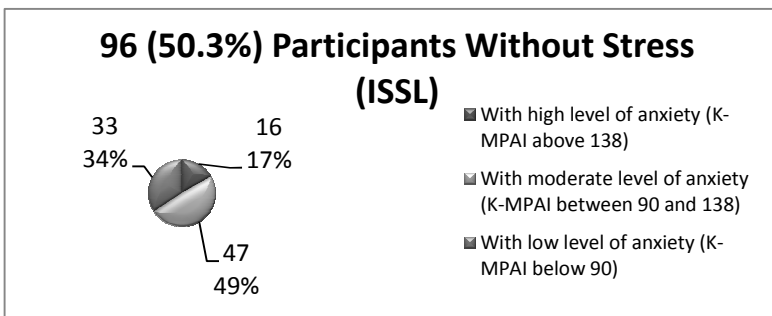


Figure 3. Participants without stress.

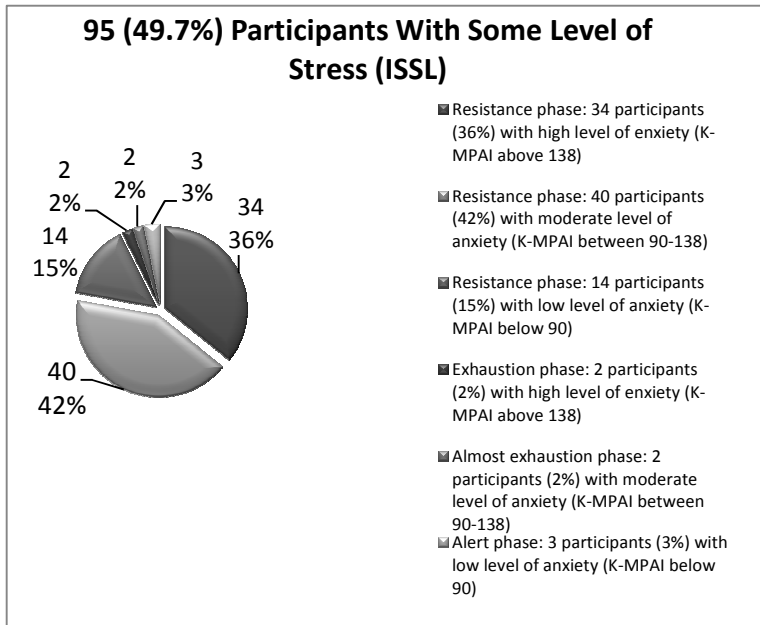


Figure 4. Participants with stress.

or stressed after receiving information on music psychology directly from their professors or close friends. In the next phase of this research, more factors from the K-MPAI inventory will be analyzed in detail and compared to the participants' daily musical routines. Another 12 universities are scheduled to be visited by the researchers to further these results.

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# Mindfulness and the self-regulation of music performance anxiety

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Mindfulness has gained prominence in alleviating anxiety and improving health outcomes across diverse populations, but little attention has been given to how dispositional and situational levels of mindfulness may leverage musicians' coping efforts to self-regulate experiences of music performance anxiety (MPA). These relationships were investigated in a sample of 159 tertiary music performance students, using self-report measures. Variables were measured at (1) the start of an academic semester, (2) one week prior to final performance exams, and (3) immediately after the performance exam. Regression analyses revealed students' ability to mindfully "act with awareness," and predicted lower levels of MPA across time. Mediation analyses indicated that dispositional mindfulness predicted greater mindfulness during the performance week through less avoidance of performance-related thoughts and feelings and a greater sense of having agency and resources to meet performance goals. During performance, greater situational mindfulness predicted lower MPA through increased focus on the positive aspects of the performance, greater self-kindness, and self-acceptance. These results support the development and evaluation of mindfulness training in tertiary music curricula and in treatments for MPA.

*Keywords:* mindfulness; act with awareness; music performance anxiety; self-regulation; musicians

Music performance anxiety (MPA) is characterized by strong and persistent anxious apprehension related to music performance (Kenny 2010). It is highly prevalent and in a recent study one-third of music students considered

MPA to be a problem (Studer *et al.* 2011) that could lead to impaired quality of performance, avoidance of performance, or the abandonment of study (Rae and McCambridge 2004, Wesner *et al.* 1990).

Mindfulness is a faculty commonly referred to as awareness and ability to attend to the present moment with a quality that is open to accept rather than judge (Kabat-Zinn 1994). Dispositional and situational mindfulness have been empirically associated with psychological well-being, self-regulated behavior, and positive emotional states (Brown and Ryan 2003), but little attention has been paid to how dispositional and situational abilities to be mindful may influence musicians' efforts to self-regulate experiences of MPA as they work toward a solo performance exam. To date, one study has found a small negative association between musicians trained in Zen (Chan) meditation and MPA (Chang *et al.* 2003).

The present study was designed to investigate the association between mindfulness and MPA further, and to develop an understanding of how a musician's ability to be mindful may be associated with coping responses to self-regulate levels of MPA as they work toward a final performance exam. We hypothesized that a musician's dispositional and situational abilities to be mindful would contribute to the use of more adaptive efforts to self-regulate experiences of MPA.

## METHOD

### Participants

One hundred and fifty-nine university music performance students (97 women and 62 men; mean age 21.9±5.8 years, range 17-53 years) were recruited for this longitudinal study. The participants were enrolled in classical performance studies (n=119), or in Jazz (n=24) and Pop (n=16). The majority were instrumentalists (59%), followed by singers (20.1%) and conductors (16.4%). The participants were predominantly New Zealand European (61%) and New Zealand Asian residents (31.4%).

### Materials

Mindfulness was assessed using the Five Facet Mindfulness Questionnaire (FFMQ; Baer *et al.* 2006). The FFMQ is a multidimensional assessment of mindfulness that enables an evaluation of the contribution of mindfulness at a facet level: (1) Act with Awareness, (2) Non-judge, (3) Non-react, (4) Observe, and (5) Describe. Music performance anxiety was assessed using the Performance Anxiety Inventory (PAI; Nagel *et al.* 1981). The PAI is based on

Spielberger's (1980) Test Anxiety Inventory, and measures cognitive, behavioral, and physiological components of MPA. Two new coping measures (previously pilot tested) assessed strategies that included planning, hope, emotional suppression, thought suppression, positive focus, cognitive focus, denial, social support, turning to religion, minimizing, and self-acceptance. Thought intrusion and avoidant response tendencies were assessed using the Revised Impact of Event Scale (RIES; Horowitz *et al.* 1979). In addition, anxiety sensitivity was screened using the Anxiety Sensitivity Index (ASI-3; Taylor *et al.* 2007).

### **Procedure**

Informed consent was obtained and participants completed three self-report online surveys over a four-month semester period. The first questionnaire was given at the start of the university semester. It screened for anxiety sensitivity, five facets of mindfulness, MPA, and demographics. The second questionnaire was administered four months later and one week prior to a solo performance exam. It assessed MPA, 11 coping strategies, thought intrusion, and avoidance (cognitive, emotional, and behavioral). The third questionnaire was completed within 48 hours of the performance. It assessed MPA, mindfulness, and 8 coping strategies used at the time of performance.

Relationships between key variables across the time points were analyzed by multiple regression tests with an alpha level set at 0.05. Preacher and Hayes' (2008) bootstrapping procedure was used to assess the mediating effect of coping strategies (at Times 2 and 3) on relationships among dispositional and situational mindfulness and MPA during performance.

### **RESULTS**

MPA had been experienced by 84.9% of participants, and 35.2% considered it to be a problem that negatively affected their performance. Females had significantly higher levels of MPA in comparison to males.

The hypothesized negative relationship between dispositional mindfulness and MPA across all three time points was supported for the mindfulness facet Act with Awareness ( $p=0.01$  Times 1 & 2,  $p=0.05$  Time 3). Dispositional Act with Awareness was a strong predictor of music students' situational ability to act with awareness during the performance week ( $\beta=0.52$ ,  $p=0.001$ ), in comparison to dispositional levels, students' situational ability to act with awareness was a stronger predictor of lower levels of MPA during performance ( $\beta=-0.53$ ,  $p=0.001$ ) and explained 19% of the variance in MPA

after controlling for gender, anxiety sensitivity, and dispositional levels of Act with Awareness.

Mediational analyses revealed the relationship between dispositional and situational abilities to act with awareness was partially mediated through less avoidance of performance-related thoughts and feelings and a greater sense of hope—understood as having confidence, agency, and the resources to meet performance goals. The total indirect effect had a point estimate of 0.0876 and a biased corrected 95% confidence interval of 0.0369 to 0.1605 (see Figure 1).

At the time of performance, the relationship between situational Act with Awareness and MPA was partially mediated through increased focus on the positive aspects (excitement, inspiration) of the performance, as well as greater self-kindness and self-acceptance of mistakes and fears of negative evaluation (from self and others). The total indirect effect through mediators

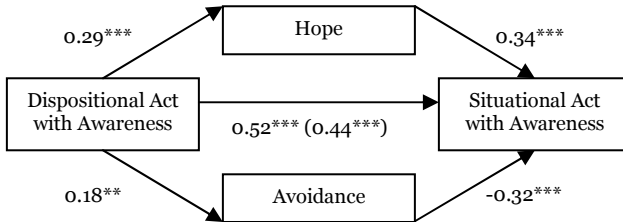


Figure 1. Partial mediation of the effect of dispositional Act with Awareness on situational Act with Awareness through coping strategies of hope and avoidance, after controlling for gender and anxiety sensitivity. (\*\*\*p<0.001, coefficient after mediation.)

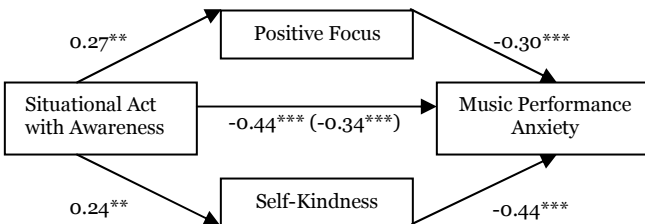


Figure 2. Partial mediation of the effect of situational Act with Awareness on music performance anxiety through coping strategies of positive focus and self-kindness, after controlling for gender and anxiety sensitivity. (\*\*\*p<0.001, coefficient after mediation.)



had a point estimate of  $-0.2347$  and a biased corrected 95% confidence interval of  $-0.4283$  to  $-0.0907$  (see Figure 2).

## DISCUSSION

In this study investigating how musicians' dispositional and situational forms of mindfulness are associated with the coping strategies they use to self-regulate experiences of MPA, the mindfulness facet of Act with Awareness emerged as the facet that most strongly predicted self-regulatory coping efforts, and less music performance anxiety at the time of performance. Prior research has demonstrated that Act with Awareness, as measured by the Mindful Attention Awareness Scale (Brown and Ryan 2003), is associated with lower perceived stress and less anxiety (Weinstein *et al.* 2009). The current findings suggest that an ability to bring one's attention and awareness to the present moment (in contrast to worrying, being distracted, or running on automatic pilot without much awareness of what one is doing) is likewise important in the self-regulation of MPA.

The negative association between mindfulness and MPA supports the findings of Chang *et al.* (2003) and extends them by demonstrating that both dispositional and situational forms of Act with Awareness are influential in reducing MPA through the promotion of adaptive coping choices. During the preparatory months, dispositional Act with Awareness promoted confidence, expectancies of success, and goal-focused determination, supported through less avoidant coping. These findings support prior research that has found an association between mindfulness, less use of avoidant coping, and higher use of approach coping prior to a final course test (Weinstein *et al.* 2009). During performance, situational Act with Awareness promoted focus on the positive aspects of performance and greater self-kindness and self-acceptance even in the face of potential imperfections. These findings add new insight by highlighting the potential of positive emotions to fulfill other adaptive functions during performance, such as providing an antidote to negative cognitions and affect (Frederickson *et al.* 2008).

In conclusion, the benefits associated with bringing mindful Act with Awareness to performance preparation and performance invite musicians and educators to reflect on how they promote attention and awareness within their practice, learning, and performance strategies. The results indicate that mindfulness is worthy of further investigation as a treatment option or skill to be developed in the management of music performance anxiety and as a potentially valuable tool to be taught within tertiary music curricula.

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**Thematic session:  
Performing together III**



# Emotional communication among performers: Modeling the affective experience as portrayed and perceived emotions

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This paper reports results from listening experiments with live performances, during which the performer conveyed distinct affects for repetitions of the same musical excerpt. Two kinds of experiment were conducted. Pilot studies were designed to test word-based interfaces for marking changes of expression. The main experiment aimed at testing how the performer conveyed his interpretations to 60 listeners, all musicians. Results indicate a bias toward higher valence in the report by the listeners than in the intended affects as conveyed by the performer, as well as an amplification of the values on the arousal axis.

*Keywords:* emotional communication; portrayed emotion; perceived emotion; music performance; affective experience

This research assumes that multiple interpretations of a work are desirable. It follows that multiple apprehensions of a performance may also be both possible and desirable. Winold (1993) suggests that "a musical work may not only afford multiple interpretations, but also present ambiguities that stimulate concomitant interpretations" (cited in Gualda 2011, p. 11). Since the nature of affective experience may transcend the possibility of modeling it as a single or central emotion, this research attempts to study the communication of the affective experience as a combination of several discrete representations of emotions on the valence-arousal circumplex (Russel 1980) as translated into Portuguese (Ramos 2008, Fornari 2010). Thus it differs from previous works, for it does not try to model how affects can be conveyed, but instead whether combinations of contrasting affects are comprehended by the listeners, as well as how they differ from those intended by the performer.

Feldman (1995) studied "the relationship between personality and the structure of the affective experience" (p. 156) by modeling variations of the

overall shape of the position of 16 mood terms on the semantic circumplex across subjects. Her work suggests that each person might have a particular bias toward amplifying or reducing the scaling of the values on the valence-arousal axes of the semantic circumplex. The dimensionality of the semantic circumplex has also been studied. Eerola and Vuoskoski (2011) suggest that three dimensional models might collapse into two dimensions, whereas Trkulja and Jankovic (2012) suggest that "cognitive evaluation" may also contribute to the perception of emotion in music (p. 1017), but it may correspond to a small percentage.

Eerola and Vuoskoski (2011) discuss some problems in the study of musical emotion: "(1) reliance on discrete emotions only, (2) focus on unambiguous exemplars, or (3) insufficient stimulus quantity" (p. 40). Zentner *et al.* (2008) propose nine musical emotions and discuss whether they are true emotions. The authors distinguish between induced emotion (emotion felt by the listener, aroused by music) and perceived emotion (imagined emotion, associated with the music) and define "attribution error" (pp. 514-515) as the confusion between emotions listeners might have imagined or perceived while listening to music with the emotions music might have induced on the listeners. This research does not differentiate between aroused and perceived emotions. It simply assumes that, even if emotions reported by the listeners could be of either nature, this does not interfere in conveying those emotions.

## METHOD

### Participants

Participants were 60 listeners, 22 years old ( $SD=4.56$  years) on average, with an average 9.8 years ( $SD=4.72$ ) of musical training. They were undergraduate and graduate music students from the Federal University of Rio Grande do Sul (Brazil), who attended an introductory class and undertook a listening experiment with live performances. They filled an eight-word interface containing discrete affects that should be associated with a performance that they had just heard. The interface accepted three levels of association (Likert scale). Since participants had probably never been exposed to this experimental setting, before starting the experiment, they performed three trials with a different musical excerpt from those utilized in the experiment.

### Materials

Three short musical excerpts from the standard oboe repertoire were selected by the performer: bars 1-4 from *Pan*, the first movement of the *Six Meta-*

The figure displays three musical excerpts on a three-staff system. The top staff, labeled 'Senza misura', features a melodic line with dynamic markings *f*, *f*, and *mf*. The middle staff, labeled 'ad libitum', shows a more fluid, improvisatory melodic line. The bottom staff, labeled 'mf molto espressivo' and 'f', contains a rhythmic and melodic passage with a dynamic marking of *f* at the end.

Figure 1. Musical excerpts utilized in the listening experiments (live performances): Britten (top), Saint-Saëns (middle), and Piazzolla (bottom).

*morphoses after Ovid, Op. 49* by Benjamin Britten (1952); the first bar of the second movement of the *Sonate pour Hautbois, Op. 166* by Camille Saint-Saëns (1921); and bars 15-27 of *Café 1930* from *Historia del Tango*, by Astor Piazzolla (1986), originally composed for the flute. The selected excerpts allowed distinct interpretations that included at least two contrasting affects. In each excerpt, the first half is structurally different from the second. Figure 1 presents the three excerpts with an additional double bar that indicates the point of that division.

Three interfaces have been devised. The first contained twelve pairs of similar affects (Russel 1980) in Portuguese (Ramos 2008, Fornari 2010). The second presented four pairs of dichotomies: agitated versus sleepy (maximal and minimal arousal), beautiful versus ugly (maximal and minimal valence), happy versus sad (positive valence and arousal, negative valence and arousal), and serene versus tense. The third version presented two lists of 8 words.

## Procedure

Three musicians took part in a pilot study in which three different materials were tested: a long list with 24 affects, a short list of eight affects that approximated the equal division of the semantic circumplex, and a double list of the same eight affects designed for comparing contrasts between affects. The third version, with contrasting affects, was chosen to be applied. Before performing each excerpt, the performer filled the same list of affects that the listeners would fill after the performance. In each performance, the performer attempted to convey a different pair of affects: one for the first half, and an-

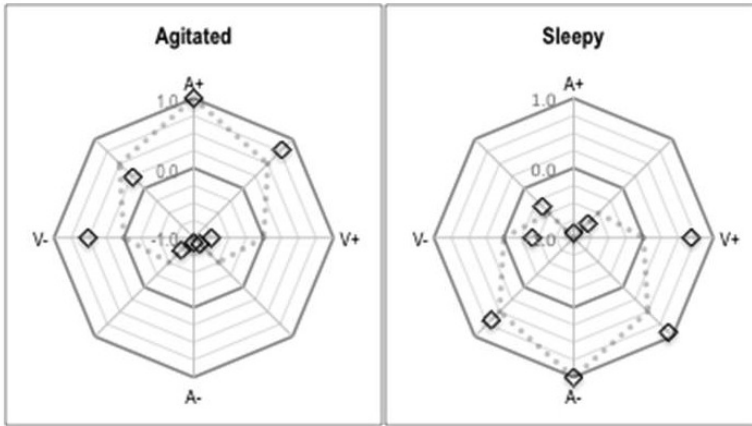


Figure 2. Polar representations of maximal and minimal arousal. The angle represents the emotion on the circumplex, and the azimuth represents the correlation of average reports on emotions. Dashed lines depict a theoretical model of ideal correlation. Maximal correlation (1.0) is represented on the outmost circumference (octagon), whereas minimal correlation (-1.0) is represented by the point on the center.

other until the end of the excerpt. In order to seek ecological validity (Clarke 2004), no further instructions were given to the listeners besides to mark the 3-point Likert scale (nothing, a little, a lot) for each affect on the lists after listening to each performance.

## RESULTS

Averaged data on reports by the 60 musicians who undertook the experiment were compared through canonical correlation. Figure 2 depicts  $r$  values on the polar coordinate system, representing the valence-arousal plane. Figure 2 also presents a theoretical model of the expected correlation among affects. It is represented by a dotted line. In agitated (maximal arousal) situations, all correlations, with exception of ugly, were very close to their theoretically expected values. Similarly, its dichotomy—sleepy—is similar to the model. Even though affects are not orthogonal, dichotomies of affects presented very strong anti-correlation, as presented in Table 1.

The level of agreement between *musicians-as-listeners* and the *performer* was not particularly high (overall agreement,  $r=0.26$ ,  $p<0.05$ ; principal effects,  $r=0.47$ ,  $p=0.0001$ ). In accordance with Feldman (1995), however,



Table 1. Correlation coefficients of the four dichotomies of affects ( $p < 0.0001$ ).

	<i>Agitated-sleepy</i>	<i>Happy-sad</i>	<i>Beautiful-ugly</i>	<i>Serene-tense</i>
r	-0.93	-0.97	-0.74	-0.64

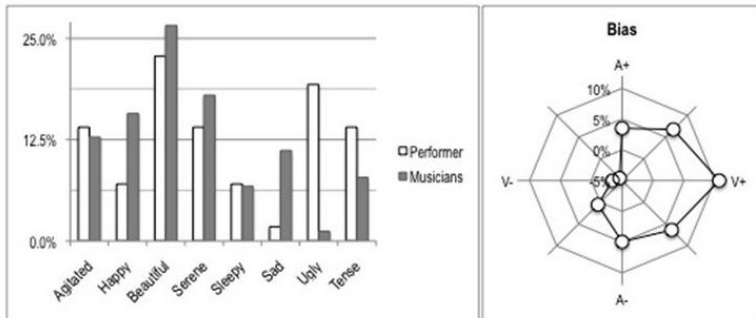


Figure 3. Performer's and listeners' percentages of marks on the eight affections considered in this study (left). The polar representation of the difference between portrayed and perceived emotions presents a clear bias toward positive valence (right).

there is an overall bias that can be measured for each listener (see Figure 3). This bias could have been a personal bias of the performer himself, who might have tried to emphasize affects on the valence axis instead of those on the arousal axis. It could also be explained by the choice of repertoire, which might favor higher valence.

## DISCUSSION

This research focused on discrete emotions, and combined averaged data on their frequency in order to represent the ambiguity of multiple or concurrent apprehensions. Performer's interpretations also presented some ambiguity that was captured by this approach. Since the performer and listeners were colleagues, his presence might have induced the student listeners to report a higher valence.

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# Co-performer empathy and peak performance in expert ensemble playing

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Optimal experiences of performance are important and desirable. In ensemble playing, these experiences are influenced by a connection between players. The present study sought to explore expert Western art ensemble musicians' experiences of peak performance and co-performer empathy in order to construct a model of the relationship between these phenomena. Focus group interviews were conducted with five expert chamber ensembles. The resulting model showed optimal performance in expert ensemble playing to be a combination of co-performer empathy, components of flow, and performance conditions such as repertoire choice and environment. Co-performer empathy itself consisted of a *shared approach* to interpretation and to working together, an *intentional awareness* of how other players are operating on a musical and a practical level, and a *special connection* between players. Analysis also revealed *spontaneous interpretative flexibility* in performance to be a product of co-performer empathy.

*Keywords:* empathy; ensembles; flow; flexibility; music

The psychology of optimal experience has received considerable research attention in the post-war years. Researchers have sought to understand what makes us happy and how we can be happier. A number of frameworks examining optimal experiences have been developed, including peak experience (Maslow 1959), Flow Theory (Csikszentmihalyi 1975), and peak performance (Privette 1981). A fourth framework—strong experiences of music (SEM; Gabrielsson 2001)—has specifically explored people's strongest experiences of listening and performing. However, despite studies agreeing that optimal experiences of music performance are important and desirable for musicians, there is very little research in this area that is specific to ensemble playing. Ensemble playing is a key area of music psychology research, since

almost all musicians rehearse and perform music with others. In recent studies exploring chamber musicians' optimal experiences of performing together, players have spoken of achieving a collective state of mind, described variously as "in the groove together" (Berliner 1994), a "group flow state" (Sawyer 2006), or "empathetic attunement" (Seddon 2005). This collective state of mind seems to be the key difference between solo and ensemble optimal experiences of performance and is likely to be linked to empathy—a relatively recent intellectual concept (Lipps 1903). Over the last few decades, empathy has received considerable research attention as a means of understanding a range of psychological phenomena and is fast drawing attention within music psychology. In the area of empathy and performance, Myers and White (2012) recently explored the role of empathy in the performing experiences of nine professional musicians. Although the study did not specifically examine co-performer empathy, participants described co-performer empathy as an essential part of performing well together.

Since optimal (or peak) experiences of music performance are important and desirable, research exploring these experiences in ensemble playing is required. Studies indicate that co-performer empathy is likely closely related to ensemble musicians' optimal experiences of performing. There was, therefore, one aim for the present study: to construct a model for co-performer empathy in relation to peak performance.

## METHOD

### Participants

The members of five established, Western art chamber ensembles (N=19, men=10, women=9, M=36.6 years, SD=16 years) were recruited and interviewed in their respective groups: a wind quintet, a vocal duo, a contemporary woodwind trio, a mixed piano trio, and a string quartet. No brass ensemble was available for a group interview, so three members of two brass ensembles were interviewed individually. All participants had been working together in their groups professionally or semi-professionally for a minimum of three years (M=16.4 years, SD=17.5 years).

### Materials

Interview questions were based, in part, on existing studies on empathy in performance (Myers and White 2012), peak performance (Privette 1981), and SEM (Gabrielsson 2001). *NVivo 9.0* was used for coding and analysis.

## Procedure

All group interviews and two of the individual interviews were conducted in person at rehearsal venues. The third individual interview was conducted over *Skype*. The interviews were transcribed, read and re-read, initial codes were developed, and then the transcripts were imported into *NVivo*. Content analysis was undertaken using an approach modeled on grounded theory, in which the aim of the analysis was to describe the data in order to derive a theory inductively. Themes were developed by collapsing, combining, or extending initial codes.

## RESULTS

Analysis revealed that expert ensemble musicians perceived their optimal (peak) performance experiences to be a result of co-performer empathy, components of flow, and two performance conditions: repertoire choice and environment (see Figure 1).

Co-performer empathy itself consisted of three main components: a *shared approach* to interpretation and to working together, an *intentional awareness* of how colleagues are operating on both a musical and a practical level, and a *special connection* between players. In addition, it was found that co-performer empathy sometimes led to an ensemble achieving *spontaneous interpretative flexibility* during performance. While in empathy, players felt able to vary aspects of musical expression spontaneously. Spontaneous interpretative flexibility was described by participants as a central feature of optimal performance experiences.

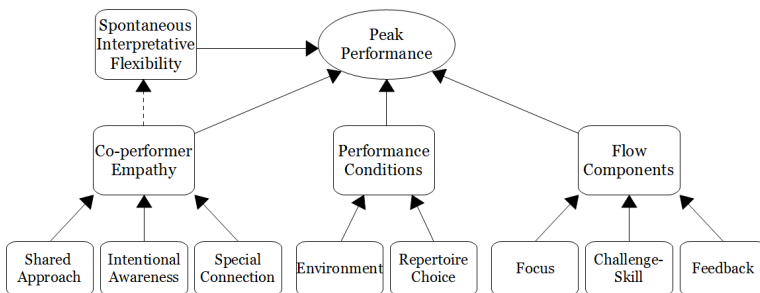


Figure 1. Peak performance and co-performer empathy model.

## DISCUSSION

Three components contributed to co-performer empathy. The first was a *shared approach*, both to musical interpretation and to working together. There were two aspects of shared approach to musical interpretation. The first concerned a shared approach to expressive detail within the music; the second, an agreement that the music should take priority over all else. One violinist described this second aspect as striving to “make the whole greater than the sum of the parts.” There were three distinct aspects of a shared approach to working together. First, it was essential for all players to agree on a style of working. Examples included whether rehearsals should be democratic, whether to work in short bursts or at length, and how blunt players should be. Second, a shared level of commitment to the ensemble was considered vital. If players felt that one colleague was contributing less, then resentment could build. It seems likely, therefore, that an equal commitment is required from all players for an ensemble to function at the highest level. Third, shared goals for the ensemble were essential. This was probably because goals affect an ensemble’s approach to rehearsals, the kind of gigs they play, how often they rehearse, or how much time they dedicate to the ensemble. A shared approach both to musical interpretation and to working together was found to be a pre-requisite condition for achieving co-performer empathy.

The second component of co-performer empathy was *special connection*. A variety of vocabulary was used to express this idea: e.g. “gelling,” “exactly synchronized,” “an intimate connection,” “in harmony,” “eyes,” “ears,” “radar,” “instinctively aware,” “sympathy,” “clicking,” “locking in,” “getting into each other’s heads,” and “being able to read the other person’s mind.” No participants used the word “empathy” before being asked direct questions about empathy during the interviews, but all agreed either that empathy was a good description of the same phenomenon, or that they understood the term in the same way. A process emerged for forging a special connection between players. It begins with an ensemble formed of players with complementary personalities. A socio-emotional connection between players is then consolidated through social bonding experiences, leading to trust between players. The connection is developed further through rehearsing together, leading to familiarity between players and a feeling of being able to predict how colleagues are likely to play or respond. Eventually, the process results in co-performers experiencing a “special connection” that is intimate and experienced in varying degrees while playing together. The special connection

component characterized almost all of the accounts of optimal performance experiences.

The third component of co-performer empathy was an *intentional awareness* of how one's colleagues are operating on either a practical or a musical level. This requires a degree of cognitive perspective-taking in order to understand the difficulties they may face. An example of intentional practical awareness given by three groups involved gauging other players' moods in order to judge how blunt one could be with criticism during rehearsals. Criticism is important for progress, but an awareness of others' states is necessary to avoid insult, maintain a mutual respect, and sustain good working relationships. On a more musical level, players described the importance of an intentional musical awareness of the different expressive ideas and roles embodied by each player at any point within the music. As one flautist explained, being unaware of other parts and retaining only an individual focus results in "bulldozing through." Sensitivity to the different parts and the ability to shift one's focus away from one's own part seems to be vital in expert ensemble playing.

Finally, *spontaneous interpretative flexibility* was found to be a product of co-performer empathy. This was defined by participants as the spontaneous production of expressive variations in performance and was described by all as desirable. If, as the model suggests, spontaneous interpretative flexibility in ensemble performance is a product of co-performer empathy, then it could also be a useful indicator of this empathy. Co-performer empathy and spontaneous interpretative flexibility are both closely associated with expert ensemble musicians' optimal performance experiences, and so further research may reveal useful insights with much-needed practical applications for chamber music pedagogy.

Other elements found to contribute to expert ensemble musicians' optimal performance experiences were components of flow and performance conditions. Unsurprisingly, the focus, challenge-skill balance, and immediate feedback components of Csikszentmihalyi's (1975) "Flow"-Theory were identified in the players' accounts of optimal performance experiences. In addition, players indicated a number of general performance conditions which had influenced their optimal performance experiences. These included repertoire choice, audience, venue, acoustics, and temperature.

The present study has examined co-performer empathy in the context of expert ensemble musicians' optimal performance experiences. From the data it has been possible to construct a model representing the components that contribute to co-performer empathy. However, co-performer empathy during ensemble playing is a constant, complex process and it is beyond the scope of

this study to develop a model of that process. For now, it is possible to assert that co-performer empathy is an essential feature for expert ensemble musicians' optimal performance experiences. It is based upon a pre-requisite condition of a shared approach to musical interpretation and to working together. It is, at least sometimes, characterized by a special connection between players, and is likely to involve a degree of cognitive perspective-taking, through an intentional awareness of one's colleagues on a musical and a practical level. However, further research to determine the process of co-performer empathy in expert ensemble playing remains to be undertaken.

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# Beating together: A case study of heart rate in partner change in violin and piano duo

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This study looked at physiological responses to stress in musicians, comparing a newly formed and consolidated violin-piano duo. The common element between these duos was the pianist. Using the non-invasive device *VitalJacket*<sup>®</sup>, developed at the University of Aveiro, Portugal, participants were monitored under various performance conditions. These included two performance venues (university and secondary school), as well as familiar versus unknown repertoire. The latter was given approximately one week before each recital. Results suggested higher heart rate for the school venue and during periods previous to music sections that could offer some technical or musical challenges. The pianist yielded an overall higher heart rate while performing familiar repertoire (regardless of violinist partner) and lowest heart rates before going onstage and playing in the newly formed duo for the beginning of the first recital. Results suggest that both conditions of unknown repertoire and partner in performance may cause higher expectations on the pianist, explaining higher stress indicators such as heart rate.

*Keywords:* *VitalJacket*<sup>®</sup>; violin and piano duo; ECG; stress; MPA

Research focusing on music performance in an ensemble context has mainly been concerned with the interaction and communication between members of the group during rehearsal and performance (Goodman 2000, Davidson and Good 2002, Davidson and King 2004). No studies have looked at stress management in instrumental duos. Although research has investigated posture-related heart rate variables, such as sitting or standing, or the impact of age and gender on heart rate, no reports on musicians' responses while per-

forming has been done (Kuo *et al.* 1999, Jones *et al.* 2003). A promising possibility to explore stress during duo performance is to look at physiological responses of the musicians, such as heart rate (Iñesta *et al.* 2008, Yoshie *et al.* 2009). The current study measures physiological responses, such as heart rate, of a pianist in a violin-piano duo, during two different performance conditions (different partner, familiar versus unfamiliar; different performance venue, university versus secondary school). Although heart rate monitoring is frequently employed in sports medicine to study athlete's performances, the current investigation is one of the first to apply non-invasive measurements to assess musician's physiological responses during performance in duos. The aim is to understand to what extent partner, venue, and repertoire (see Pappageorgi *et al.* 2013) have an effect on the physiological responses of the pianist.

## METHOD

### Participants

Three musicians, a pianist (female) and two violinists (both male), took part and were assigned to two instrumental duos. Each duo had the same pianist (P) and a familiar and an unfamiliar violinist (V1 and V2, respectively). For the purpose of comparisons between duos, the one having the familiar violinist will be referred as PV1 and the other by PV2. The three musicians were all healthy, with similar professional training and experience, and were between 41-51 years old ( $M=46$ ,  $SD=5$ ).

### Materials

A T-shirt with a non-invasive Holter-type cardiac monitoring—*VitalJacket*®—was worn under the concert dress clothes. The shirt has three electrodes to which an electronic device is attached. The latter is held in the shirt's pocket and possesses an accelerometer (as posture influences heart rate) and a security card where data for the heart rate are stored for later analysis. This device, designed by the University of Aveiro, and manufactured by *BioDevices* (Porto, Portugal), is the only currently available in the market that allows recordings of large datasets (up to 7 consecutive days of data). Data can be later analyzed with VJ Desktop Pro v2.1 software, displaying data as a set of graphs, tables, and lists automatically. Heart rate, expressed as beats per minute (bpm), was monitored during all recitals (8) of approximately 60 minutes length. In addition, heart rate was also measured 15 minutes before and after each performance.

## Procedure

Duos (i.e. PV1 and PV2) were asked to perform a total of four concerts each: two at the Aveiro University concert hall (venue A) and two in a secondary school auditorium of Aveiro (venue B). For these concerts, two series of repertoire were performed: the 1st series of concerts included well-known repertoire for PV1 (Mozart's *Sonata in B, K. 378* and Schumann's *Sonata in D minor, Op. 121 No. 2*) but not for PV2; the 2nd series of concerts included well-known repertoire (Mozart's *Sonata in B, K. 378*) and first-time performed repertoire (Mozart's *Sonata in C major K. 303* and A. Goeticke's *Sonata for violin and piano, Op.10*). For both series, two pieces never rehearsed before by PV1 nor PV2 were performed on stage, by both duos, for the first time: (1) J. Field's *Melancolie* (venue A) and Eller-Wilhelmj's *Valse Diabolique* (venue B) for the 1st series of concerts and (2) E. German's *Bolero* and A. Wilhelmj's *All'Ungherese* (for venue A and B, respectively). These pieces were prepared individually one week prior to the duo performance. PV1 and PV2 were randomly allocated across concerts and venues.

## RESULTS

Overall, P was the least-stressed musician across the whole performance ( $M=102.39$ ,  $SD=11.76$ ) as compared to V1 ( $M=136.51$ ,  $SD=2.66$ ) and to V2 ( $M=127.93$ ,  $SD=7.70$ ). V1 presented overall the highest heart rate during the recitals. For P, maximum heart rate peak was observed when playing in the PV1 duo, for venue B ( $M=117.02$ ,  $SD=11.98$ ) and for the well-known repertoire. For V1, maximum heart rate peak was found to happen during the performance of the non-rehearsed piece and also at venue B. Concerning V2, the results suggest a maximum heart rate peak also for venue B; however, it was not associated with the performance of non-rehearsed repertoire.

Figure 1 represents an example of heart rate measures for pre (off stage) and during (performance) moments for PV2 and the first concert in the whole experimental-observational study. A difference can be observed in heart rate and body movement for V2 during performance as compared with P: P presents more changes in heart rate for the whole performance (changes associated with technically and musically challenging sections) as compared with V2. The latter shows a higher peak for the beginning of the performance but then stabilization with not so evident changes across the whole performance. This corroborates the higher SD values presented by P.

Concerning mean values of heart rate for the 1st and 2nd series of concerts, results show: for P and V1 (and also for PV1), mean heart rates were higher for the concerts performed at venue B, independently of repertoire

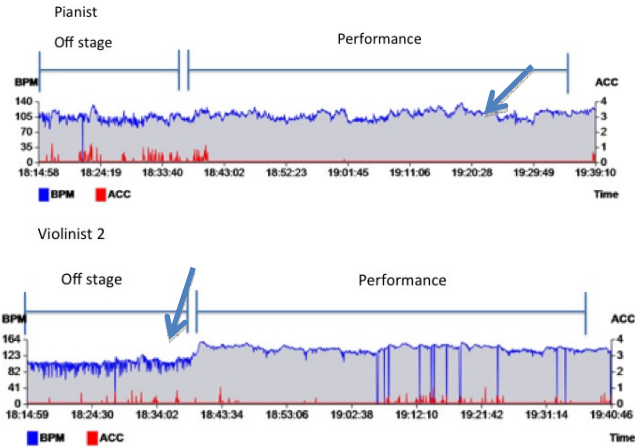


Figure 1. Heart rate (in BPM) and accelerometer values for PV2 duo, during the performance of the first concert of the 1st series of concerts, in venue A. The arrows point at examples of clear changes in heart rate for both P and V2. (See full color version at [www.performance-science.org](http://www.performance-science.org).)

Table 1. Mean and standard deviations (SD) for different venues and repertoire (well-known and unknown) performed by the duos. P=pianist, V1=Violinist 1, V2=Violinist 2, PV1=consolidated duo, and PV2=newly formed duo.

Venue/ Repertoire	P BPM/SD	V1 BPM/SD	V2 BPM/SD	PV1 BPM/SD	PV2 BPM/SD
Venue A	99.23(10.75)	135.04(2.74)	130.06(7.33)	99.23(19.88)	113.82(21.86)
Venue B	105.56(13.43)	137.97(2.30)	125.81(10.30)	121.48(21.45)	115.96(15.76)
Well-known	110.83(8.75)	136.35(4.58)	134.17(1.52)	122.08(18.30)	124.01(12.10)
Unknown	93.96(7.50)	136.66(0.45)	121.70(4.48)	117.36(22.67)	105.78(19.01)
Overall duo				119.72(19.24)	114.89(17.68)

Note. \*Although for V2 there was no distinction between well-known and unknown repertoire, this distinction was needed to clarify differences in repertoire for PV1.

(see Table 1); for V2, mean heart rate was higher for the concerts performed at venue A (also independently of repertoire) but not for PV2, which was also higher for venue B (see Table 1). The repertoire seems not to constitute an important element in determining heart rate mean values, as for V1 there were no differences, for P heart rate values were always higher for well-

known repertoire and for V2 it was always when performing the first time ever in duo (PV2).

## DISCUSSION

For all recitals, musicians presented maximum heart rate peaks for venue B during moments of technically or musically challenging sections. It was evident that, although both V1 and V2 showed higher maximum peaks as compared with P, the variability of heart rate was higher for P. This could be a gender effect, as heart rate has been found to be different between genders. However, many other factors could account for the found differences, such as level of musical experience, fitness, posture and personal traits such as anxiety and level of perfectionism (Mor *et al.* 1995).

Concerning mean value differences of heart rate across the whole performance, unexpected results were found: (1) PV1 showed higher values compared to those of PV2 (independently of venue and repertoire); (2) both P and V1 showed maximum mean heart rate values for the performance of well-known repertoire; and (3) these PV1 higher values were found for venue B. One would expect that P (even being the least-stressed musician in the duos across all performances), would show higher values when playing in a non-consolidated duo (PV2), non-rehearsed repertoire, or in the presence of a more academic audience (venue A). This was not the case. PV1 presented higher mean values of heart rate for the well-known repertoire played at venue B. One could partially explain these results taking into account the musician's expectations. It seems that when playing in a duo, music that has been already performed several times might create higher expectations towards the quality of the artistic desired outcome than less a well-known work or partner. Thus, the performance duo experience seems to be a rather important element in creating higher stress levels in musicians. However, this might not necessarily impair performance quality; results of previous research indicated that certain levels of arousal (that could be expressed also by means of heart rate) are determinant to achieving higher performance quality (Papageorgi *et al.* 2013). Concerning the differences found for venues, one would also expect to find higher heart rates when playing to a more erudite audience; however, this was not the case for PV1. Perhaps PV2 showed higher values because V2 presented the highest mean heart rate values when performing at venue A. This could possibly be explained by the fact that he was a member of staff at the university. This is corroborated by the fact that his highest heart rate peak was achieved when playing the first time ever across the whole experiment.

Although this constitutes an observational exploratory study, it seems that expectations towards certain artistic desired outcomes achieved with well-known partners in performance and repertoire constitute an important element in determining heart rate during performance. Higher levels might constitute good indicators of desired arousal levels in the performance. Of partner change, repertoire, and venue, the first two elements seem to be more influential in determining symptoms of performance stress, such as heart rate levels, for duo performance.

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## Graduate award paper





# The influence of performers' stage entrance behavior on the audience's performance elaboration

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This study proposes a typology of the initial stage entrance behavior of performers based on audience members' first impressions of selected video recordings at an international violin competition. Against the theoretical background of social interaction theory, it is assumed that performance evaluation can only be understood as an interaction between expectations of audience's sub-classes and observable behavior of groups of performers. An analysis of performer behavior was conducted in three steps: (1) based on methods of classical test theory and item response theory, a selection of six items that best describe performer behavior with regard to the audience's forming an impression was presented, (2) by means of a multi-level latent class analysis, responses could be described by one of three classes of the audience's first impression judgments ("appropriate," "acceptable," and "inappropriate" stage entrance behavior) resulting in two groups of performers' stage entrance behavior evaluation, (3) the association between audience first impression classes and the audience's motivation for performance continuation was used as an indicator for a more in-depth performance elaboration. Results suggest that for the adequate understanding of audiovisual performances, a model of *performance elaboration* can be an alternative to models of musical communication.

*Keywords:* music performance; performance evaluation; multilevel latent class analysis; audience; music performance elaboration

One way to look at music performance is by means of communication models (Juslin and Timmers 2010). With these widely distributed models, music performance can be summarized as an exchange of information between performer (as "transmitter") and audience (as "receiver") through the modifi-

cation of physical space. This modification of space results from the performer's intentional operations for the successful realization of musical meanings (Davies 1994). Consequently, all auditive (Juslin 1997) as well as visual (Inge and Leman 2010) perceived modifications of the physical space within a performance were affiliated to the transmission of the compositional meaning. However, a recent meta-analysis (Platz and Kopiez 2012) revealed a medium effect size for an enhancement effect of the visual component, and the authors argue that the audience's music appreciation might not be sufficiently explained by music communication models in which the visual component's function has been marginalized to a supporting role. An alternative approach could be derived from social interaction theory (Goffman 1959), which explains the audience's music performance appreciation in terms of an impression formation embedded in a persuasion process (Knape 2003, Petty and Cacioppo 1986). Within this framework, all operations of both the performer and the audience result from their individual aims to regulate their objectives.

According to Goffman (1959, p. 123), the audience's first impression at a concert event is made when a performer successfully takes on the front-stage mode by "the putting on and taking off of character" while entering the stage. Thus an *impression type* could therefore be defined as an audience member's preexisting mental-person schema (Fiske *et al.* 1999) of a performer's impression management (Goffman 1959). Additionally, every mental person-schema is connected with preexisting evaluative judgments, such as emotional judgments or feelings. Depending on the audience member's success at allocating a performer to a unique category of person-perception, impression types could therefore have a different motivation on the audience's *performance elaboration*. Specifically, music performance elaboration is defined in this study as the extent to which a person deals with performance-relevant impressions and how long the audience wishes to continue paying attention to the performance. However, up until now, the importance of a performer's stage entrance behavior has been widely neglected in music performance research (Gabrielsson 1999), although McPherson and Schubert (2004, p. 71) mentioned a dominating influence of first impressions more as a result of an expectancy evaluation process on the part of the audience and less as the reflection of objective performer features.

The aims of this current study are three-fold: first, to identify the best attributes that can describe the variety of performers' initial stage entrance behavior; second, to develop a statistical model-based typology of stage entrance behavior that explains impression types of behavior as an interaction between audience sub-classes' expectations and groups of performers' be-

havior; finally, to test the relationship between impression types and audience sub-classes' motivation for ongoing performance elaboration.

## **METHOD**

### **Participants**

Participants were recruited from a commercial online panel provider. In total, 1,530 participants took part in our online study. 528 subjects were excluded due to insufficient time on tasks, response bias, or stopping the video sequence too early. As a result,  $N=1002$  subjects (50% females; mean age=38.27 years,  $SD=11.97$  years) served as the sample in this study.

### **Materials**

First, we created a corpus of video-recorded competitors at a German international violin competition ( $N=27$ ; mean age=22.38 years,  $SD=3.52$  years). After that, a new standardized video sequence was produced for the beginning of each competitor's first stage entrance. The end of a competitor's public (spoken) announcement was used as the video's starting point, whereas the end of the experimental video sequence was marked by the conclusion of the preparatory playing gesture. In the study, we presented twelve video sequences in which all musicians started their competition program with the same piece. Second, items were generated and validated in two pilot studies in terms of classical test theory as well as item-response theory to identify the preliminary attributes for the audience's impression of performer stage entrance behavior.

### **Procedure**

Participants were first informed about the task of the online study, and then required to give their informed consent. Participants were then asked to give details about their socio-economic and demographic status, as well as their musical sophistication (Ollen 2006). After the one-time presentation of the video, participants rated their impressions of the musician's stage entrance behavior by means of ten dichotomous items resulting from the pilot studies. All video sequences were fully randomized between subjects. Finally, participants were asked to indicate whether they would like to continue with the musician's performance. The entire procedure took approximately 10 minutes.

## RESULTS

The software Latent GOLD 4.5 (Vermunt and Magidson 2005) was used for multi-level latent class analysis (Vermunt 2003). According to Vermunt and Magidson (2004a, p. 549), a latent class model (LC model) can be defined as a statistical model in which parameters may differ between unobserved, so-called latent subgroups. Specifically, the response probability of an item represents such a parameter of a LC model, whereas the subgroups represent discrete categories of a latent variable (Vermunt and Magidson 2004b). Compared with conventional cluster analysis (Aldenderfer and Blashfield 1984), finite mixture modeling (McLachlan and Peel 2000)—such as LC models—offers more flexibility combined with lower degrees of freedom in the researcher's decision process, resulting in a more reliable and confident data analysis. As an example, only one parameter, namely the number of classes, has to be fixed a priori for an explorative LC model. The plausibility for the appropriate number of classes can be confirmed with regard to Bayesian information criteria (Burnham 2004) and further model fit indices (Vermunt and Magidson 2005). In contrast to a LC model, in a cluster analysis more than one parameter must be defined, and the problem of algorithm-dependent results remains unsolved. Further on, the main advantage of a LC model compared with cluster analysis is the statistically, and therefore theoretically oriented, decomposition process of the mixture distribution, depending on the items' response format. To summarize, a LC model can be regarded as a top-down approach for statistical data modeling, while cluster analytical techniques represent a bottom-up approach.

The data analysis consisted of five steps: (1) identifying the appropriate number of latent classes (level-one), (2) redeeming local independence assumption by removing four of the ten items with significant bivariate residuals (Magidson and Vermunt 2004), (3) obtaining the hierarchical structure of the data (individual ratings nested within musicians) by extending the preliminary model to a nonparametric random-coefficient LC model (level-two), (4) classifying audience sub-classes (level one) and groups of performers' behavior (level-two), and finally (5) testing whether there was a significant, medium relationship between the audience's first impression types and the motivation for ongoing performance elaboration. The data analysis revealed that the observed response data could best be described by a nonparametric random-coefficient latent class model based on 6 items (see Table 1). The final model is comprised of three audience-related classes of appropriateness judgments for musician's stage entrance behavior (level-one).

*Table 1.* The final 6-item questionnaire for the typology construction of the audience's first impression of musicians' stage entrance behavior.

<i>No.</i>	<i>Item</i>
	I found it appropriate...
1	... how often this performer nodded at the audience
2	... how often this performer changed his/her gaze
3	... how often this performer touched her-/himself
4	... which stance width the performer used for stage entrance
5	... which step size the performer used for stage entrance
6	The musician's stage entrance behavior is resolute

The response probabilities of the six items were high for the first class, which contained 45.17% of all participants. This class described the audience's impression of appropriateness, whereas the second class (44.10%) summarized all impressions of acceptance. The third class (10.73%) revealed all judgments based on perceived impressions of inappropriate stage entrances. Further on, all class sizes depended on two video groups representing the musicians' stage entrances (level-two). The video groups differed from each other in their (level-one) class size proportions. In other words, stage entrances associated with Video Group 1 would be expected to be more appropriate (48.01%) in contrast to those associated with Video Group 2 (32.25%), which would primarily be judged as more acceptable (53.33%). Therefore, the first mixture component (Video Group 1) could be classified as musicians with successfully executed impression management in contrast to the musicians in the Video Group 2. Based on this classification, we observed a medium to strong relation between stage entrance judgment and a rater's motivation for the continuation of performance elaboration ( $X^2(2)=36.64$ ,  $p<0.01$ ,  $V=0.46$ ).

## DISCUSSION

Against the background of music performance evaluation research, the results are in line with findings from previous studies that first impression types have an influence on music performance evaluation (McPherson and Schubert 2004). On the basis of the item selection for evaluative classification of the first impression of stage entrance behavior, a medium to strong effect size for the influence of first impression types on the motivation for performance elaboration continuation ( $V=0.46$ ) was found. This was a quantification of an effect that appeared as an evaluation criterion for overall impression judg-

ment (Stanley *et al.* 2002). Whereas first impression formation has been seen as an influencing factor at the beginning of a persuasive process (Ybarra 2001), up until now it has been discussed in music evaluation research only as a peripheral cue during the preparatory phase of a performance (McPherson and Schubert 2004). However, this study proposes a more psychologically oriented model of performance evaluation by assuming a general persuasion process (Petty and Cacioppo 1986). Furthermore, persuasion is based on *music performance elaboration* resulting in an *involvement through optimal participation* as the main purpose of experiencing music performance. It remains unanswered how sustainable the positively motivational effect of the appropriate stage entrance behavior type is for the whole performance elaboration. Additionally, the question of cross-validity between latent classes, as well as latent groups, and the winner of the international violin competition remained unanswered because the winner of the competition was not part of the video corpus. Future research in music performance evaluation should focus on music performance as a psychological function of impression formation perception.

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I am indebted to Stephan Hintze (Hanover University of Music, Drama, and Media) for his expert comments on selected video sequences, to the anonymous reviewers for their helpful comments on a previous version of the manuscript, and to Maria Lehmann (Würzburg) for the final editing. For an extended version of this manuscript with more methodological detail and additional data analyses, see Platz and Kopiez (2013).

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# Workshops



# The actor becomes

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In Western theatrical tradition, the actor prepares to become a character onstage. The process is an internalization of the personality profile of the character wherein the actor becomes those qualities in order to perform a character, tell a story, and enhance audience belief. Personality psychology suggests a potential for the actor to be vulnerable to diffuse states of self. Does becoming a character onstage change the personality of the actor offstage? How might that change impact his or her personality? This theoretical paper analyzes theories of Western theatrical culture and psychology to suggest vulnerability.

*Keywords:* theatre; actors; performing; psychology; personality

Psychology has limited studies with artist populations as the subjects of research. Research on actors has looked at cognitive, personality, and biological traits; contextualized studies examined the socio-cultural dynamics operating within creative ensembles, between actors, and their audience (Thomson and Godin 2011). Social psychology has looked at the social influences that enhance the process of acting, which include clear direction, trust, freedom, respect, challenge, collaboration, unity with the audience, and spontaneity (Nemiro 1997). Developmental psychology has discovered that actors have an early affinity for fictional worlds, the alternative world of others' minds, and the ability to imitate and memorize, all of which lay the groundwork for performance (Goldstein and Winner 2009).

Personality psychology asks: *how does an actor become a character? How does personality influence the art of acting?* Fundamental to acting is not only *playing* a character, but *becoming* one. It will be considered whether playing a character in a theatrical format can change an actor's personality and the implications for an ensemble.

## MAIN CONTRIBUTION

### Acting as a creative activity

Creativity is a relatively new term used to describe human endeavors. Many cultures around the world perceive artists to be messengers of a higher source, while many theorists distinguish artists as individuals who apply the imagination within a specified field. A Western-dominated psychology of creativity distinguishes art from creativity by referring to it as a domain. The domain of performance was born out of cultural, social, and human complexities; it was meant to be a form of expressive communication and a means for the realization of human kind (Barba and Savarese 1991). Actors train to translate the energy and potential of mind, body, emotions, voice, and text to, then, be a multidimensional transmitter of stories to an audience. The actor transports themes, morals, and story lines through the performance of a character.

Konstantin Stanislavsky's training at the Moscow Arts Theatre emphasized a system of acting utilizing the imaginative structures of "what if" and "affective memory" in the actor (Banham 1995). Stanislavsky (1950), within his system of acting, encouraged the actor to acquire a complete mastery of "the art of self-possession," that is, an ability to forget all about oneself, and "yield his place to the character on stage" (p. 117). His system was later adapted into a more psychologically and emotionally based "Method" approach, which characterized the trainings of the Actor's Studio in New York. Both approaches referred to the portrayal of truth in the actor-subject. Stanislavsky (1968) explained, "it is only when his sense of truth is thoroughly developed that he will reach the point when every pose, every gesture will have an inner justification, which is to say they express the state of the person he is portraying" (p. 185). Training leads the actor to truthfully represent the state of his character, a process requiring him to become one with it.

### Acting and becoming

The art of acting is a developmental activity. The actor trains, rehearses, and performs characters to live audiences. The enterprise of acting stimulates and engages the creative imagination of the actor and the spectator. Any study that investigates the performing arts must appreciate that performing artists are always embedded within a contextual setting, momentary interactions with others, and draws from personal, past, and relational experiences, and imaginings with self, other, and/or the environment (Thomson and Godin 2011).

For the actor trained in method acting, the qualities of a character in a story are imagined and adapted from within the actor-resource. An actor is trained to take a character from a text and bring it to life. He defines the basic qualities of a character including age, marital status, residence, the era he lives in, and social concerns of that time. The actor will, then, infer more complex details of a character such as his feelings, opinions, behaviors, and objectives. The actor will create a personality profile for the character that he plays, which will serve as a trajectory of information in order to become a character.

The actor must be open in order to become. "Open people tend to be more imaginative and curious, and so it is not surprising that open people are more creative. This is not just a theoretical connection, but an empirical one" (Feist 2010, p. 121). Actors have a natural propensity for openness, stepping into the world of stories, and becoming another. A study comparing the childhood of actors and lawyers found that actors tended to report reading and enjoying fiction more, as well as engaging in more pretend and role play than lawyers (Goldstein and Winner 2009). Actors also endorse higher fantasy proneness, which is significantly associated with the disorienting effect of dissociation (Thomson and Jacque 2011).

Actors have "the ability to engage in heightened states of absorption that cause diffuse self-states and intense sensory emotional imaginative experiences" (Thomson and Godin 2011). Diffusion occurs as a result of embodying the character's personality profile, while boundaries are created in order to maintain distinction.

### **Personality and boundary blurring**

Personality is a dynamic organization within the individual of those psychophysical systems that determine her characteristic behavior and thought (Costa and McCrae 1994). Personality is also the unique and relatively enduring set of behaviors, feelings, thoughts, and motives that characterize an individual (Feist 2010). It is those behaviors, feelings, thoughts, and motives that are presented by an actor when she becomes a character. Similarly, the actor's personality traits determine the quality by which she approaches her craft.

The five-factor model provides an analysis of trait concepts. It indicates five central human concerns: (1) Surgency (Extraversion), (2) Agreeableness (Warmth), (3) Conscientiousness (Will), (4) Emotional Stability (Neuroticism), and (5) Culture (Intellectance, Openness to Experience). The five factors cover a vast conceptual space that encompasses the central human con-

cern concerns of power (Surgency), love (Agreeableness), work (Conscientiousness), affect (Emotional Stability), and intellect (Culture; McAdams 1992).

Research has indicated that artists believe imaginative assertiveness, cultural competence, intrinsic motivation, and having many ideas enhanced creativity (Gluck *et al.* 2002). Method actor training may, then, be associated with individual or combination factors in (1) Surgency (Extraversion), (5) Culture (Intellectance, Openness to Experience), as well as (3) Conscientiousness (Will). Professional actors demonstrate higher levels of extroversion, openness to experience, agreeableness, and empathy as compared to a general population sample (Thomson and Jacque 2011). Actor traits may, then, be correlated with factors (1) Surgency (Extraversion), (2) Agreeableness (Warmth), and (5) Culture (Intellectance, Openness to Experience). An actor's ability to submerge into the emotional experiences of becoming a character marks the emotional regulation indicated in factor (4) Emotional Stability.

Boundaries are developed in actor training to establish emotional, mental, physical, and psychic distinctions between self and character. It is a wall between the vast diffusion of self-states and imaginative experiences, so there is little-to-no distortion. Boundary blurring may occur as result of contrasting traits.

All traits are a spectrum with its contrasts, and actors maintain both their own personality and their characters. For example, factor (4) has contrast traits which include nervousness, moodiness, and temperamentality (Golberg 1993). Actors who fluctuate in emotional stability within their own personality due to nervousness, moodiness, and temper, yet are open, may be more vulnerable to boundary blurring. More psychologically and emotionally based "Method" acting styles may lead to potential increase of distress if actors are not able to regulate shifts between their self and their characters, hence, the process of blurring boundaries between role/self.

## IMPLICATIONS

How, then, do individuals who work with actors onstage and offstage support the potential for boundary blurring of role/self? Actors, like most people, are composed of the relationships between traits, the environmental and natural factors that communicate with traits, and the individual self as a living system with other selves. Congruently, the characters they portray have their own personality profiles. When working with an ensemble, these relationships are

multiplied thereby making diversity of experiences imperative in one's relationship with actors.

Building sensitivity within an ensemble is paramount. It is important to create rehearsals which honor the transmission of experiences in a safe way, which can include meditation, warm-ups, and vocal and other body exercises which emphasize entering and releasing of a character. Alternatively, facilitating conversations between actors where they communicate role/self-boundary blurring without bias on the part of others to qualify and/or define their experiences as negative or positive.

A significant consideration in the occurrence of boundary blurring of role/self is to engage one's sense of reality. It is important to ask oneself: what factors in this role constitute change in self? How do I perceive change in self? How am I able and/or unable to deal with these changes? These observations should be documented.

If boundary blurring of role/self has occurred to the extent that the individual and/or the ensemble are in threat, other forms of immediate interventions may be needed, based on the resources of the artist community. They may include a mental health clinician, a psychiatrist, a spiritual leader, a body healer, and/or other specialists who may deal with the dissociation of role/self. Due to vulnerability inherent in the art form, caution should be considered, safety is recommended, and support networks should be made available in times of dissociation.

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# The craft of collaboration: Collecting the features

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In a paper-performance, van Rosmalen will discuss his exploratory, theoretical, and artistic work on bringing professionals from arts, business, science, and non-profit organizations together in what he calls “Connecting Conversations.” With an artistic background as a free improvising cellist and director of small scale music theater performances, his fascination for interdisciplinary collaboration was challenged through growing worries around the rather isolated position of the arts in society. Why are the arts not in the center of the knowledge economy and new ideas about entrepreneurship and innovation? Why are the arts rather locked up in highly specialized disciplines, performing in specific venues for fixed audiences? Van Rosmalen develops a collection of forms, exercises, attitudes, and strategies to catalyze collaboration and innovation in the arts and between arts and other disciplines. Re-telling the myth of the muses, nine interdisciplinary collaborative sisters in ancient Greece, is the leading metaphor. Four muse-inspired features frame the collection: (1) fulfilling and feeding the need for *narrative*, (2) an expressive approach to reflection: thinking by *making*, (3) performing the work instead of regular working: *playing*, (4) collective action from a group with articulated individual voices: *sharing*. In line with these findings, the paper will be partly spoken and partly performed in collaboration with visual artist Barbara Philipp.

*Keywords:* craft; collaboration; collecting; features; muses

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Friday  
30 August 2013



Keynote paper



# Follow my leader? String quartet synchronization

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Timing variations in individual musical performance include both intentional expressive and unintentional error components. Such timing fluctuations contribute to the liveliness of group musical performance but need to be kept under control to create a sense of ensemble. The nature of this control is the focus of this paper. We first report an experiment in which we manipulated visual cues given by violin 1 to the other players in a quartet. We then review a new model of synchronization, and finally we describe a new listening test to determine whether people can distinguish adjustments being used to maintain ensemble synchrony. Such techniques will contribute to understanding of the nature of synchronization in music ensembles.

*Keywords:* timing; synchronization; string quartet; feedback correction; listening test

Many areas of human endeavor involve synchronization of individual actions to produce coherent ensemble performance in the group. Examples include walking, rowing, and music performance. Individuals tend to vary in their timing, which may be intentional (as part of performance strategy) or unintentional (due to inherent variability of biological timing systems), yet, when working in a group, they keep together. How do they do this? One possible method is to adjust one's own performance on the basis of sensory information about timing discrepancies with others. Vision, hearing, and, in some cases, touch may allow detection of asynchronies so that corrective action can be taken to get more in step, pull more together on the oars, or place different players' note onsets in better temporal alignment.

In musical performance, players do not rigidly follow the scored timing, but shape note timings for the purposes of musical interpretation. This is a personal matter, but rehearsal may be expected to bring different interpretations together as players learn to predict each other's timing. Yet musical liveliness is a matter of interpretation varying from one performance to another. Thus the Guarneri Quartet revealed that in their performances they did not seek to anticipate all expressive timing variations, but instead kept themselves ready to respond to variations in timing (and dynamics) as required (Blum 1987). Responding to asynchronies between each other's playing would be one method to maintain ensemble.

This paper is presented in conjunction with the first author's keynote address at ISPS 2013. We review feedback correction in the context of music performance. Using the string quartet as a model, we first describe a study of sensory contributions. We then provide a theoretical treatment of the adjustment process, finishing with a current study in which we are using listening tests to examine the perceptibility of timing variations in music performance.

## MAIN CONTRIBUTION

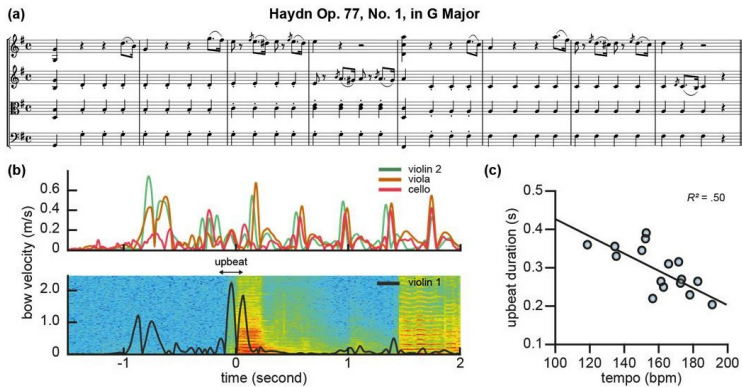
### **Sensory contributions**

The sense most obviously involved in musical performance is hearing, but vision is also important. But which sound? What visual stimulus? In a music group there are multiple possible cues; many different notes and different movements, all from different players, which might be used. One way to explore the relative importance of different possible synchronization cues is to change or remove selected cues in order to determine consequent effects on performance.

In an orchestra the conductor provides a clear visual focus enabling, for example, the simultaneous entry of whole sections of the orchestra at the start of a piece, as well as providing support for sections faced with tricky entries. Making a successful entry together is also an issue in performance by small groups, such as a string quartet, and it is common practice for the leader to take the role of the conductor by making a clear signal—a silent upbeat—prior to the start. Thus, a shared glance, a postural shift, or a lift of the instrument might all serve this role. But how might the researcher determine which are the critical aspects of such movements?

We asked a professional string quartet to play an excerpt from the opening of the first movement of Haydn's Op. 77 No. 1 (see Figure 1a) while the bow motions of the players were recorded using specialized motion capture equipment. Figure 1c summarizes 16 performances and shows that violin 1's

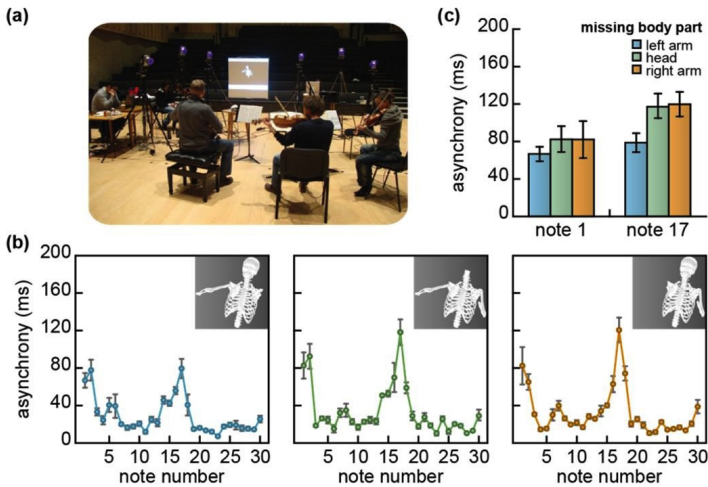




*Figure 1.* Silent upbeat bow velocity of violin 1 correlates with subsequent musical tempo of the quartet: (a) the excerpt: Haydn Op. 77 No. 1; (b) velocity of bow movement time-locked to the onset of the first note in the spectrogram played by violin 1; (c) scatter plot showing the negative correlation between the upbeat movement duration and the tempo of the music. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

silent upbeat duration before measure 1 was negatively correlated with tempo of the following excerpt, suggesting it might have been used as a visual cue for the rest of the quartet. However, there are a number of possible visual cues associated with the upbeat movement, including not only movement of the bow arm, but also movement of the head and the violin.

In order to provide an indication as to which of these is more important, we ran another study in which the players attempted to synchronize with a video (without sound) in which their leader's playing movements (without violin) were shown in skeletal form with either left arm, right arm, or head removed (see Figures 2a and 2b). The note-by-note asynchrony variability between the three players reveals increases in variability at the start, mid-point, and end of the excerpt. Figure 2c summarizes how the average absolute asynchrony between the three players over the 5 repetitions is greater when the right arm or head is missing, consistent with their roles as visual cues for synchronization at the unison entry points. In further research it will be important to extend this analysis of entry cues to more realistic situations where, for instance, sound cues are also available.



*Figure 2.* (a) Recording setup. The participants faced a projector screen where the avatar was displayed and the cameras tracked the bow and instrument movements; (b, c) the averaged absolute asynchrony between violin 2, viola, and cello at measure 1 and measure 5 unison entries depends on the availability of visual cues of the leader's movements at entry. (See full color version at [www.performance-science.org](http://www.performance-science.org).)

## Feedback adjustment

The previous section focused on visual cues for synchronization at entry points. During the intervening periods of relatively continuous playing by all members of the quartet, it seems likely that auditory cues to synchronization would be more important. A linear feedback model describing the maintenance of synchrony by a quartet was proposed by Wing *et al.* (2013). Each player was assumed to adjust the timing of her next note in proportion to the asynchrony between her current note and the other players' current notes (see Figure 3). In such a model there are 12 proportional correction factors (gains) between all pairs of players.

Consider the musical excerpt from the fourth movement of Haydn's Op. 74 No. 1 shown in Figure 4a. Each player has a long series of eighth notes to be played simultaneously with the others. The homophony affords an interesting opportunity to explore feedback correction effects on synchrony. Simulations of a quartet playing this piece were run using the feedback model for

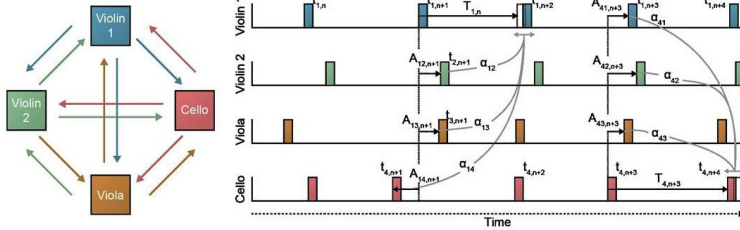


Figure 3. Asynchrony feedback correction model of quartet synchronization. The next event time,  $T_n$ , is derived from the current asynchrony against each other player,  $A_n$ , and the correction gain ( $\alpha$ ) shown for violin 1 and cello. Random timing noise ( $\sigma$ ) is assumed to affect the intervals,  $T_n$ .

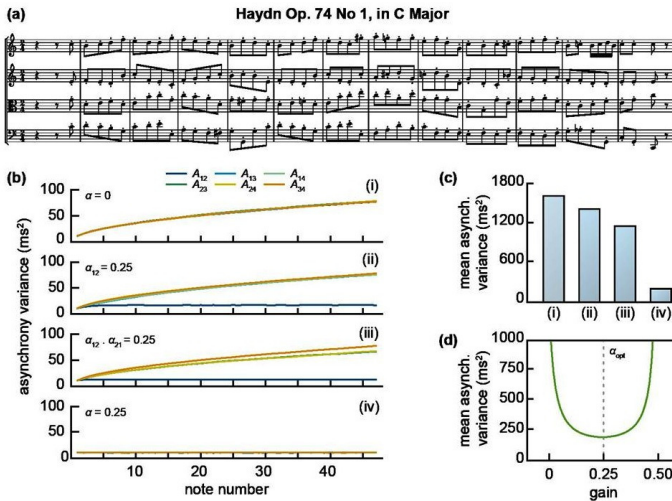


Figure 4. (a) Excerpt from Haydn Op. 74 No. 1; (b, c) asynchrony variances and their means for the 6 pair-wise combinations in a simulated quartet; (d) effects of gain on mean asynchrony variance. (See full color versions at [www.performancescience.org](http://www.performancescience.org).)

48 notes, repeated and averaged over 10000 runs. The simulation included timing variability ( $\sigma=10\text{ms}$ ) in the intervals  $T_n$ . Four conditions, where the correction gains were varied were run to study the effects on asynchrony variances (Figure 4b). When all gains were set to zero, all pairwise asynchrony

variances asymptotically increased with note number (i). When a single gain was set to 0.25 (e.g.  $\alpha_{12}$ ) but the rest remained zero, the asynchrony variance was stable only for this pair (ii). With the reciprocal gain ( $\alpha_{21}$ ) set to 0.25, this yielded a further decrease of asynchrony variance, and the asynchrony for those paired with player 1 or 2 was also slightly reduced (iii). When all gains were set to 0.25, stability was observed across the quartet (iv). Figure 4c summarizes the average asynchrony variance for all the conditions. The gain of 0.25 was used for the simulation since the average asynchrony variance is at a minimum when the gain is 0.25 in this model (Figure 4d).

In summary, the simulation showed effects on synchronization of the correction gains between players in a quartet. In two case studies of professional quartets playing the excerpt in Figure 4a we have observed gain estimates approximating the value of 0.25, which is optimal in the sense of minimizing asynchrony variance (Wing *et al.* 2013). Elsewhere in this volume we ask if players are aware of the feedback corrections they apply (Timmers *et al.* 2013). In the next section we propose a new approach to determine whether listeners can hear the corrections.

### Listening tests

Individual variability in inter-note intervals (timing noise) results in asynchrony variance. Correction restores ensemble, reducing asynchrony variance. If the correction gains of a quartet vary, what difference does it make to the listener? Figure 5a shows changes in the asynchrony variance of a virtual quartet with two levels of timing noise and across correction gains, which were set to be equal over all player pairs. Figure 5b shows that the level of the asynchrony variance can be equivalent for a low-correction, lower timing noise quartet and for an optimally adaptive, higher timing noise quartet (e.g.  $\alpha=0.03$ ,  $\sigma=5\text{ms}$  versus  $\alpha=0.25$ ,  $\sigma=10\text{ms}$ ). In the current research we are asking listeners to discriminate between the playing of two musical excerpts in which (1) gains are equal but the timing noise varies and (2) the gains vary but the timing noise levels are matched. This allows us to investigate the listener's sensitivity to the amount and form of variance in note asynchrony.

Two pilot experiments were conducted, both using the same task: three participants listened to two instances of the virtual quartet playing the 48-note excerpt shown in Figure 4a, and then reported which had the larger asynchrony (i.e. which was the target quartet). In the first experiment gain was fixed at 0.25, and the timing noise level of the target,  $\epsilon$ , was varied by a staircase algorithm. Participants' timing noise detection thresholds were measured and the asynchrony variance at threshold,  $\sigma^2[\epsilon=\text{thresh}, \alpha=0.25]$ ,

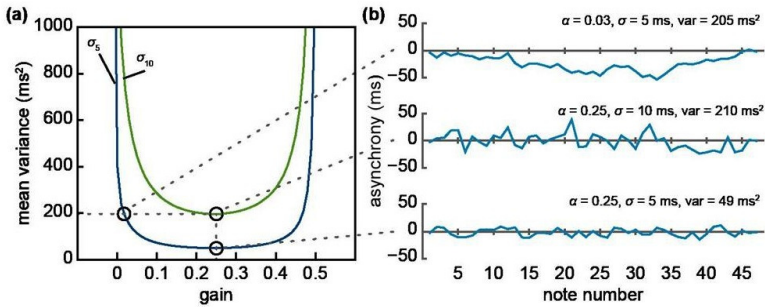


Figure 5. (a) Effects of correction gain and timing noise on asynchrony variance; (b) single trial examples of asynchrony time series when gain is optimal but timing noise is higher (middle) and when the timing noise is smaller but lower than optimal gain (top); the bottom trace shows optimal gain with lower noise. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

was computed using curves such as those in Figure 5a. In a second experiment, the timing noise in the target interval was fixed at half the participant's detection threshold and the gain was varied. Asynchrony variance at threshold in the second experiment,  $\sigma^2 [\varepsilon=\text{threshold}/2, \alpha<0.25]$ , was found to be significantly lower than  $\sigma^2 [\varepsilon=\text{threshold}, \alpha=0.25]$  indicating that people do not discriminate asynchrony using variance amplitude alone: the structure of the asynchrony caused by the lower gain was influencing evaluation of quartet performance.

## CONCLUSIONS

In this paper we reviewed synchronization in string quartets, describing a new empirical study of the use of visual cues in timing of entry points, presenting simulation results for a feedback correction model of timing, and reporting on a new listening test to determine effects of timing variability and feedback correction on the listener's perception of ensemble. The development of these techniques is helping us understand the nature of ensemble synchronizations.

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## Poster session





# Effects of musical experience on synchrony judgment accuracy: Taking into consideration its relation to cochlear delay

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Musicians are sensitive to the synchrony of multiple tone onsets. However, even when several sounds have a simultaneous onset, their temporal relationship might not be preserved at the cochlear level because of “cochlear delays” in perception. The purpose of this study was to investigate whether cochlear delay significantly affects synchrony judgment accuracy and whether this phenomenon is dependent on musical experience. We conducted a psychoacoustic experiment to measure synchrony judgment accuracy in professional pianists, amateur pianists, amateur instrumental musicians (non-pianists), and non-musically trained people. Our experimental stimuli comprised three types of chirps, which allowed us to control for the amount of cochlear delay. We found that, regardless of the type of instrument, musicians had more accurate synchrony judgment. This may be due to the effect of careful listening, which is required as part of musical training. However, asymmetric aspects of temporal processing in the human auditory system were unaffected by musical experience.

*Keywords:* musical experience; cochlear delay; auditory periphery; synchrony judgment; pianists

A change in onset asynchrony of musical notes of just a few milliseconds can result in a significant difference in musical expression. Thus, it is important for musicians to be able to carefully discern the synchrony of tone onset. However, even when the components of discrete sounds physically begin at exactly the same time, their temporal relation might not be preserved at the

cochlear level because of “cochlear delay” (e.g. Békésy and Wever 1960). The stiffness of the cochlear basilar membrane gradually decreases from the basal side to the apical side (e.g. de Boer 1980). As a result, the higher components of an input wave excite the basal side, while the lower components excite the apical side. The vibration in the region of the cochlear membrane associated with the lowest frequency is thus delayed by about 10 ms relative to the vibration in the region associated with the highest-frequency (Uppenkamp *et al.* 2001).

In our previous research, we measured synchrony judgment accuracy using three types of chirps that elicit different amounts of cochlear delay: a compensated delay chirp, enhanced delay chirp, and intrinsic delay chirp (Aiba *et al.* 2008). We found that judgment accuracy was higher for the enhanced delay chirp, which evoked enhanced cochlear delay, than for the compensated delay chirp, which cancelled out the cochlear delay. This finding indicated that the human auditory system may have an asymmetric aspect on temporal information processing. We also found that the judgment accuracy of professional musicians was significantly higher than that of non-musicians (Aiba *et al.* 2011). In this case, most of the musicians were pianists, who are able to simultaneously control the timing of many different tones in order to play their instrument. Therefore, we hypothesized that pianists in particular have a greater ability to judge synchrony than other types of musicians.

The purposes of this study were (1) to investigate whether the amount of cochlear delay has a significant effect on synchrony judgment accuracy and (2) to assess whether musical experience has an effect on synchrony judgment accuracy.

We conducted a psychoacoustic experiment to measure synchrony judgment accuracy in professional musicians, amateur musicians, and non-musicians. We used three different types of chirps to manipulate levels of cochlear delay.

## METHOD

### Participants

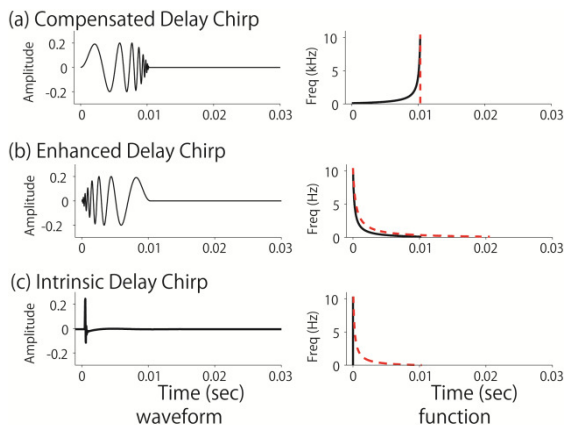
Eight professional pianists (25.5±4.7 years of training), eight amateur pianists (17.4±7.2 years of training), five amateur musicians (non-pianists, 6.6±4.5 years of training) and seven non-musically trained people (0.4±0.7 years of training) with normal hearing and no history of hearing problems participated in this study. All of the professional pianists had received at least one prize in a domestic or foreign competition.

## Materials

We employed three types of sounds meant to induce different amounts of cochlear delay: (1) compensated delay chirp, (2) enhanced delay chirp, and (3) intrinsic delay chirp (see Figure 1). In the compensated delay chirp, the frequency was instantaneously increased to cancel out the cochlear delay. We used a frequency pattern originally calculated by Dau *et al.* (2000), wherein the frequency increases as a function of time. In the enhanced delay chirp, the temporal function was opposite to that of the compensated delay chirp. In these two chirps, the frequency either increased from 0.1 to 10.4 kHz or decreased from 10.4 to 0.1 kHz. The stimuli had tapered transients at both ends with a raised cosine wave of 0.1 kHz. We also used an intrinsic delay chirp (pulse), which had no delay imposed on any frequency component. The intrinsic delay chirp was passed through a low-pass filter with a cut-off frequency of 10.4 kHz.

## Procedure

We used a two-interval, two-alternative forced choice (2I2AFC) procedure wherein participants were asked to detect synchronous pairs of stimuli. Two pairs of sounds were presented to the participant in each trial: one interval



*Figure 1.* The panels on the left show the waveforms of each chirp, and the panels on the right show the corresponding function of cochlear delay. The solid lines on the right show the frequency pattern as a function of time for each delay condition. The broken line shows the time required for all frequencies to reach maximum amplitude at the basilar membrane. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

contained a synchronous pair and the other interval contained an asynchronous pair. The asynchronous pairs had seven types of temporal asynchrony (0.2, 0.4, 1.0, 2.3, 5.1, 11.4, or 25.6 ms), spaced in a rough logarithmic pattern. The order of presentation of the synchronous and asynchronous pairs was randomized across trials. The two pairs were separated by a 500–700 ms inter-stimulus interval. The type of sound was consistent within each trial.

There were three sound-type conditions: (1) compensated delay, (2) enhanced delay, and (3) intrinsic delay. The total number of stimulus-type combinations was 72 (three sound-type conditions, twelve variations of temporal asynchrony, and two patterns of synchronous pair order). The participants repeated each combination 10 times, which brought the total number of trials to 720. All factors (sound type, temporal asynchrony, and presentation order) were randomized and executed as within-participant factors.

The participants were informed that each trial would have two intervals containing two sounds, and that the two sounds would be synchronous in one interval but asynchronous in the other interval. They were asked to choose the interval containing the synchronous pair. Participants had as many training trials as they felt they needed, and received feedback after each judgment. They were able to take breaks at any time.

Thresholds were estimated from the seven points on the psychometric function by fitting a sigmoid function on the data for each participant and computing the temporal asynchrony value corresponding to 75% correct responses.

## RESULTS

The average estimated thresholds for each level of musical experience and each sound type are shown in Figure 2. A two-way factorial fixed-effect ANOVA was performed with music experience and sound type as the main factors. Music experience ( $F_{3,80}=7.14$ ,  $p<0.01$ ) and sound type ( $F_{2,80}=21.7$ ,  $p<0.01$ ) were both significant as main factors.

The accuracy of synchrony judgment was highest among the group of professional pianists. We found no interaction between level of music experience and sound type. We used the Tukey-Kramer HSD test to investigate detailed differences in sound type and music experience, respectively. We found a significant difference between professional pianists and amateur pianists and non-musically trained individuals in terms of judgment accuracy. Additionally, we found no significant differences in judgment accuracy between amateur musicians (non-pianists) and amateur pianists. There were significant differences in judgment accuracy among all three sound types.

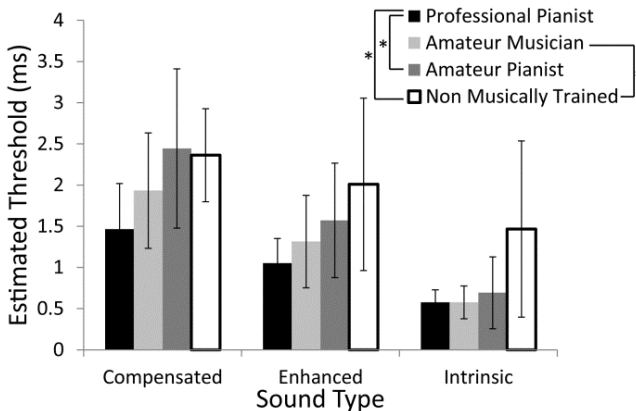


Figure 1. The average estimated thresholds and SDs in ms for each level of music experience and sound type. The arms at the side of the graph legend indicate the participant groups that showed significant differences ( $*p < 0.05$ ).

## DISCUSSION

We found the judgment accuracy of professional pianists and non-musically trained individuals to be the highest and the lowest of the participant groups, respectively. However, we found no significant differences between amateur musicians (non-pianists) and amateur pianists in terms of judgment accuracy. Our results indicate that, regardless of the type of instrument a musician plays, careful attention regarding the synchrony of tone onset is important for musical performance. It is possible that, as musicians work to improve their instrumental performance, the accuracy of their synchrony judgment increases.

With regard to sound type, the synchrony judgment accuracy of individuals with all types of music experience decreased in the following order: compensated delay, enhanced delay, and intrinsic delay condition. This suggests that asymmetric aspects of temporal processing in the human auditory system do not change with music experience. In all types of music experience, the auditory system appeared less sensitive to this delay following the intrinsic, natural direction; that is, cochlear delays. There is the possibility that the improvement of synchrony judgment accuracy of musicians occurred in the upper levels of cochlear range.

In our future research, we plan to compare the onset judgment of professional pianists, who work more with sounds that have a sudden attack, with that of violinists, who work with sounds that often have a gradual onset.

## Acknowledgments

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# “The more the merrier”? Understanding the wellbeing of professional musicians in collaborative and solo work settings

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Recognizing the need to include professional musicians in mainstream wellbeing profiling, and to move beyond a focus on the potentially debilitating factors of the music profession, this study aimed to understand how professional musicians experience wellbeing in the light of positive psychology. In particular, acknowledging the role of inter-personal relationships in wellbeing, the goal was to explore wellbeing profiles in relation to collaborative and solo-oriented working contexts. Participants included six professional musicians, three belonging to fixed-group work settings (orchestra, choir, and chamber ensemble) and three engaged in a solo-oriented musical route (soloist, composer, and conductor). Two in-depth interviews were conducted with each participant, separated by a two-week period of individual record-keeping using the Day Reconstruction Method. Results revealed identity as an overarching sustainer of wellbeing. Relationships and “musical moments” emerged as key elements in the construction of wellbeing, while the transition to the professional phase was often challenging. Group identity appeared as a vehicle for wellbeing among the collaborative musicians, although this type of activity also placed demands on social skills. Solo musicians highlighted freedom of expression as a source of purpose although a lack of feedback represented a challenge. Implications are discussed in relation to the role of holistic training in educational settings.

*Keywords:* wellbeing; positive psychology; professional musicians; flourishing; qualitative methodology

Psychological research has for many years tended to focus on alleviating symptoms. Recent studies have re-defined how being psychologically well means more than just the absence of disorder (Seligman 2008). At the fore-

front of *Positive Psychology* has been the attempt to study what we can do to help individuals not just get by, but to flourish and live to their fullest potential. Shifting from an initial focus on happiness and positive emotions, a multidimensional construct of wellbeing is now emerging, bringing to light the importance of components such as meaning, purpose, engagement, relationships, and mastery. Professional musicians, however, are yet to be included in mainstream wellbeing profiling, and there is a need to move beyond a focus on the potentially debilitating factors of the music profession.

Making music has been identified as a wellbeing enhancer in many contexts: everyday use (e.g. Västfjäll *et al.* 2012), community (e.g. Perkins and Williamon *in press*), clinical settings (e.g. Pothoulaki *et al.* 2012), and education (e.g. Boyce-Tillman 2000). Music has also been clearly associated with flow experiences—moments of optimal state through energized focus (Csikszentmihalyi 1990), both in professional and education settings. However, continuous music activity at a professional level has been considered a threat to holistic wellbeing through different mediators: e.g. physical injuries (Fishbein *et al.* 1998), stress and mental fatigue (e.g. Steptoe 1989), boredom (e.g. Parasuraman and Yasmin 2000), and Music Performance Anxiety (e.g. Kenny and Osborne 2006). Following the need to address musicians' psychological experience of wellbeing through a positive lens and honoring the construct's holistic nature, the aim of this study is to understand what it means to live "psychologically well" as a professional musician, having as a framework the PERMA model of Flourishing (Seligman 2011). In the context of this model, wellbeing is defined as a multidimensional construct including Positive emotions, Engagement, Relationships, Meaning, and Accomplishment. Specifically, acknowledging the high prominence for overall wellbeing that positive relationships have proven to represent (Reis and Gable 2003), this study explores wellbeing profiles in relation to collaborative and solo-oriented working contexts in music.

## METHOD

### Participants

Participants included six professional musicians (age=32-52 years) from four countries, working either in fixed-group settings (orchestra, chorus, or chamber group) or with an individually-oriented professional context (soloist, composer, or conductor). Acknowledging the fluid nature of his activity, the conductor was placed in the solo-oriented group for having an essentially individual preparation routine and not belonging to a fixed group of work. Three participants were male and three were female. Years of professional



experience ranged from three to thirty-two. All participants were working full-time as musicians, with a highly acclaimed level of performance in their field of musical expertise.

## **Materials**

Data were collected through in-depth interviews and the Day Reconstruction Method (DRM) (Kahneman *et al.* 2004). In the form of a structured self-administered questionnaire, the DRM is designed to reduce recall biases and assess how people spend their time and how they experience the various activities and settings of their lives.

## **Procedure**

Two interviews were conducted with each participant: a non-structured interview at the beginning of the study and a semi-structured interview at the end, built upon the five components of the PERMA model of Wellbeing. In-between the interviews, the participants engaged in daily record keeping through the DRM over a period of two weeks. The project was approved by the CUK Research Ethics Committee and subject to informed consent from all participants. Data were fully transcribed and analyzed through Interpretative Phenomenological Analysis.

## **RESULTS**

All musicians reported high overall wellbeing and satisfaction linked with their professional musical activity. Emergent themes highlighted general as well as activity-specific enhancers and challenges for wellbeing.

### **Identity**

Identity emerged as a central, overarching sustainer of wellbeing. Knowing oneself well, learning to accept limits, and filtering negative inputs were consistently regarded as fundamental. A tension between music as being and music as doing was recurrent in all accounts. Making music was for all participants an intrinsic need, a definer of the self, and a strong source of meaning: “there is just not a way I could work on something else because this is who I am in my essence” (composer). At the same time, the structure of music as a professional business activity brought specific challenges. Collaborative-setting musicians placed an emphasis on monotony from routine and repetition: “I miss music in the midst of the mechanic production of music. Sometimes, at rehearsal break, I run hysterically to my dressing room to just do

music” (choral musician). Increasing the variety of repertoire and participating in solo moments or smaller groups emerged as significant strategies for enhanced engagement. Solo-setting participants stressed self-expression, freedom, and autonomy as vehicles for wellbeing. A challenge emphasized recurrently concerned the politics, power roles, and conflicts of interests in the music business, which were seen as responsible for the suppression of the centrality of music and truth. A tension was felt between being artistically true to oneself and, as the soloist put forward, “being an emotional machine, just pleasing powers by playing the game.” In relation to this, there emerged the recurrent view that being successful in the music world is not dependent primarily on musical quality. Concurrently, a structuring theme for the global accounts of wellbeing in this group was the need to create a self-concept and belief of self-worth that is independent from musical characteristics and achievements.

### **Transition to professional phase**

The transition to being a professional emerged as the most challenging stage in terms of wellbeing. Collaborative-setting musicians highlighted integration and group acculturation as major challenges in the first years. The sense of having to prove one’s worth to the group and the pressure of competition emerged as dominant. For solo-setting musicians, the need for self-regulation and the lack of available feedback appeared as the major demands. For both groups, this transition brought more extreme emotional responses. The establishing of a solid professional career at the highest level after this period was mentioned as a strong enabler of perceived accomplishment.

### **Musical moments**

All musicians referred to “musical moments” as a fundamental source of positive emotions and engagement. Concerts as “moments of transcendence” or “peak experiences” were mentioned by all participants and in all accounts the shared nature of the moment was a central feature. The more experienced musicians reported a decrease in the quantity of peak moments with time, but an increase in intensity.

### **Relationships**

Positive relationships in family, social, and work-related contexts appeared as central for wellbeing. For the collaborative group, emphasis was placed on group identity as a source of meaning and on engagement through learning

with colleagues. Convergence in musical ideas and symbolic meaning creating “oneness” in performance recurred as both a highly significant vehicle for wellbeing and a major challenge. All collaborative musicians highlighted the need to develop specific social skills to maximize group wellbeing: flexibility, tolerance, and communication. For solo-oriented musicians, relationships appeared hard to establish and maintain, particularly outside of the music world. Self-sufficiency and the lack of a regulation entity made discipline and self-regulatory practice routines an additional challenge. Consistently highlighted by the composer was the need to force oneself to not be isolated by music and “be connected” through normal routines: “I would tell any beginning composer: make sure you wash the dishes, help change the baby’s diapers and make it to family reunions.”

## DISCUSSION

The experience of musicians’ wellbeing seems to be, overall, a positive one. In addition to general satisfaction with life, all participants found positive meaning in work. The specific challenges usually associated with the profession may not be as limiting to wellbeing as could have been thought. *Positive emotions* emerged as highly related to “musical moments.” Variety of repertoire and ensembles appeared as a central source of *engagement*. The shared nature of the musical experience emerged as the core source of *meaning* and an established professional career in music appeared to lead to high perceived *accomplishment*. Additionally, the study highlighted the centrality of *identity* for wellbeing among professional musicians, and reinforced that key processes for positive functioning involve responses to, and regulation by, interpersonal *relationships*.

However, collaborative and solo musicians are presented with different challenges that need to be addressed, particularly at an educational level. The need for regulatory feedback through meaningful relationships that seems to be structural to a solo career, especially in its initial phase, brings to light the crucial role of mentoring as a lifelong education tool. Further, the high emotional instability and demands on social-skills that professionals highlight reinforce the double role presented to music institutions: going beyond refining musical skills and focusing also on resilience and social adaptation in an anticipatory approach to professional life. Innovative educational programs have been emerging in an attempt to maximize this process (e.g. Johnsson and Hager 2008), focusing on forming a sense of identity that goes beyond music skills and accomplishments, enabling, through a “living curriculum,” the development of the whole individual.

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# *The Imaginary Bird:* A dialogic performance in a contemporary music for solo flute

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*The Imaginary Bird* for solo flute uses all technical features of the instrument, including the creation of new resources through the use of extended techniques. The flute is itself central to the composition as it becomes the imaginary bird. It takes the warble of the *Uirapurú* bird as the sound source and recreates it as transcription fragments in a plaiting of natural sounds and overtones, using an extensive range of technical approaches. Interpretively, the aims are to solve the composition's complexity, releasing its intellectual energy into a performance with meaningful physicality.

*Keywords:* performance; contemporary music; solo flute; instrumental technique; *The Imaginary Bird*

*Uirapurú* is the legendary bird from the Amazon forest that has been connected with several folk legends. The *Uirapurú* is “the bird that is not a bird” in the indigenous Tupi language because, for the *Tupis*, the *Uirapurú* is a god who takes the form of a bird, always in the companionship of other birds, with the mission of leading lost people (who own a talisman) to their homes. The *Uirapurú* has a pure warble similar to a flute playing high tones; it is so rare that only recently have a few samples been recorded, contributing to the ever-increasing legends of its existence (Frisch 2005). The Brazilian composer H. Villa-Lobos composed the Symphonic Poem *Uirapurú* in 1917, inspired by the sources he collected over a long trip to the Brazilian north region.

The *Uirapurú* warble is only sung during nesting, about 10 minutes in the early morning and again by evening, only 15 days a year. In *The Imaginary*

*Bird*, composed by the first author, the flute takes the warble of the *Uirapurú* and recreates it as a transcription fragment, quoted in bars 51 to 55, 64 to 66, 86 to 89, and 119 to 122. The work incorporates other birds' fragmentary songs in a plaiting of natural sounds, overtones, reconstructed fragments, and sound material developed from those sources, using a variety of technical approaches. The rhythmic landscape provides structured changes where melodic layers flow almost as organic improvisations.

The research, composition, and performance of contemporary music are immersed in complexity due to the massive range of data to which one has access. This is perhaps the biggest challenge to overcome, since, for effective filtration of information, it is necessary to have a deep understanding of musical language and its forms of expression and interpretation.

It is valuable to review Pythagoras' concept of *Mousiké* applied to contemporary music, where music is understood as a dialogue between languages, frameworks, and compositional processes in the context of the creation and performance of contemporary works, explaining music theory critically and holistically, and designing musical thought both as complex and multiform (Tomás 2002).

Ricciardi (2013) lists three fundamentals of musical activities, in what he called a *fusion of horizons*, returning to these fundamental Greek concepts: music theory, composition and performance, and interpretation.

Related is the Danish composer Per Nørgård's use of the concept of *Interferens* (interference) in his music, in which when two events affect each other and cause a third occurrence that emerges in the consciousness of the listener (Nørgård 2009) creating what he calls *Mellemværender* or *Mellemhandlende* (here translated as *intermediate space*). Thus, the most important features are not manifested physically but rather in the consciousness of the listener or musician.

## MAIN CONTRIBUTION

The *Imaginary Bird's* formal and rhythmic structures are built on mirrored processes. These compositional techniques, widely used in contrapuntal compositions, have had a revival in modern and contemporary music. The golden section and the *Fibonacci sequence* are widely used compositional features, though each composer puts them to particular use.

The *Uirapurú* warble (see Figure 1) is quoted four times in the work, sometimes literally, sometimes in condensed form. The warble is composed mostly of major seconds, fourths, and fifths. The composition and structure of



$$\frac{a}{b} = \frac{b}{(a-b)} \cong \emptyset$$

$$\downarrow$$

$$\frac{134}{83} = \frac{83}{134-83} \cong \emptyset$$

$$\downarrow$$

$$1.61 \cong 1.62 \cong \emptyset$$

Figure 3. Golden section relationships between section lengths in *The Imaginary Bird*.

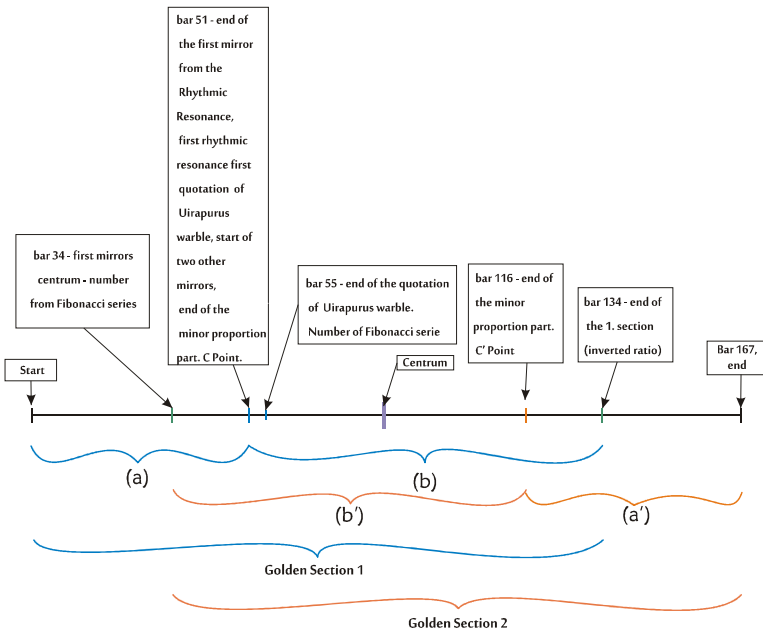


Figure 4. Mirrored structures and key bars in *The Imaginary Bird*.



a Fernando Lellis, o flautista voador  
**O pássaro imaginário**  
2007

Sílvia Berg

Flauta Solo

Figure 5. Bar 1 of *The Imaginary Bird*.

Figure 6. Bar 61 of *The Imaginary Bird*.

## IMPLICATIONS

In the performance and interpretation of any work, one must consider (1) what is immanent to the work and has (or has not) to be executed (performance considerations and implications), and (2) what is not immanent to the work and should (or should not) be executed (interpretative considerations and implications)

In the process of studying a work, the following strategies may be used in order to understand the processes of its composition, and thus how it is to be interpreted and performed: (1) analytical strategies, in order to understand the structure of the work, its materials, and its compositional processes; (2) technical strategies, in order to process the reading of the score and the notation of melodic and rhythmic structures connected with the use of all technical possibilities of the instrument and its expanded technique; (3) performative strategies, in order to create a systematic reading, as well as an identification and memorization of complex structures; and (4) interpretive strategies, in order to process the work as a whole and to solve the composition's complexity, releasing its intellectual energy into a performance with meaningful physicality and transcending the processes of analysis, technical resolutions, and performance.

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# The effect of intentional, preplanned movement on novice conductors' gesture

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Variety and effectiveness of gesture differentiate expert conductors from novice conductors. Preplanning movement in conducting may be one way to widen the student's vocabulary of gesture and promote motor awareness. To test the difference between guided score study and guided score study with preplanned intentional movement on the conducting gestures of novice conductors, undergraduate music students (N=8) were assigned to one of two conditions and then evaluated on their conducting performance. In the first condition (score study with preplanned intentional gestures), students assigned and practiced specific gestures to the articulations, dynamics, cues, texture, and phrase shapes. In the second condition (score study only), students were guided through the piece in terms of form, articulation, dynamics, orchestration, and texture, discussing only the sound of the ensemble. All participants were videotaped conducting the piece with a university instrumental ensemble. Performances were evaluated by two conducting experts on gestures of dynamics, articulation, cues, releases, and phrasing. Analysis of the mean scores for each rating revealed a significant difference ( $p < 0.05$ ) for articulation, cues, releases, and phrasing, with the intentional-movement-participants rating higher than the score-study-only participants. No significant difference was found for dynamics.

*Keywords:* conducting; movement; motor cognition; gesture; pedagogy

Conducting is one of many skills music majors must develop during their undergraduate careers, yet the study of conducting is often undertaken with little or no prior training in movement. Quality of movement is one of the distinguishing characteristics of expert conductors, as they differ from novices primarily in the variety and selection of gestures applied to the music being conducted (Byo and Austin 1994).

Gesture involves voluntary movement and the development of motor skills. Neuroscience and behavioral motor research has shown that we are not necessarily aware of body movement but rather of the intentions of movement (Desmurget and Sirigu 2009, Fournieret and Jeannerod 1998, Jenkinson and Fotopoulou 2010, Sarrazin *et al.* 2008). Research in motor cognition has established that when motor commands are created, an efference copy is also produced and is used to predict the sensory feedback of the movement (Desmurget and Sirigu 2009, Imamizu 2010, Jeannerod 2006). Conscious monitoring of movement results from the output of matching central (or efferent) and peripheral reafferent (visual and kinesthetic) signals and occurs after the movement. Because consciousness is a slow process, our goal-directed actions are mostly automatic, relying on the prediction (efference copy) of our intended movements without the inherent delay of the sensory feedback system. As long as the initial goals are met and discrepancies are small, consciousness is not brought into play.

If conductors are not specific in their intentions of movement, they will not be aware of small differences between the sensory feedback and the efferent copy. For example, novice conductors tend to have repetitive hitches that detract from their expressivity and are unaware of these movements (Byo and Austin 1994). An explanation from motor cognition research would be that the novice conductors' proprioceptive sensory feedback of the hitch does not vary enough from their intended movement. It would seem that if novice conductors were clear about their intentions, it would be more likely that they will notice (proprioceptive sensory feedback) any differences between their actual movement and their intentions. Drawing on such a model of motor cognition, one may propose that there are two purposes to preplanning movement in conducting: (1) to widen the student's vocabulary of gesture and (2) to promote motor awareness.

The purpose of this study was to test the difference between guided score study and score study that includes preplanned intentional movement on the gesture quality of novice conductors.

## METHOD

### Participants

Participants (N=8) had completed two undergraduate conducting courses at a large Northwest university and included music education (n=6) and performance (n=2) majors. Both instrumental (n=4) and vocal majors (n=4) were represented. Participants were matched for ability and two largely equivalent groups were created: the Gesture group (n=4) and the Score group (n=4).

## Materials

The first movement, “Un ange a fa la credo,” of *Suite Provençale* by Jan Van der Roost was chosen as the musical excerpt for several reasons: it was unfamiliar to the participants; it avoided technical difficulty and unfamiliar tonal language as confounding variables; it incorporated a variety of articulation styles, dynamics, changes in tempo and instrumentation; and it contained repeated melodic material to facilitate learning.

## Procedure

The researcher led the participants through two 30-minute score study sessions which included marking the score, listening to recordings, and singing through the melody and countermelodies. While one group was allowed to practice conducting gestures (Gesture group), the other was not (Score group). The Gesture group selected and wrote appropriate gestures in the musical score to demonstrate the musical choices they made in terms of articulation, dynamics, and texture. They then imagined the sound from beginning to end with their chosen conducting gestures in mind while viewing the score, and sang through the piece while physically conducting. The Score group thought about and wrote in the musical score descriptors of the ensemble sound in terms of articulation, dynamics, and texture. They then imagined the sound of the entire piece while viewing the score, and talked through their musical decisions. The scores remained with the researcher between the sessions and the participants were asked not to search out recordings or practice conducting.

Participants conducted the movement once with a live ensemble and completed a 10-minute post-conducting interview. Videos of the conducting sessions were evaluated by experienced conductors who rated each participant's skill at demonstrating articulations, dynamics, entrance cues, releases, and phrasing using a 5-point Likert-type scale. Inter-observer reliability was calculated for the rating scale. A difference larger than one point between the evaluators was considered a disagreement while a difference of one point or less was considered an agreement. The reliability for the evaluators was calculated using the following formula: agreements divided by (agreements plus disagreements). The inter-observer reliability was 99%, above the conventional threshold of 85% (VanHouten and Hall 2001).

## RESULTS

Conducting ratings were averaged for each of the skills, yielding five mean ratings for each of the eight conductors. The mean ratings of the Gesture group conductors and the Score group conductors were then compared using independent t-tests for each skill. The Gesture group demonstrated a higher level of skill in terms of articulations, cues, releases, and phrasing, according to the ratings of the evaluators. Significant differences were found between the intentional movement and score study only groups' ratings for demonstration of articulation ( $t_6=2.55$ ,  $p=0.04$ ), cues ( $t_6=2.5$ ,  $p=0.05$ ), releases ( $t_6=3.72$ ,  $p=0.01$ ), and phrasing ( $t_6=3.57$ ,  $p=0.01$ ). Conductors in the Gesture group were rated higher than participants in the Score group (see Table 1). There was no significant difference found between the two groups' ratings for demonstration of dynamics.

## DISCUSSION

Although both groups had spent the same amount of time learning the piece, the group that made decisions about their movement and had practiced the movements led the ensemble with more specific and obvious gestures. However, we cannot say if one group "knew" the piece better than the other. In fact, in the post-conducting interviews, the Score group participants indicated that they knew what they had wanted in the music but felt they were unsuccessful in demonstrating those decisions through gestures.

Participants in both groups commented that their gestures reflected what they were hearing in the ensemble, as revealed through this statement by one of the Gesture group conductors: "most of my gestures were delayed reactions to what I heard." The Gesture conductors felt that the ensemble "reminded" them of their intended gestures: "I forgot about the legato, but once I heard it in the ensemble, I remembered it." Conversely, the Score group participants were reminded of where they were in the music.

*Table 1.* Mean ratings and standard deviations (SD) for conducting performance skills.

<i>Conductor group</i>	<i>Articulation</i>	<i>Dynamics</i>	<i>Cues</i>	<i>Releases</i>	<i>Phrasing</i>
Gesture	3.13*	2.75	2.63*	3.75*	2.63*
SD	0.86	0.64	0.75	0.5	0.75
Score Study	1.88	2.13	1.63	1.63	1.63
SD	0.48	0.63	0.23	0.63	0.26

*Note.* Maximum possible rating=5, Minimum=1; \* $p<0.05$ .

The post-conducting interviews demonstrated that there was a higher level of awareness of movement in the intentional movement group, which is in agreement with neuroscience research (Jenkinson and Fotopoulou 2010, Desmurget and Sirigu 2009, Sarrazin *et al.* 2008). However, this may have been due to the fact that they had a greater variety of gestures to be aware of or because they had written reminders in their scores. One of the Gesture group participants made the following comment: “I was trying to show the staccatos, but I think I subdivided way too much because we talked about not doing that. I guess that is an autopilot reflex when I see or rather hear staccato in the band, I automatically subdivide the staccato.” He was aware of the subdivision yet did not change his movement during the performance.

Building on previous research in score study (Lane 2006, Silvey 2011), students need to be guided through the process of studying a score and making decisions about physical movement, which will communicate the musical intentions. Conceivably, more courses on conducting may be needed to continue to develop skills past the basic competencies to a more holistic approach to conducting, providing students with opportunities to expand their gesture vocabulary while practicing their score study skills.

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# Scratching that creative itch: The amateur choir and orchestra as examples of the learning-creative organization

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The “right” orchestra or choir conductor is a catalyst for excellence and creativity. The “result” is the performance—group creativity within a complex organization. Business organizations have become increasingly interested in the workings of orchestras and the like, yet there has been little research in the reverse direction. This paper explores lessons of creativity *from* complex organizations *to* ensembles. Part 1 outlines literature survey and statistical methodologies. Part 2 evaluates individual creativity of members of some great orchestras and choirs and continues to explore what happens when “The Creative Organization” merges with “The Learning Organization” to form “The Learning-Creative Organization.” Researchers ask, “What is individual versus group creativity, and does one contribute to the other in these ensembles? Does the creative contribution of members decline over time? Is there a new paradigm to stimulate an individual’s creativity and contribution to the group? Should conducting be more about new understandings of leadership and teamwork that stimulate the individual’s creative contribution?” The purpose of this research is to test The Learning-Creative Organization as a model, coming up with further paradigms for music organizations to tap more deeply into the creativity of each member.

*Keywords:* learning-creative; performance; leadership; creativity; conducting

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# Chamber-instrumental interpretation issues on examples of Prokofiev's chamber sonatas

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The twentieth century was a period of searching, artistic tendencies, and generalization of style. Its characteristic features were the expansion of the information field, the opening of dialogue between styles originated in different epochs, the transformation of old traditional forms, and the generation of new genres. It was important that composers of the twentieth century added new interpretations to content possibilities, while using past genre models. They put a modern person's outlook and a "breath" of social cataclysmic dimensions in their creations using innovative composition techniques and means of performance. In this context it is interesting to study the creations of Sergei Prokofiev, in particular his compositions for chamber ensemble (specifically the chamber sonatas with piano). This research is important as there isn't sufficient information concerning the interaction rules of the expressive means of the piano with other instruments—in this case the violin and flute.

*Keywords:* chamber music; performer; Prokofiev; twentieth century; interpretation

Analysis of music for chamber ensemble requires an individual approach from a researcher-performer. On one hand, it is important to study the works themselves to reveal their structural genre and semantic content, and, on the other hand, to search for peculiarities in the performance and tasks. For the interpretation of instrumental chamber music it is very important that performers clearly define the structure of the work (e.g. tasks of the ensemble and difficulties in the composition). The research objects, Sergei Prokofiev's (1891–1953) sonatas for violin, flute, and piano, are analyzed from this perspective. Despite a great body of practical experience, a well-developed methodology of chamber ensemble studies does not yet exist. The greatest part of this research refers to chamber performances, in particular to the individual

roles of the piano and strings (wind instruments) in the ensemble. There are different forms of ensemble music which contain a piano part. There are various chamber ensemble music genres: sonatas, trios, quartets, piano duets, etc., as well as instrumental and vocal works with accompaniment. Ensemble music with piano, therefore, has a special meaning in the research context. The characteristics of the piano as an ensemble instrument are heightened strikingly in instrumental and vocal chamber music, where the piano differs significantly with its individual timbre, register, dynamic, and articulation. In such structures it is most important to achieve intonation, integrity, timbre, and an agreeable sound.

This study considers the entire, complexly organized system of piano ensembles. This system can be divided into two parts which point out its peculiarity: one part is represented by the stringed and wind instruments and the other one by the piano. The division of the ensemble into subsystems is determined by the composition and the expressive means of the piano, because it offers more possibilities of variation than other melodic instruments. The organization of the piano part gives us the foundation to imagine the model of an ensemble. Therefore, the performing-piano process can be considered: (1) from the practical viewpoint, e.g. how to use a pianist's performing potential effectively; (2) from the scientific-theoretical rules of the piano ensemble performance; and (3) in view of the pedagogical practice of the scientifically approved knowledge in an ensemble.

### **MAIN CONTRIBUTION**

The main aim of this research is to show the means of reaching an artistic result by shedding light upon the specific character of piano ensembles. To achieve this goal, some historical-theoretical and performing tasks should be explored, particularly: (1) the expressive potential of the piano as a synthetic and universal instrument, (2) the specific character of piano ensembles with concrete examples, (3) the rules of creating the piano part with the different instruments in an ensemble, and (4) the individual parts (piano, strings, and wind instruments) in view of their specific functions in an ensemble

The methodological foundation of the research is a systemic approach, which is used to consider the complex system of the ensemble parts. The above-mentioned method is significant from a scientific point of view. The relation between the means of instrumental performance and their content possibilities is defined with the help of a semantic analysis.

### ***Sonata for Flute Op.94 and the second Sonata for Violin Op. 94bis: issues of performance interpretation***

The *Sonata for Violin and Piano* is the composer's most light and calm creation. Prokofiev arranged it for violin, prompted by David Oistrach (1908–1974), who also premiered it in 1944. Although the virtuosity of the original instrument (flute) is only partly converted for the violin part, the sonata is distinguished by a frank and lyrical exactitude of images. A number of complicated passages represent a development of the main themes' variations. The multicolored melody lines remind of a vocal coloratura (in the flute version), which organically link to the *virtuoso* passages. The sonata requires virtuoso skills and artistic depth from the performer. It is important to define the right tempo at the beginning of the performance. Contrary to the traditional sonata form, the first part is not *allegro*, but a more restrained *moderato* (Nestiev 1973). The tempo for the violin version can be more flowing, while the tempo for the flute version can be calmer (Richter 1961). This does not exclude the fast character of the motor episodes or the cheerful mood. The tempo of the flute version is more vocal and fitted for human breath, and is defined by this factor.

The second part is fast: *virtuoso scherzo (presto)*. It is important to note that Prokofiev made exact metronomic notes only for the first and third parts (Oistrach 1961). In the *scherzo* and *finale*—the fastest parts of the sonata—Prokofiev gives the performer freedom to define the tempo (Prokofiev 1961). This author's opinion is that the *scherzo* can be performed at half tempo; the tempi for the violin and the flute versions are different. With the flute the tempo is more restricted, and with the violin it is faster: *molto presto* and *virtuoso*. The fast, sharp *staccato* in the piano introduction should be performed in the marked tempo with an exact rhythm and with metric accents. In this part it is important for the piano to move naturally from the accompanying sharp metric figuration to the sharp solo "insertion" and return to the rhythmically light "accompanying" part. It is complicated to perform the different characteristics with the left and the right hand—left hand=*staccato* and right hand=ties.

The third part, a slow, lyrical *andante*, sounds as if it were painted with water-colors. The *andante* is a typical example of Prokofiev's lyric melodies (Aranovski 1969, Neigauz 1961). The middle part is more vivid, which does not contrast with the leading theme. On the contrary: it continues it on a new basis. This is a kind of improvisatory duet for the violin and the piano which is free from rhythmic frames. The figuration of triplets in both instruments should be performed in a singing manner with absolute exactness and *legato*

(Glebov 1961). In the finale (*allegro con brio*), the beauty of the flute (the violin) part is stressed by equal movement of the piano. Here appears one of Prokofiev's peculiar features—the concrete character and almost visual perception of the musical images and their fast changes, similar to a “film sequence” (Tarakanov 1968). The whole *allegro con brio* should be performed at a fast speed. In the end of this research, based the material presented here, performing advice for general ensembles will be offered with the intention of helping performers in their work on this sonata.

Shifting from lyrical to faster movements requires fast reactions from the performers while moving from one texture to another in the first part of the sonata. The repetition of themes in a second key, for example from C major to D major, requires smooth pedaling from the pianist. Rhythmic changes of the texture (dotted rhythm, triplet repetitions) require an exact and clear performance of the rhythmic picture from the performer. In the violin part, a great number of double sounds, as well as jumps in the second and in the fourth parts of the sonata, increase the difficulty. This is due to specific features of the instruments, particularly in the violin part where the tempo is faster than in the flute part. It is important that a pianist performs the *staccato* metric accents accurately and with sharp articulation. A difficulty in the piano part is shifting from the accompaniment to the *solo virtuoso* insertions, simultaneously performing different traits in different registers, in particular stopped and continued phrases (Rostropovich 1961). The synchronicity of the passages of both instruments is another difficulty. It is desirable that performers reach a similar feeling of pauses and traits (Gilels 1961). In the third part of the sonata the task for the ensemble is to play the violin (flute) and piano as an improvisatory duet. To achieve a transparent sound in the piano part (changing from major to minor keys) the performer should use the soft pedal. The smooth chords of the piano part require from the pianist a feeling of a multicolored harmony. In the fourth part of the sonata, the difficulty is the linking of contrasting textures (the violin's in particular) to the accurate synchronization of dissonant vertical accents in the piano part.

### IMPLICATIONS

This research highlights how Prokofiev's chamber ensemble sonatas pose the following performance difficulties: (1) shifting of contrasting episodes which aim for fast reaction, moving from one texture to another; (2) rhythmic changes requiring the exact and clear performance of the overall rhythmic picture; (3) a synchronous feeling of the passages, pauses, and traits in both instrumental parts; (4) the contrasting textures linking instrumental parts;

and (5) carrying out different textures in the violin (flute) and piano parts simultaneously, requiring an accurate observance of the vertical line

Both of the sonatas discussed above are characterized by a variety of complex means of expression, including: (1) a variety of musical expressions, (2) the differentiation of musical material, (3) a wide range of action for all expressive means, and (4) convenience and flexibility in reflecting performance processes by performers.

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# Performance dialogisms in two Brazilian art songs by Silvia Berg

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Musicians typically perform with other musicians. Vocal solos tend to be with an ensemble, orchestra, quartet, choir, or other accompaniment; rarely are they *a capella*. The aim of this study was to analyze and understand the dialogism through the Bakhtinian philosophical perspective involving composer, pianist, and singer. While most studies concerning ensemble practices and performances focus on methods and strategies for rehearsing, we examined the entire performance taken together, so that each part is considered only in relation to the whole. We discuss the compositional and performing aspects of two songs: *Oração para Aviaadores* (Prayer to Aviator) and *O Amor* (The Love), written for soprano and piano by Brazilian composer Silvia Berg. The process includes the dialogism of the compositional aspects of the two songs, the dialogic flow between the composer and performer, and the dialogic interchange between singer and pianist. As a result, we reveal the singularity of the fusion, immediacy, and impermanence of the songs, and also the grounding experience within musical performance. Moreover, we identify the unique aspects of the composer, performer, and listener within the process.

*Keywords:* dialogism; Brazilian art song; performing together; Silvia Berg; voice and piano collaboration

Vocal solos in an ensemble, orchestra, quartet, or choir are commonly observed. Unaccompanied vocal performances, however, are rarely seen. We, more often than not, watch musicians in collaborative performances. Studies on ensemble practice and performing, as done by Davidson and King (2008) and Goodman (2004), were concerned with methods and strategies for rehearsing. Some aspects have been considered to achieve the best results,

including coordination (keeping time), the role of the individual and social factors, the importance of a positive socio-emotional ambience, the interaction and cohesion that govern the group, and finally the method of communication (aural and visual signals). While most studies concerning ensemble practices and performances are focused on the methods and strategies for rehearsing, this paper examines and identifies the dialogisms of the composer, pianist, and singer as they interact with entire performance taken together, so that each part is considered only in relation to the whole. Moreover, we observe the assorted relations among individuals, and the appropriate exchanges in formal procedures and performances to facilitate the underlying principles of the act of performing music as a social interaction.

The composer, pianist, and singer are also the participants and authors of this article. The two Brazilian art songs created by the composer—to be performed by singer and pianist—are the material of this investigation. We examined the set of information collected from the dialogisms of the composer in the process of creating these songs, and from the dialogism between the singer and pianist through a dialogical analysis. A dialogical interaction analysis refers to a way of exploring human communication which is based on the theory of dialogism. For Mikhail Bakhtin (1895-1975), all language—indeed, all thought—appeared dialogic. Dialogism is given a literary conceptualization by Bakhtin, a Russian literary critic, social thinker, and philosopher of language. However, the term “dialogic” does not just apply to literature. His work may best be thought of as philosophy of another kind; philosophy across the board as in Emerson and Holquist (1986). Bakhtinian philosophical perspectives can also be applied in performance (Marshman 2012). Therefore, dialogism is more than the communication mentioned above. Holquist (1990), a Bakhtinian researcher, declares that dialogism is a form of architectonics, the general science of ordering parts into a whole. In other words, architectonics is the science of relations. In addition, Bakhtin emphasizes that “a relation is never static, but always in the process of being made or unmade” (pp. 29). There are transforming movements, as the dialog between the composer, pianist, and singer is being established unceasingly through analyses and investigations of the composer’s life and pertaining historical background, on an appraisal of the compositional resources, and the studies of poetry or other sources of inspiration in the tradition of western music. However, the meaning of dialogism is more than dialogue, as Holquist continues: “sharing existence as an event means among other things that we are—we cannot choose *not* to be—in dialogue, not only with other human beings, but also with the natural and cultural configurations we lump together as *the world*” (pp. 29). That is the reason that dialogism could be useful in under-

standing the relations of composer, performer and listener in music performance.

The main goal of this approach was to use the Bakhtinian philosophical perspective to clarify the process of dialogism among composer, performer, and listener through two Brazilian art songs.

## MAIN CONTRIBUTION

### **Compositional dialogisms in two Brazilian art songs: The composer's voice**

The work of the Brazilian poet Manuel Bandeira (1886-1968) is one of the most inspiring sources for modern and contemporary Brazilian art song composers. This is mainly due to the rich imagery contained in his verses, the nostalgia imbued in his poetry, and the irregularity of the meter that, at the same time, offers great rhythmic variation. All in all, each of these elements is easily adaptable to various compositional processes.

The poem *Oração para Aviadores* (Prayer to Aviators) was chosen because it depicts the immediate relationship between the musical structure and landscape of the region: large plantations, slightly hilly areas, and views of large tracts of earth. This was the first composition the composer wrote upon returning to Brazil and establishing residence in Ribeirão Preto, a city north-east of state of São Paulo, after more than twenty-four years living in Denmark. The day the song was written the composer had the sight of a major storm approaching on the horizon.

The vocal identification (soprano) was extremely important in designing the structure of the song. The prior knowledge of the specific technique—both vocal and instrumental—of each performer was also essential (the composer knew the musicians that would perform the song), as the compositions are conceived organically from these assumptions. The melody is exposed syllabically by the voice and melismatic flights are exposed by the piano. Moreover, it contrasts between its dilated (not simultaneous) and contracted (simultaneous) forms, sometimes in octaves and, at times, meddling with the increase of octaves and harmonics.

Both songs were created as a dialogue based upon the compositional processes of Robert Schumann, found in his Opus 48 song-cycle *Dichterliebe* (Poet's Love). More precisely, in the works *Und die Blumen's wüssten* (And the Flowers Knew) and *Das ist ein Flöten und Geigen* (There is a Fluting and Fiddling). The vivid function of the piano, as in *Dichterliebe*, assumes a complementary function to the poem, as in Cook (1998), therefore providing sub-

liminal layers of meaning, yet sensed, but not directly described in the writings.

The song *O Amor* (The Love) was composed months later, inspired by the compositional processes of the song *Im Rhein, im heiligen Strome* (In the Rhine, the Holy River) by Schumann from the same collection *Dichterliebe*. In addition, the composer used a quote from the Brazilian folk song *Atirei uma Pedra n'Água* (I threw a Stone into the Water), drawing from Hoquetus technique, which combines fragments superimposed and juxtaposed with silences, forming a surface exposed to the elements that will trigger processes of propagation. While the song *Oração para Aviadores* (Prayer to Aviators) builds itself with a set of images structurally in the "air," in *O Amor* these processes occur by propagation. The allusion to "throw a stone into the water" is described by a circle of resonances on the piano. *Ostinati* are methodically used in this song, complementary to the text, but in disagreement with their original structural function of repetition. They are instead systematically employed with variation and as surprise elements, and often including structural silences. From this texture emerges a quotation of instrumental accompaniment forms as a dialog with compositions of different periods and styles.

### **Dialogism between the singer and piano collaborator**

The dialogical partnership between a singer and a pianist starts with an overview of the piece they will perform. An important distinction in this study was that, once a collaborator, the pianist's role goes beyond the simple task of accompanying. The pianist is also a singer, and when the composer is aware of this and treats the instrument this way, the musical result is much more persuasive. In the two works of Silvia Berg, the piano is responsible for setting the mood of the songs.

In *Oração para Aviadores* the constant rhythmic figuration in groups of thirty-second notes in the piano's introduction (*agitato, legatissimo*) could be translated as the scenery that depicts the wind and the movement of the airplanes in the air. It makes a sharp contrast with the prayer that follows (*Calmo e fluente [calm and fluent]*). The dynamic arch of this introduction, going from *piano* to *forte*, *mezzo-piano*, *pianissimo*, and *piano-pianissimo al niente*, prepares the entrance of the voice. However, one must observe here that the mood, the tempo, and the whole atmosphere of the voice part that follows are different from that of the introduction. When practicing, singer and pianist must work on this sudden change or the entrance of the voice part could be jeopardized. The pianist synthesizes this change in one chord whose

resonance will blend with the singer's first note. Although the piano score indicates *piano* at the beginning of the prayer section, the inflection of the words in the musical phrase is to be observed and carefully followed with the help of dynamic shadings and the use of legato touch in the piano part. Piano and voice are very much dependent on one another. As the piece progresses, the thirty-second note figurations in the piano part appear as an interlude. The return of these figurations gives another perspective to the prayers' meaning. From this section on, the dynamic *forte* and the movement of the piano part that now permeates the musical discourse intensifies the invocation.

In the introduction of *O Amor* the sonority of the piano anticipates the sound of the voice in such a manner that, once the singer starts, it is a natural continuation of the piano's resonance. The piano and voice parts are interwoven with each other, and the projection of the voice is amplified with the aid of the overtones provided by the piano sound and texture. The shape of the phrases gives the opportunity to breathe naturally and the flow of the song is conducted by the piano. When the accompaniment and the voice part have the same rhythm, the inflection of the words has to be carefully followed, and, as stated by Katz (2009), pianists "have to replicate that shape exactly or imperfect ensemble will result.... [The collaborator] must know the inherent shape of a group of words to be able to predict and synchronize what happens at the piano with our inflecting partner" (pp. 23). Another interpretive aspect in the piece is that the manipulation of the tempo and dynamics is directly related to the words' diction and meaning. These aspects of interpretation have to be carefully practiced in order to keep the balance between parts, and to bring the real dimension of the piece alive. All of this "air" scenery and the huge landscapes suggest a soprano voice with controlled vibrato. Pianist and singer must work dialogically on the sound and touch on each phrase together, keeping in mind the meaning of the text, in order to decide on the correct dynamic nuances and tempo and preserve the flow of the piece.

## IMPLICATIONS

Further research will seek to deepen understanding of the dialogical process of musical performance between the composition, performer, and audience. Brazilian art song will also continue to be the focus. Bakhtinian values should be studied in order to better comprehend performance dialogism through inferences of "utterance," "polyphony," "heteroglossia," and "grotesque body." We continue to question whether one could measure all of the dialogisms linking the composer's process of creation: between the composer and per-

former, composer and listener, among performers, and between performers and listeners. Performers and listeners are not static entities, but individuals in continuous transformation through time and space. Therefore, the entire process of dialogism as a measurable aspect collaborative performance is yet to be fully understood and utilized. As in Berenson (2001), “all art, including music, has been created in order to be experienced. The creator of art experiences its creation at every point and so does the spectator or the audience” (pp.67). Berenson continues, referencing Sartre: “there is no art except for and by others.”

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# Cryptic crossword expertise and fluid intelligence

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Solving cryptic crosswords involves understanding how cryptic clues are constructed, an ability to think laterally and not to be misled by “red herrings,” and a good knowledge of words. As cryptic crossword solvers tend to be educated to at least degree level, often in mathematics and science related disciplines, it is plausible that they have higher than average fluid intelligence (“thinking on one’s feet”). Twenty-eight crossword solvers (18 expert and 10 non-expert) solved a bespoke cryptic crossword and completed the Alice Heim tests of problem solving (AH5), a timed high-grade fluid intelligence test, measuring verbal and numerical (Part I) and non-verbal diagrammatic (Part II) reasoning abilities. In the 45 minutes allowed, 17 experts and 2 non-experts correctly finished the crossword. The experts scored significantly higher on the AH5 overall and on Part I than the non-experts. There was also a significant correlation between finishing time and the Part I AH5 scores for those who finished the crossword: faster finishing times associated with higher AH5 scores. In this case at least, specific psychometric ability does seem to relate to level of expertise. Differences with previous literature on this issue are discussed.

*Keywords:* expertise; cryptic crosswords; fluid intelligence; problem solving; cognitive testing

Puzzle solving is a major pastime for many people, and this has increased markedly in the last couple of decades, as evidenced by the pages of crosswords, sudokus, and other puzzles in daily newspapers. Of these puzzles, crosswords have a long history, it being 100 years since the first “word-cross” was published in the *New York World* in December 1913. In the UK, the crossword puzzle developed into two distinct forms during the 1920s: non-cryptic (“straight definition”) and cryptic. In essence, cryptic crossword clues

contain a straight definition of the required answer together with coded instructions (“wordplay”) leading to the answer. In many cases the surface reading of the clue is specifically designed to be misleading, and successful solving requires both a knowledge of how clues work and relevant vocabulary, but also an ability to resist being “led down the garden path.” This research investigated cryptic crossword expertise.

Expertise relates to performance, skill-sets, or knowledge, usually in a particular domain (Ericsson and Towne 2010), which is reproducibly superior to that of most others who are active in the domain. The general mechanisms of expertise have been widely researched using several approaches, including diary studies and the expert-performance approach. This latter approach (Ericsson and Smith 1991, Ericsson and Towne 2010) involves identifying domain-specific challenging situations and presenting them to experts in controlled studies, and then endeavoring to explain the cognitive and physiological mechanisms underlying the expert performance. Such an approach has been used in various domains, including music, chess, sport, and Scrabble (Ericsson and Towne 2010). Diary studies have suggested that practice is one of the most important contributors to becoming an expert. With few exceptions, 10 years appears to be the minimum required to reach an international standard (Ericsson *et al.* 1993). This has been demonstrated in various domains, including chess, music, and sport. Moreover, Ericsson and colleagues make the important point that less structured, “suboptimal” practice will not suffice, but it must be what they term *deliberate practice*, which involves considerable effort and is not inherently enjoyable (Ericsson *et al.* 1993, Tufiash *et al.* 2007).

An alternative approach investigates individual differences between experts and non-experts, using psychometric tests both of intelligence and of other domain-relevant sub-skills. However, many such attempts have failed, possibly due to the tests used being either too blunt or not being appropriate for the specific domain, underlying the importance of an explicit theoretical model for how such abilities could underlie expert/non-expert performance differences (Ericsson and Towne 2010).

Recently we have started investigating cryptic crossword expertise using the expert-performance approach, asking both experts and non-experts to solve a bespoke cryptic crossword. However, we also included an aspect of the psychometric approach, but with a clear theoretical explanation for why we might expect a group difference. Previous research (Fine and Friedlander 2010, Friedlander and Fine 2009) surveyed over 750 cryptic crossword experts and non-experts and showed that over 80% had at least one degree, and 55% had studied math, science, medicine, or engineering. Of the experts, over



40% had higher degrees (masters and doctorates) and over 60% were currently working in IT or a science-related subject. As many of these disciplines and careers involve problem solving and adaptability, we would expect such people to have high fluid intelligence, which is the ability to use available data efficiently to draw conclusions and to solve problems by “thinking on one’s feet.” If there is a high ability entry threshold into the cryptic crossword solving domain, then we would expect all solvers to show a high fluid intelligence compared to the general population, with experts showing even higher scores than non-experts.

The main aim, then, was to investigate whether a group of expert cryptic crossword solvers showed higher fluid intelligence than non-experts, and whether there was a positive relationship between fluid intelligence and solving speed on a bespoke cryptic crossword.

## METHOD

### Participants

Twenty-eight crossword solvers participated ( $M=50.9$  years,  $SD=11.0$  years). Eighteen ( $m=15$ ,  $f=3$ ) were experts and ten ( $m=9$ ,  $f=1$ ) non-experts. Criteria for inclusion in the expert category included being a successful speed-solver (with a good track-record in the *Times Speed-solving Championship*), a successful *Listener* solver (a weekly “advanced” cryptic), or a professional editor or setter. There were no differences in experience between the experts and non-experts, in terms either of years solving (experts= $36.7$ ,  $SD=11.3$ ; non-experts= $32.6$ ,  $SD=13.1$ ) or hours per week solving (experts= $7.6$ ,  $SD=3.3$ ; non-experts= $7.6$ ,  $SD=3.5$ ).

### Materials

Participants completed the AH5 test of problem solving, a timed high-grade fluid intelligence test (Heim 1968). There are several AH tests, and the AH5 test was designed for high-ability university students and research workers (Deary and Smith 2004). Each of the two parts contains 36 questions. Part I measures verbal and numerical reasoning abilities and Part II non-verbal (diagrammatic) reasoning abilities.

### Procedure

Participants were first allowed 20 minutes to complete each of the two sections of the AH5 test. Then, after two warm-up word games, participants solved a bespoke cryptic crossword of the standard found in a British broad-

sheet newspaper while speaking their thoughts out loud. They were allowed 45 minutes to solve it. As this was part of a larger study, the word games and the verbal protocols will not be discussed here.

## RESULTS

Of the 28 participants, 19 (17 experts, 2 non-experts) finished the crossword within 45 minutes. Total AH5 scores were significantly higher ( $t_{26}=2.264$ ,  $p=0.032$ ) for the experts (46.8,  $SD=9.6$ ) than the non-experts (39.0,  $SD=6.9$ ). This was also the case for Part I ( $t_{26}=3.394$ ,  $p=0.002$ ), with experts (24.7,  $SD=5.2$ ) scoring higher than non-experts (18.3,  $SD=3.8$ ). For Part I, compared to the highest achieving band of Heim's nine high-ability populations (high-grade engineering apprentice applicants,  $n=1375$ ), the experts were in the top 10% and the non-experts in the middle 40% (Heim 1968). There were, however, no group differences for Part II scores. For all participants, Part I scores correlated significantly with Part II scores ( $r=0.557$ ,  $p=0.002$ ), which is clearly in the range ( $0.49 < r < 0.62$ ) for Heim's populations given in the AH5 manual (Heim 1968).

Those who finished the crossword ("finishers") in the allotted time were compared with those who didn't. Finishers (46.9,  $SD=9.6$ ) had significantly higher ( $t_{24,93}=3.106$ ,  $p=0.005$ ) total AH5 scores than non-finishers (38.0,  $SD=5.5$ ). On Part I, finishers (24.7,  $SD=5.2$ ) likewise had significantly higher scores ( $t_{25,99}=5.107$ ,  $p < 0.001$ ) than non-finishers (17.4,  $SD=2.4$ ). For the 19 finishers, their solution time (ranging between 11:07 and 40:35 minutes,  $M=23:35$ ,  $SD=9:21$ ) correlated significantly ( $r=-0.554$ ,  $p=0.014$ ) with their Part I AH5 scores.

Part I contains 4 subsections: similar relationships, directions, verbal analogies, and numerical series. The scores on all but the first differed significantly between the experts and non-experts ( $p < 0.02$ ). Solving time for the finishers correlated significantly with similar relationships ( $r=-0.555$ ,  $p=0.014$ ) and verbal analogies ( $r=-0.530$ ,  $p=0.020$ ) but not with the other two Part I subsections or with Part II or any of its subsections.

## DISCUSSION

This study investigated whether cryptic crossword experts have a higher fluid intelligence than non-expert crossword solvers. There were a number of relevant findings. Firstly, the majority of the experts, but very few of the non-experts, managed to finish the crossword in the allotted time, endorsing the criteria for inclusion in the expert group. One potential problem with much expertise research is the lax criteria by which expertise is defined, and Eric-

son has repeatedly made the point that expertise should be objectively endorsed, and that it is not the same as extended experience (e.g. Ericsson and Towne 2010). Our expert participants all had external and objectively benchmarked measures of their expertise.

Secondly, all participants scored highly on the AH5, which is designed specifically for high-ability people, supporting our hypothesis that cryptic crossword solving has a high ability entry threshold. Moreover, the experts scored significantly higher than the non-experts on the AH5, both overall and for Part I, which assesses verbal and numerical abilities. This suggests that a higher fluid intelligence is important for expert cryptic crossword solving. Given the experts' generally higher academic qualification level and the fact that many of them studied and/or worked in a discipline requiring a high level of problem solving ability, this was expected. In particular, the experts were significantly better at directions, verbal analogies and numerical series. These sub-tests may be tapping into particular sub-skills necessary for successful cryptic crossword solving, which will be the subject of future research.

Thirdly, quicker finishers had higher AH5 Part I scores, as well as being better at the similar relationship and verbal analogy sub-tests in Part I. This strengthens the posited relationship between fluid intelligence and cryptic crossword solving skill. Finally, it is worth noting that there were no group differences on the Part II scores, nor did they correlate with solving time for the finishers. Although Part II may be tapping into logical problem solving abilities, it appears that non-verbal diagrammatic abilities are less related to, and perhaps less necessary for, successful cryptic crossword solving.

As the experts and non-experts did not differ in experience, their levels of performance cannot easily be explained by practice effects. We did, however, find significant differences in fluid intelligence between the groups, suggesting that this can influence cryptic crossword solving performance. There are various future avenues of research, including identifying some of the specific sub-skills relevant to cryptic crossword solving, and uncovering some of the cognitive mechanisms involved.

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# SmartSense: Using your smartphone for music performance research

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There has been a wealth of research on musicians' movements in performance science and musicians' medicine. Although it is often implied that the results could be interesting for music performers and pedagogues, this research is ignored by most practitioners. One reason might be that today's musicians have no prior experience with objective movement measurement. Without that, they may find it hard to relate to the results of that research and experience, judging it as too technical. On the other hand, the progress of technology has led to the situation that inertial movement sensors are all around us, e.g. in the smartphones that we carry around. SmartSense is a motion sensing system based on a smartphone, a tablet, and (optionally) a MIDI keyboard attached to a computer. The smartphone is strapped to the player's arm and provides continuous sensor data. The data is streamed to the tablet where it is visualized. In order to make the system as easy-to-use as possible, the components are discovered automatically on the local wi-fi network. SmartSense provides motion sensing to musicians, who can start to explore their own movements based on introspection and objective motion measurement, so that they, too, can participate and contribute to the field.

*Keywords:* movement; sensors; smartphone; introspection; popularization of performance science

There is a wealth of research focusing on movements of musicians. Such movement related research can be found in two academic fields: (1) in musician medicine, where the causes of occupational injuries are studied, such as physical overexertion, excessive use of force, bad posture, etc.; and (2) in performance research, where, for example, movement strategies of experienced musicians and beginners are compared. Oftentimes, it is either explic-

itly or implicitly assumed that musicians could benefit from this research—that they could reduce the risk of occupational injury and improve their practicing habits and technique. Unfortunately, it seems rather obvious that this research is of little concern to most musicians and music pedagogues.

One reason might be that today's musicians have no prior experience with objective movement measurement. Without practical experience they may find it hard to relate to the results and experience it as too technical. On the other hand, the progress of sensor technology has led to the situation in which inertial movement sensors are all around us, e.g. in smartphones. The aim of this work was to make objective movement measurement widely available for musicians, so that they can begin to gain own experience. This may also help to popularize our research field.

The first attempts to capture musicians' movements were done in the 1920s and 1930s by Ortmann (1929) and Hodgson (1934). They tracked the movements by attaching lights to the players, which were then photographed with extended exposure time. They also developed and used special mechanical devices. Today, the most common ways to capture the movements of musicians are the following:

- Optical motion capture (e.g. Goebel and Palmer 2008, Goebel and Palmer 2009, Sforza *et al.* 2003, Ferrario *et al.* 2007), where multiple cameras track passive or active markers so that the exact 3D-position can be triangulated.
- Inertial sensing (e.g. Großhauser *et al.* 2010, Nicolls 2009, Young 2007, Hadjakos 2011, Hadjakos *et al.* 2009) based on miniature MEMS sensors, which are able to sense the proper motion, often in combination with magnetometers by sensing the earth's magnetic field.
- Electromagnetic motion capture (e.g. Maestre *et al.* 2007, Guaus *et al.* 2009) based on a magnetic field generator and several magnetic field sensors.

In order to apply such sensor systems a high level of technical expertise is required. Furthermore, commercially available sensor systems are rather expensive. Therefore, various researchers have built their own solutions. MacRitchie (2011) uses a camera with a high frame rate to track UV reflecting markers that are painted onto the pianist fingers and hands. Gorodnichy and Yogeswaran (2006) developed a method that recognizes which finger has pressed a key based on a camera mounted over the piano. Castellano *et al.* (2008) analyzed expressive movements of the upper body by tracking a colored marker placed on the head of a pianist. Burns and Wanderley (2006)

developed a computer vision method to detect guitarists' left hand finger movements with a camera mounted onto the guitar neck. The advent of affordable depth cameras has provided further alternatives for capturing the movements of musicians (Hadjakos 2012) and ensembles (Hadjakos *et al.* in press).

While such (depth-)camera-based solutions provide relatively inexpensive sensing options, they still require considerable preparation in order to install the camera in the right place. For our *SmartSense* system we aimed to minimize such preparation steps as much as possible in order to reduce the entry barrier for non-technical users.

### MAIN CONTRIBUTION

*SmartSense* is based on one or more smartphones, a tablet computer, and (optionally) an ordinary computer with MIDI interface and a musical keyboard. The smartphone is strapped to the user's arm and provides inertial movement measurement data, in particular 3D accelerometer, gyroscope, and magnetometer data. The data of all connected smartphones is streamed via wi-fi to the tablet computer, which may stand on an ordinary music stand, visualizing the sensor signal graphs (see Figure 1). One could, for instance, equip the members of a small ensemble with smartphones to study how the individual members synchronize their movements. If a piano player is part of the ensemble, MIDI data could be streamed to the tablet and be visualized in conjunction with the sensor data. The components automatically find each other in the local network based on *Zero Configuration Networking* (zeroconf); no configuration by the user is necessary.

### IMPLICATIONS

Today's movement measurement systems used in laboratories are either complex, costly, or both. With *SmartSense*, we provide an accessible system that can be used by musicians to examine their movements, thereby gaining practical experience with objective movement measurement. This can help to raise their interest in movement-related research by making a connection to their everyday practice. Although other factors may also play an important role, such as establishing music performance research more widely in music performance and music pedagogy curricula, it is also important that musicians and music pedagogues have access to objective movement measurement so that they can participate and contribute to the field as well.



*Figure 1.* The inertial sensor data captured by the smartphone is streamed to the tablet computer and visualized. Here, the accelerometer sensor data is shown. The three dotted lines mark an acceleration of  $-1g$ ,  $0g$ , and  $1g$ . (See full color version at [www.performance-science.org](http://www.performance-science.org).)

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# Piano education: Purposes and ways

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In this research, the author attempted to foresee the future of some activities involving the piano, relying on examples from its present and past conditions and on statistics from different countries. The main issues that worry pianists and pedagogues today are many, such as the decreasing interest of the concert-going public, a “sportsman-like” approach towards performance by the interpreters, absence of meaning and depth in their interpretations, the beginners’ impatience towards practice, and very low levels of initial and intermediate education in many countries. These factors lead us, the community of professional pianists, to a highly pertinent question: will our profession survive or will we end up without work and, most importantly, without inspiration and demand? This paper is part of a larger work devoted to analysis of the societal attitude towards music in general and the state of pianistic education in Turkey. Also, the fabric of piano repertoire must be compared with modern ideas and thinking and the characteristics of a national approach of the performers from different cultures. The results of such analyses show that piano activity tends to spread to many new areas across the world and has had varying impact on human development.

*Keywords:* piano education; statistics; music schools; conservatories; Turkey

In this article, statistical information concerning musical and piano education is presented, based on examples from countries with different political and religious structures (Bo 2011, Hva 2007).

Also, some of the greatest composers are quoted (Schumann 1970), whose compositions are performed relatively often in our time and whose works are still considered to be relevant to contemporary schools of thought (Velikovich 2002).

The future of electronic musical instruments is also analyzed. The aim of this research is to present an objective view of modern piano education around the world and to predict its development.

### **MAIN CONTRIBUTION**

When observing differing developmental trends of musical education based on geographical location, we see that countries such as Russia, China, and Korea have all benefited from the interest of their respective cultural and financial elite with wide-spread ramifications, namely state subsidies.

#### **The state of music and piano education in different countries**

In 2006 in Germany, with a population of 83.2 million people, there were approximately 950 music schools for children, where over 1 million children were receiving education: the population of children and teenagers between 6-14 years old in Germany was approximately 12.5 million. Every child, according to the education plan in most schools, was receiving an individual lesson of 30 minutes per week. In Russia, with a population of 142 million at that time, there were approximately 5200 elementary music schools, where every child received an individual lesson of 45 minutes, twice per week. The population of one region holding a music school was 28,400 people, with approximately 4000 children up to 14 years old. In South Korea in 2006, with a population of 46 million, there were 13,358 elementary music schools—called “hagwon.” Every child that attended a Korean hagwon received 5 individual and group piano lessons per week, 45 minutes each. A region that had a hagwon, would have a population of 3500 people with 497 children up to 14 years old. Thus we can conclude that the availability of music schools for children in South Korea was around 25 times higher than in Germany and 8 times higher than in Russia (Hva 2007).

In China, since the time of Confucius and based on his tradition of spirituality, music always held a venerated position within society. Already in his time special institutions for musical education started to appear and the musical profession flourished.

After 1978, economic development increased the level of material comfort, which allowed the acquisition of more expensive musical instruments, such as the piano, to become far more common in middle-class families. Acquisition of an instrument and educating the child on the piano became a matter of pride among the middle class. The policy of “being open,” that was led by the Chinese government in the beginning of the 1980s, based on a European model, developed the general education level of the public. This policy

was put in place through many specific policies. Among them was the opening of numerous conservatories and foundation of musical faculties in almost every pedagogic institute and in most universities. In every school of general education, mandatory music lessons were included in the curriculum, which would be either singing or playing the piano. A very intense start was given to building music and opera theaters in almost every city. There were a tremendous number of festivals and competitions organized in the country, where the piano was predominant (Bo 2011).

The common public of Turkey started to familiarize itself with musical education around the time of the establishment of the republic, in 1923, when the Ottoman Empire collapsed. Already in 1924-25 musically gifted young talents were sent to study abroad. The famous “Turkish Five”—5 composers that represent classical music in Turkey—were among those who received education in Europe. They included talented composers such as Ahmet Adnan Saygun and Cemal Resit Rey. Their achievements have been the most notable in Turkey so far.

The founder and the first president of the Republic of Turkey, Mustafa Kemal Atatürk said: “it is necessary to collect the high thoughts and statements of the nation expressing fine emotions and ideas, and to work on them within the general rules of western music. Turkish national music can only evolve in this way” (Tarman 2011).

Already in the first years of the republic, the education reforms divided the musical education into 3 types: general musical education in schools, training of music teachers, and the training of performers.

Currently there are 25 state conservatories integrated in the higher education system of Turkey, a country with a population of almost 75 million people. But only ten of them provide piano education more-or-less consistent with the European standards, starting education from elementary school. Other conservatories are at the stage of formation and in many of them piano education is taught to beginners, but of university grade. After a four-year musical education, the level of graduates enables them to work only as music teachers in public schools.

The availability of a job for conservatory graduates is complicated too. If a graduate does not stay on to work at a conservatory, due to the absence of public music schools, it is practically impossible to find any other state-sponsored work. Another option would be to perform and play concerts, but since concert work for a regular classical musician in Turkey is currently so scarce, it is mostly not possible to make a living from it. The current Turkish government does not consider culture and art to be a primordial need of the people. It is focused primarily on technological progress and increase of the gen-

eral materialistic level of the wellbeing. All these factors decrease the popularity of professional musical education in conservatories.

In the Republic of Bashkortostan, which is the Ural district of the Russian Federation with a population of around 4 million, approximately 70% of the public practice Islam. At the beginning of the 2011-2012 academic year, 120 piano departments in state schools opened their doors for a total number of 8000 piano pupils. This situation naturally creates favorable conditions not only for those willing to get a piano education, but also new jobs and a lot of educated listeners. One other interesting point about the music education in Bashkortostan is that the number of pupils in folk music departments takes second place in the statistical data (National Training Center for Education 2011).

### **Parallels between the popular works of the piano repertoire and modern schools of thought**

In his letter to the composer and piano virtuoso Ignaz Moscheles, Robert Schumann, regarding his own piece *Carnaval*, said: "I added the names of the movements later. Does the music not always satisfy anyway, and is it not sufficient by itself?" (Schumann 1970).

Rachmaninoff in *the unique character of performance* section of his "10 characteristic signs of an excellent piano playing" mentions that "each composition is an entity in itself" (Velikovich 2002).

From the above quotes, we could conclude that knowing and understanding a musical composition is an individual process by itself and is extremely subjective. But now we have an incredible archive of outstanding performances, recordings, and editions at our disposal which can be examined, as well as guidebooks that could provide us with goals and ways to reach the desired musical understanding. The contents of Baroque, Classical, Romantic, and Modern music have also been analyzed by musicologists in a great number of textbooks.

The compositions of the piano repertoire often reflect the dramatic and eventful side of human life; a struggle for freedom against any restrictions or personal dramas. Throughout many years people have learned through performing and listened to and shared many experiences together through music.

Modern public and state structures do their best to harmonize and protect our life to the maximum. Despite this, the constantly increasing availability of training, education, and means of travel do not always enable one to experience the events that inspired the outstanding compositions of the past. Social

problems of modern man are mainly related not to the absence of capabilities, but their abundance and the lack of willingness or ability to use them.

Musical compositions by European composers may often not carry the same meaning for non-European listeners. Many people fall in love with piano compositions as aesthetic objects that serve as a base for expressing their own personal feelings. And their own interpretation inevitably may occur through, as in Muslim countries, the meditative basis of Islamic texts, which are projected through their rhythm and meaning on top of classical compositions, much like a regular prayer call of muezzins.

Turkish national music is quite different to its European counterpart and is highly fascinating. There are 24 unequal intervals in one octave in Turkish traditional national music (Ozkan 2006). One tone can be divided to nine intervals (named *coma*). People who grew up in this musical environment often have great difficulties adapting to the European musical pitch. The finest emotional shades in a musical composition are expressed by these narrow intervals.

Performances are filled with meaning, but not ones Europeans may be accustomed to. In fact, through the lack of understanding of its intended meaning, the performance can seem superficial and even lifeless. The same can be said about performances by pianists from the Far East. One may derive more satisfaction from listening to any music performed by these artists if one is more familiar with their social, psychological, and aesthetic background rather than their emotional one.

### **The future of electronic gadgets in music**

The recent development of electronic instruments plays a positive role in the popularization of piano classes, due to low prices, volume control, and mobility. General pianistic issues, such as smoothness of sound, synchronicity of intervals and chords, finger fluency, and a rich palette of nuances, may gradually be improved on these instruments. If music and sound can be envisioned in one's head, should one study hard for twenty years to be able to reproduce it? In the given case, computer engineering and improved instruments are rendering a large service to mankind. Today, MIDI software and the quality of electronic instruments may be already starting to compete with the natural acoustic way of creating and producing music. And what about tomorrow? The near future may bring the possibilities of communicating with each other by newly composed musical phrases, comparable to today's instant messaging.

It may sound utopian, but both speech itself and writing were developed gradually. And if we take into account the fact that, according to history, the general and special musical education has been around from the inception of education, it may have a higher form of necessity in the development of the human being. Perhaps even to solve problems in a pacifistic way by “spreading fingers like Chopin who never formed a fist” (Brodsky 1976).

### IMPLICATIONS

Based on what was mentioned above, the conclusion one may draw is that musical education in general, with particular emphasis on the piano, has a tendency to expand as a result of many variables. The awareness of specific requirements of each musical territory, based on cultural traditions, is of the utmost importance. Last but not least, the role of technological development and distribution in the optimization of pianistic education may prove highly beneficial.

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# How to explain the process of creating a musical interpretation: The development of a methodology

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Our research aimed to develop a methodology in order to analyze the entire creative process in the work of interpreting a musical piece. We conducted a pilot study with a single case. The first step of our study was to collect our data according to the instrumental work validated by different researchers (rehearsal recordings, verbalization of reflexive questionnaires, observations). Then, we conducted a content analysis of the previously gathered data. As a second step, we used an interview technique inspired by the self-confrontation interview method. All of the data collected were then analyzed through a grounded-theory analysis. Although we used work stages previously mentioned in the scientific literature, we have observed a new work stage we described as *appropriation artistique* or artistic appropriation. In this stage, the subject would associate the abstract sense of musical discourse to his own life experience through the use of analogies and narratives in order to give a more convincing interpretation. The results of our research cannot be generalized, however the methodology developed will lead us, in future research observing several subjects, to study the entire creative process in the work of interpreting an original musical piece.

*Keywords:* creativity; interpretation; methodology; phenomenology; practice

When interpreting music, the professional musician must demonstrate technical mastery, expressiveness, and originality. To understand how to create a musical interpretation is essential to train future musicians, who will be judged in part for creative interpretation. While research on the work of expert musicians has identified the concepts of deliberate practice (Ericsson *et*

*al.* 1993), effective learning strategies (Parncutt and McPherson 2002, Jørgensen and Lehmann 1997), elements which constitute expression (Williamon *et al.* 2002, Juslin and Sloboda, 2010), and described the stages of practice (Chaffin *et al.* 2003), few have explored the creative aspect of interpretation. While Webster (2002), in his general model of creative thinking, has proposed four types of creative products including interpretation, he did not explain the creative process underlying the work of interpretation. However, it should be noted that some authors have studied creativity in the context of musical performances or recordings in a musicological angle (Clark 2012, Rink 1995), though none of them have studied *in situ* the creative process of the work of musical interpretation by expert musicians.

The purpose of this exploratory research was to determine a methodology to study the creation of an interpretation from expert musicians. Thus, the objective of this paper is to present the methodology and results of a case study to describe the creative process of musical interpretation.

## METHOD

### Participants

One of the researchers, also a professional performer, recorded and videotaped himself while practicing an unfamiliar musical piece, in order to identify the contents of each rehearsal.

### Materials

We observed the work of interpretation of a piece for guitar entitled *Why* by Andrew York. The musician did not know the piece, which helped to avoid the presence of a mental model prior to the first reading. We chose a piece of medium difficulty in order to present all the work stages. The piece was also short to reduce the time spent on rehearsals. The subject was instructed to end the experimentation when he would judge the results of his interpretation satisfying.

### Procedure

Data collection was conducted, in the first instance, by videotaping 14 rehearsals with verbalization, combined with reflexive response to a questionnaire. We completed our data collection with the viewing of all video footage by an external observer who described the actions taken by the subject as well as the elements the subject worked on during the rehearsals. The first data collection was then codified (Nvivo8) and subjected to content analysis (Bar-

din 2007). To start, we split the data collected during the rehearsals (content of verbalizations and descriptions of actions performed by the external observer) into four broad categories based on the length of the passages worked on by the subject, drawing from research conducted by Chaffin *et al.* (2003): *short passages* (4 bars maximum), *medium length passages* (5-14 bars), *long passages* (15-34 bars), and *full cleave* (35 bars). Subsequently, we identified the actions performed by the subject and then regrouped them by themes: *reading, structure analysis, selection, evaluation, assimilation, memorization, and visualization*. These themes are associated with more specific *work elements: dynamics, attacks, fingerings, tone, voicing, phrasing, tempo, expression, and inspiration drawn outside of a musical context*. The identification of the object and the length of the passages worked on by the subject allowed us to link the work of the subject to the work stages identified by Chaffin *et al.* The answers to the questions were related to the content of the rehearsals. Furthermore, a second data collection was conducted by self-confrontation interviews (Theureau 2010). To obtain additional data on certain moments where elaboration was necessary or when the subject forgot to verbalize his actions, we conducted interviews using this technique, encouraging the verbalization of the action *a posteriori*, stimulated by viewing excerpts of videotaped rehearsals. To analyze all of the data obtained through content analysis of the rehearsals and the self-confrontation interviews, we used grounded theory analysis (Paillé 1994). The main tool of this approach is the creation of conceptual categories, allowing us to "...raise the analysis to a level of understanding of a behaviour, a phenomenon, an event or an element part of a psychological or social context" (Paillé 1994, p. 160).

## RESULTS

The qualitative content analysis of the first data collection revealed the presence of four specific steps: *scouting-it-out, section-by-section, gray stage, and maintenance*, supporting previous studies (Chaffin *et al.* 2003) but also denoting the presence of a new phase of *appropriation artistique* (artistic appropriation). We also found the formation of a global image of the musical piece guiding the work. Moreover, between rehearsals, the subject began to hear passages of the piece in his head. These memories eventually became longer and more accurate to the point where the subject could reproduce the whole piece in his head. Then, the memories subsided when the subject entered the *maintenance stage*. This suggests that there is "something" happening between rehearsals akin to a form of incubation of the mental representation of the piece, in terms of the creation of the interpretation. Also,

when the subject created a clear and stable mental representation of the structure of the piece and of the right sound, we have identified a stage absent from the literature that we called *appropriation artistique*.

In the stage of artistic appropriation, our subject would seek a feeling of accuracy in the expression (phrasing, dynamics, tone, etc.), corresponding to his global image of the piece. To achieve the expressiveness sought after, the subject connected extra-musical analogies and narratives to the music, making his interpretation more convincing. For example, he used the analogy of *grayness* to designate the sound of a specific chord and the character of the piece, thus improving his technical execution through a gesture corresponding to the emotion (sadness, in this particular case). He also associated emotions (sorrow, regret) to the music and used metaphors to make the musical interpretation more personal and emotional. For the subject, the emotions emerging from these analogies and metaphors during the interpretation of the piece were indicators that the choices he made were relevant, accurate, and coherent. The feeling of authenticity and accuracy of the expressiveness in the interpretation was used by the subject as a criterion of validation of the quality, authenticity, and legitimacy of musical interpretation.

## DISCUSSION

What seemed to be most likely to inform us about our subject's creative process in the work of interpreting a musical piece was the stage of artistic appropriation, characterized by the search for a sense of accuracy and the use of extra-musical material (analogies, narratives) to facilitate expressiveness. Moreover, according to Lubart (2011), analogies and metaphors are the product of emotional connections between a task (in this case, a work of interpretation) and past emotions felt in different situations (in this case, grayness and regret). Thus, we can assume that the character, *with sorrow*, and the title of the piece, *Why*, triggered a form of significance in the subject, and generated what the authors call a *creative association*. Also, according to Guilford (1968), the creation process is characterized by a constant back and forth between convergent thinking (evaluation and analysis) and divergent thinking (analogies and metaphors). Thus, in the construction of his interpretation, we noted that our subject used divergent thinking to generate analogies and narratives, but also used convergent thinking when evaluating his choices of extra-musical materials, before validating with the score or with the title of the piece. Additionally, as these materials allowed the subject to give a personal sense to the musical text and therefore a convincing interpretation of the piece, we can conclude that there are physical effects to the in-

strumental execution. Indeed, researchers argue (Damasio 2010, Bosse *et al.* 2008), that emotions have physical impacts measurable by somatic indicators such as heartbeat, sweating, muscle tone, etc. Consequently, we can explain the role of extra-musical materials in our subject, with the emotions they triggered, as materials that would have altered muscle tone to achieve the expressiveness sought, as was the case to find the sound of the first chord and the character of the piece. The methodology we used (the entire data collected through the videotaped rehearsals, reflexive questionnaires, videotapes described by an external observer, self-confrontation interviews, content analysis, and grounded theory analysis) led us to identify a new stage in the instrumental work. We believe it is reasonable to think that what we call an artistic appropriation of the piece by our subject is an important part of the creative process of interpretation. Although the results of our case study are not transferable, the methodology developed will allow us to explore in future research the entire creative process of several subjects in the work of interpreting an original musical piece.

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# French horn embouchure: An electromyographic facial kinematic study

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This study investigated embouchure-related muscle activities and related facial skin movement in trained French horn players. In relation to pitch and intensity of tone produced, amplitude of surface electromyogram (EMG) from five selected facial muscles and related facial skin kinematics were examined during pre- and post-attack phases. There was no difference in EMGs and facial kinematics between these two phases, indicating importance of appropriate preparation for embouchure formation. EMGs in all muscles increased linearly with an increase in pitch, and they also increased with tone intensity without interacting with the pitch effect. Facial skin movement remained constant across all pitches and intensities, except for lateral retraction of the lips during high-pitch tone production. These findings indicate that contraction of the embouchure-related muscles is fundamentally isometric for flexible sound parameters in order to modulate lip tension and firmness. Horn players seem to have developed a specialized ability to precisely balance facial muscle contraction with inter-oral pressure.

*Keywords:* French horn; embouchure; EMG; skin movement; pitch

Human facial muscles are basically built and developed for speech, mastication, and expressing affections and emotions. The same muscles also play a vital role in singing and playing musical instruments. While playing a brass instrument, muscles located in the middle-to-lower front of the face, throat, and tongue act together to form a playing-related face/lip configuration adjusting to the mouth piece: the so-called “embouchure.” There have been

some attempts to study the functional role of the embouchure-related muscles (Heuser and McNitt-Gray 1991, White and Basmajian 1973). Unfortunately, only qualitative electromyographic (EMG) data were dealt with in these studies, and thus, there was no statistical testing of the results. Quantitative EMG data prior to the tone commencement and during the tone production could explain the control of muscular tension for pitch and intensity modulations. Additionally, information on accompanying skin movement during embouchure formation is also lacking. The purpose of the study, therefore, was to investigate the effects of pitch and intensity on facial muscle activity and facial skin movement during two phases of sound production: prior to tone commencement and during the tone production.

## METHOD

### Participants

Thirteen trained French horn players (mean age=23.2 years) with more than 7 years of horn training each served as participants.

### Materials

Using his/her own French horn with the mouthpiece, each participant performed four sets of three successive 6 second sustained tone productions at different levels of sound intensity (*pp*, *mf*, and *ff*) twice. Each set had a target pitch randomly selected from Bb1, F3, F4, and Bb4 tones. Surface EMG signals from the levator labii superioris (LLS), depressor anguli oris (DAO), zygomaticus major (ZYG), risorius (RIS), levator labii superioris (LLS), and depressor labii inferioris (DLI) muscles on the right side of the player's face were collected using an 8-channel EMG recording system (x 500) and PC sampling at 1 kHz. For the kinematics of the facial skin, 1 mm diameter reflecting markers were attached to the skin over each of the target muscles on the left side of the face (see Figure 1).

### Procedure

Two high-speed digital cameras (sample frequency=50 Hz) were used to record movements of these markers during the experimental tasks. A sound signal was collected simultaneously with the EMG using a sound-level-meter mounted on a wooden frame attached to the side of the horn bell. The mean value of the EMG, the kinematic data for the duration of 375 ms prior to the onset of sound production (the "pre-attack phase" in Figure 2) and 750 ms 3



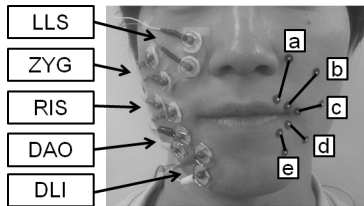


Figure 1. EMG electrode and facial marker placement. EMG electrodes were attached on the right side of the face, and kinematic markers were attached on the left side. Marker-to-marker distance for each muscle: a=LLS, b=ZYG, c=RIS, d=DAO, e=DLI.

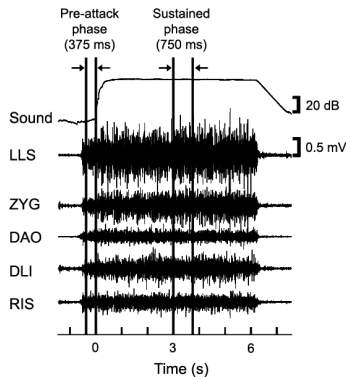


Figure 2. A representative time-history curve of rectified sound and EMG signals for the five muscles examined during Bb<sub>4</sub> tone (466 Hz) with *ff* production task in one participant.

seconds after the onset of sound production (the “sustained phase” in Figure 2) were computed.

## RESULTS

Bursts of EMG in all muscles commonly started about 750 ms before the tone commencement (Figure 2). For example, the mean values of the pre-attack activity duration for DLI at *pp*, *mf*, and *ff* were  $760 \pm 56$ ,  $723 \pm 108$ , and  $766 \pm 189$  ms, respectively. The activity reached a sustained level before the tone commencement, and this pre-activity was also clearly intensity-dependent. EMGs indicated that all muscles examined participated in embouchure formation. MANOVA performed on the EMG data revealed significant main

effects of intensity ( $p < 0.001$ ) and pitch ( $p < 0.001$ ). The phase effect and all of the interaction effects were non-significant. Post hoc univariate tests for each muscle revealed a main effect of intensity for ZYG, DAO, LLS, DLI, and RIS (see Figure 3). Univariate tests also revealed a significant pitch effect for ZYG, DAO, DLI, and RIS. MANOVA on the distance in ten participants revealed a significant main effect of pitch ( $p = 0.032$ ). Univariate tests for each muscle revealed a significant pitch effect only for the markers placed on RIS, which decreased from 92% at Bb1 to 86% at Bb4. The markers placed on LLS and DLI showed elongations by a few percent across all levels of pitch, whereas those on ZYG and DAO showed shortening on average to 95% and 91%, respectively.

## DISCUSSION

The present findings confirmed that pre-attack setting of muscular activity and accomplished skin movement were equivalent to those used during actual production of a tone at varied pitches and intensities. A sound error commonly committed by brass players is unintended pitch at tone commencement, known as an “off-pitch” tone attack. Successful tone production at the intended pitch requires brass players to set their lip tension properly by moving the lips toward their teeth. The proper lip tension is accomplished mainly by contraction of the orbicular oris muscle, while pulling the lips laterally using the groups of perioral facial muscles. This phenomenon can explain the clear pitch-related preparatory activations of the ZYG, DAO, DLI, and RIS in the present study. Findings of a previous study (Fletcher & Tarnopolsky 1999) indicated that the threshold of blowing pressure (BP) required for tone commencement increased in proportion to the pitch. In the present study, the facial kinematic analysis indicated that none of the muscles were lengthened during preparation for tone production at a higher pitch. Therefore, the pitch-related increase in facial muscle activity can also be explained by pre-attack elevation of muscular tension in order to stiffen the wall of the oral cavity to cope with preparatory increased BP. Related to the facial kinematics, the skin over the RIS was shortened in parallel with increased muscular activation during the higher pitch preparation. The present study confirmed that tone intensity is also a preparatory parameter of embouchure muscles. The kinematic analysis of the facial markers further indicated no intensity-related change for all muscles examined. Common problems associated with intensity control among less experienced players are production of sound error, such as an unintended explosive attacking tone for an expected soft tone, and a delayed tone commencement in a high-intensity range. These

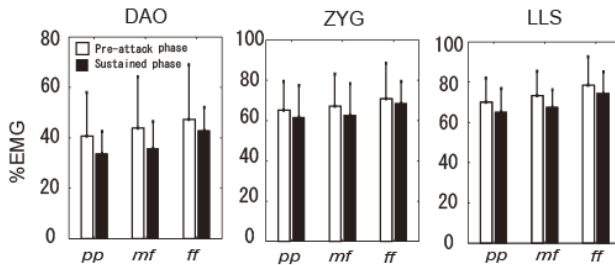


Figure 3. The mean and SD (vertical bars) values of EMG for ZYG, DAO, and LLS at *pp*, *mf*, and *ff* for the pre-attack (□) and sustained (■) phases.

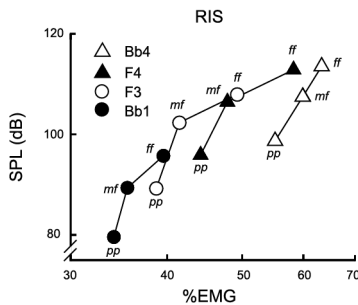


Figure 4. SPL-dependent changes in mean EMG for the RIS muscle. EMG values are shown in a logarithmic scale.

could occur if the prepared embouchure setting and the BP were mismatched. Isometric pre-attack muscular activity that was modulated with the level of BP was thus expected prior to tone commencement. In agreement with this hypothesis, all muscles examined in the present study showed an intensity-dependent change in pre-attack facial muscle activity.

Pitch and intensity independently influenced the level of muscular activity during the sound-sustained phase. There was also no pitch- or intensity-dependent modulation in the marker-to-marker distance, except for the RIS during pitch control, indicating that tone production at a higher pitch or louder intensity demands stronger isometric contraction of embouchure muscles. The level of isometric EMG activation has been known to be approximately proportional to tension developed in the muscles. Our data suggested that the relationship between tension developed in the perioral facial muscles and resonance frequency (RF) of the lips during the current sus-

tained tone production could also be proportional. According to Fletcher and Tarnopolsky (1999) the brass player's lips act as an acoustic generator within a narrow frequency band quite close to their natural mechanical RF, which can be simulated fundamentally by a simple mass-spring model. The RF of the player's lips may then be expressed by a simplified model as  $RF=(MT/EM)^{1/2}$ , where MT is tension of the lip and EM is effective (vibrating) mass. Elliott and Bowsher (1982) deduced that lip mass is inversely proportional to the vibrating frequency, by taking measurements of the mouth-piece pressure while producing various tones at different pitches, estimated average volume flows, and average opening of the lips. It can then be hypothesized that RF of the player's lips is modulated in proportion to MT (Fletcher and Tarnoplosky 1999). The findings of the present study indicated that this relationship was reasonable within the range of tones examined. Intensity of a tone produced is adjusted by changing the rate of air volume blown into the instrument and a corresponding change in BP. The louder the tone is, therefore, the greater the airflow rate and BP at any pitch. Fletcher and Tarnoplosky (1999) demonstrated that the intensity-related increase in BP became stronger during the production of higher pitch, which was also the case in our EMG-SPL relationship (see RIS in Figure 4). Consequently, our EMG data suggests that embouchure muscular tension is also involved in the respiratory function required for the adjustment of tone intensity. Since the present kinematic data showed no intensity-related skin movement, it is most likely that the muscular tension is used for resisting increased BP in order to sustain a constant orofacial posture across all intensities.

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# Upgrading creativity: Dynamics of acting in groups

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The paper aims to examine the role of social factors in the process of creating together in the context of artistic group activities such as performance. The research questions focus on the added value of formatting a group (instead of merely having some people together), the interaction between the participants, and the support and openness of the others. The paper argues on the relevance of social factors such as group dynamics and the support by the group members. The aforementioned factors and features are interpreted by analysis of examples from the field of drama, music, and dance. The analyses make it also clear that group performance can be examined as a creative process. Performing is a creative process heavily influenced by social factors. The process of performing an artwork has a huge complexity. There are many determinants identified. This paper offers a framework to understand the correspondences of the determinant and influencing factors of a successful performance regarding the interpersonal context (relations and the supporting circumstances). The implications to teaching art, music, and drama are also discussed.

*Keywords:* creativity; group performance; group dynamics; social factors; art psychology

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# Model and analysis of individual rehearsals

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This work focuses on the quantitative improvement over time made by a musician rehearsing a specific piece of music. In particular, this study considers the attention paid by the musician alternately to the instrument and the score during rehearsal, in order to describe the evolution of this attention over time, and discusses how this attention is dependent on the musician's ability to memorize. A selection of musicians (playing guitar, bass clarinet, or violin) was made to individually rehearse short pieces (by Beethoven and Bach) up to and exceeding 20 times. The musicians were instructed only to look at the instrument or the score when necessary and otherwise to keep their focus on the camera (to emulate the presence of an audience or conductor). This process was annotated and modeled using UML diagrams, in particular the Use Case diagram. The annotation includes the attention to the score and the instrument, respectively, when applicable. Via these observations, hypotheses are formed and discussed regarding the development of a musician's Long Term Memory (LTM) in relation to the score, as well as how much s/he is able to store in Short Term Memory (STM) while playing.

*Keywords:* music rehearsal; memory; rote learning; UML; guitar

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# Acceleration of dance movements: The master and a disciple of Nihon Buyo

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Toshihiro Irie<sup>2</sup>, and Mieko Marumo<sup>1</sup>**

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*Nihon Buyo*, one type of Japanese traditional dance, needs high-level technique. Therefore, the high skill of the master has been the target of this research using motion capture. The dance of Senzo Nishikawa, who is a national living treasure, was analyzed. The purpose was to acquire aesthetic elements by analyzing dance movements. An optical motion capture system was used to study the movements of the master and a disciple. Senzo Nishikawa and his disciple danced a part of *Musume Doujyoji*. The relative acceleration from the sacrum was calculated at five places, as well as the face, hands, and feet, using motion data. As a result of examining five relative accelerations, two differences between the master and his disciple were observed. Firstly, as the maximum acceleration for every choreography was compared, maximum values of the master exceeded the disciple significantly on the accelerations of both hands and feet. Secondly, in a viewpoint of the envelope on the time variation of accelerations, we found a difference in the method of acceleration. In particular, we found a remarkable change of motion in the master's data, which may have affected visual impressions. Since the liveliness of dance motion related to this acceleration, the validity of investigating acceleration change was supported by this research.

*Keywords:* motion capture system; Nihon Buyo; motion analysis; acceleration; national living treasure

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# Assignment of leadership role changes performers' gaze behavior during piano duo performances

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The purpose of the current study was to examine modulation of gazing behavior and synchronization in piano duos under manipulation of the leader/follower relationship. Three pairs of skilled female pianists who were social equals in everyday life participated in the experiment. The primo and secondo players were located in separate soundproof rooms but allowed visual contact through a glass window. The primo and secondo parts did not signify leader and follower. We video-recorded the performance and analyzed each performer's gaze behavior frame-by-frame. Participants played under three conditions: reversed leader/follower role conditions and a control (i.e. without leadership assignment) condition. The results showed that gaze behavior during music performance was altered in the presence of leadership assignments. Followers' and leaders' gaze durations lengthened and shortened, respectively, with respect to the control condition. Mutual gaze just before tempo changes enhanced synchronization regardless of leadership condition. The timing lag between performers under the leader/follower conditions did not significantly differ from that under the control condition. These results suggest that social relationships between performers influence gaze behavior, although they do not significantly affect visual communication strategies for synchronization.

*Keywords:* leadership; gaze; piano duo; synchronization; role

Various types of visual cues arise during ensemble performance. However, only a few studies have focused on gaze behavior or eye contact, even though many performers have indicated the importance of gaze for several functions. Indeed, performers in popular music bands often make eye contact (e.g. Davidson 2005).

Do gaze behaviors, then, contribute to synchronization? Prior studies have barely observed gaze behavior when performers play pieces with little tempo variation. For example, either anticipation or auditory imagery of performance is essential in musical synchronization (Pecenka and Keller 2009). However, when ensemble performers feel difficulty with synchronization, they employ visual cues to coordinate, and mutual gaze behaviors occur. Williamon and Davidson (2002) observed frequent eye contact at important locations (e.g. new entrances of one or both performers after an extended rest). Kawase (2012) observed frequent gaze behaviors toward co-performers during tempo change points in piano duos, and suggested that mutual gaze facilitates synchronization and captures movement cues. Thus, gaze behavior that seems to contribute to collecting movement cues facilitates synchronization, particularly when performers play a piece that contains remarkable tempo changes.

On the other hand, interpersonal social relationships are crucial to performers' behavior. In musical ensembles, there are various types of social relationships; the leader/follower distinction defines a typical one. Prior studies have indicated that the leader/follower relationship influences non-verbal behaviors and synchronization in ensembles. In some cases, the leader/follower relationship in ensembles is regarded as a musical role (e.g. Goebel and Palmer 2009, Rasch 1988). Furthermore, although the experimental situation differed from that of a musical ensemble, Schmidt *et al.* (1994) suggested that complementary social competence levels seem to produce higher degrees of coordination than matched levels. Those studies' results suggest that performer behaviors vary according to leadership and that such behaviors influence inter-performer synchronization.

We hypothesized that these social relationships influence ensemble performance by affecting performers' gaze behavior. The purpose of the current study was to examine gaze behavior and synchronization in piano duos under manipulation of leader/follower relationships.

## METHOD

### Participants

Three pairs of six female skilled pianists, five of whom were prize-winning, participated in the experiment. They had no regular experience with piano duets. To eliminate any influence of superior-subordinate relationships, the pairs were social equals in their everyday lives.

## Materials

We used *Prologue de Coq'licot* (composed by Yumiko Kano). The piece incorporates two parts: primo and secondo, and nine changes of tempo, during which the two performers must coordinate timing and begin to play simultaneously after a long pause (approximately 1.5-3 seconds).

## Procedure

Each performer was located and played in a separate soundproof room with a glass window. They received a score on the day of the experiment and selected a part: primo or secondo. Primo/secondo part did not necessarily signify leader/follower role in the current study; primo could follow while secondo could lead. Each performer kept playing only one part through all trails. After adequate practice, they played the piece three times using electric pianos (P-155, Yamaha) while receiving auditory feedback via loudspeakers under three conditions: a control condition (i.e. without instruction), with a player assigned as leader, and with another player assigned as leader. The participants began to play without guidance (such as a metronome) after the experimenter asked they begin to play. When the instruction “play as a leader” was ambiguous for participants, the experimenter explained leader by using examples such as “band master.”

We analyzed the occurrence of gazing behavior by using a behavior coding system (IFS-18C, DKH). To obtain the correct data without disturbing the players' performances, we adopted the observational method of Argyle (1994), analyzing footage of performers' behavior captured by a camera (NTSC standard) located behind a co-performer. We measured tone lag between performers using *Sound Forge* (Sony Pictures Digital Inc.) with reference to the waveform and sound, which were recorded in separate tracks. The measurement precision was under 1 ms.

## RESULTS

We examined gaze behavior around tempo changes (i.e. the moments of coordination when performers' gaze toward their co-performers occurred the most under each condition). We analyzed the period within 3 seconds before and after the moment of coordination (i.e. tone onset). The results demonstrated that each performer frequently looked toward the co-performer just prior to tempo changes.

We compared average duration of gaze toward the co-performer among all conditions (see Figure 1). Average duration was 0.91 seconds in the control

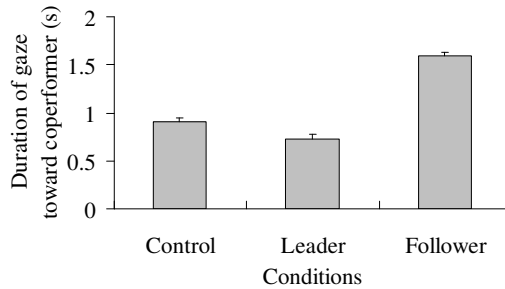


Figure 1. Duration of gaze toward co-performer. Error bars represent standard errors.

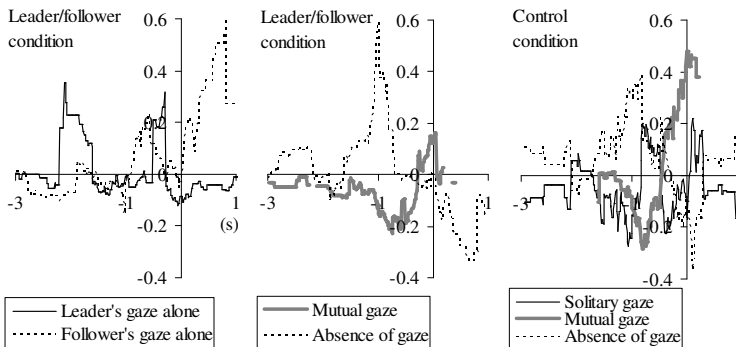


Figure 2. The point biserial correlation coefficient under leader/follower condition and control condition. The horizontal axis represents the timing of performance sound (zero means starting time of performance sound). The vertical axis represents the point biserial correlation coefficient.

condition. The leader's average duration of gaze toward the follower was 0.73 seconds, whereas the follower's duration of gaze toward the leader was 1.59 seconds. An ANOVA on gaze duration among conditions showed significant differences ( $F_{1,88,303.26}=160.39$ ,  $p<0.001$ ). We conducted multiple comparisons and confirmed significant differences among all conditions (Bonferroni's method,  $p<0.05$ ).

The average timing lags between performers were 77 and 74 ms under the control and leader/follower conditions, respectively. A t-test for timing lag showed no significant differences between the two conditions. Next, we analyzed the influence of gaze behavior on timing coordination. We coded per-

formers' gazing behavior as mutual gaze, solitary gaze, and absence of gaze and binarized those variables (occurred [1] or did not [0]). We calculated the point biserial correlation coefficient (i.e. Pearson's product-moment correlation coefficients to the binarized variables) of timing lag and the binarized value of gaze behavior at each moment of coordination (see Figure 2).

The results showed that the correlation coefficient of mutual gaze was significantly low just before the moment of coordination under all conditions. The minimum values of mutual gaze under the control condition were  $r=-0.28$  ( $p=0.011$ ). The minimum values of solitary gaze were  $r=-0.273$  ( $p=0.01$ ). The minimum values of mutual gaze under leader/follower condition were  $r=-0.23$  ( $p=0.003$ ). Simultaneously, the correlation coefficients of both the leader's and the follower's solitary gaze behaviors had positive or near-zero values.

## DISCUSSION

The results suggest that followers' gaze durations at co-performers became longer, whereas those of leaders became shorter than those under the control condition. Under both the control and leadership conditions, mutual gaze just before tempo changes enhanced synchronization. This suggests that social relationships between performers influence gaze behavior, although they do not significantly affect visual communication strategies for synchronization.

Under the leader/follower condition, the duration of the follower's gaze towards the leader was longer. What, then, is the significance of the long duration of followers' gazes? One possible explanation is that followers might try to catch leaders' movement cues more eagerly than leaders tried to do. Prior studies of piano duo performance have suggested the importance of movement cues for synchronization (e.g. Goebel and Palmer 2009). These findings suggest that gaze behavior is related to the perception of movement cues. Thus, followers looked toward leaders more frequently because they might have to coordinate with leaders by employing movement cues.

Mutual gaze just prior to tone onset may facilitate coordination regardless of leader/follower relationships. When performers looked toward one another just prior to onset of tone, lag of tone between performers was smaller under all conditions. This result is consistent with those of previous studies. Kawase (2012) investigated piano duo performances in which performers had equal relationships and found that mutual gaze just before the onset of tone facilitates synchronization. Thus, leader/follower relationships may not influence the correlation between gaze and synchronization, although it alters gaze behavior between performers.

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# Understanding relationships between music and EFL learning

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Music is commonly used in the EFL (English as a Foreign Language) classroom. Although relationships between music and second language learning have been explored, little is empirically understood about relationships between music and EFL learning/teaching. Various types of classroom-based investigations, which target Japanese EFL learners, have been conducted in an attempt to elucidate such relationships, especially focusing upon important learning/teaching elements in the EFL classroom, such as general listening, sound discrimination, and vocabulary learning. It has been found, for example, that (1) there is a statistically significant relationship between the amount of listening to music when learning English and general listening proficiency ( $N=59$ ,  $r=0.39$ ,  $p<0.05$ ) and (2) the combination of three language-related variables (listening-based vocabulary power and perceptual discrimination performance of English vowel and consonant minimal pairs) and one music-related variable (the experience of musical instruments in childhood) generates the highest predictive power to explain the variance of general listening proficiency ( $N=59$ ,  $R^2=0.32$ ,  $p<0.01$ ). In the paper, based upon the results of two classroom-based investigations conducted in 2012 and 2013, the nature of relationships between music and EFL learning/teaching elements, including interactions between music-related and language-related variables, are discussed.

*Keywords:* musical ability; EFL learning; listening proficiency; sound discrimination; interaction

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# Learning to perform in older adulthood: Implications for physical and mental wellbeing

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Western society is rapidly changing with the ratio of older adults constantly increasing, making their contributions to society even more vital than before. Therefore, strategies enabling them to maximize their potential of living healthy, independent lives while minimizing the need for long-term (nursing) care are growing in importance. This exploratory study, a strand of the *Rhythm for Life* project at the Royal College of Music, London, investigated the role that music could play as such a preventive strategy. The study used a quasi-experimental mixed-methods design with 72 participants aged 50 years and older, and an age-matched control group. Participants were grouped into either experimental (learning an instrument) or control (activity as usual) groups, and assessed at baseline level and after ten weeks. Qualitative data were obtained through observation, as well as an individual case study, and quantitative data through established self-report assessment questionnaires. Results presented a positive impact of learning an instrument and making music on older adult learners, especially an improvement in mental wellbeing and hand flexibility.

*Keywords:* making music; older adults; wellbeing; stress management; flexibility

The number of people aged sixty and above is expected to double by 2050 and surpass the number of younger citizens (United Nations 2009). Consequently, (Western) society will increasingly depend on the contributions this significant part of the population is able to make. The importance of finding preventive strategies to reduce or delay age-related decline becomes an increasingly relevant priority for public health. Cognitive and physical decline (slower reaction time, decrease in perception, memory and motor skills) are common with increasing age and associated with a decline in motivation and

natural withdrawal from (social) activities and a lower quality of life (see Figure 1). Research has examined these challenges in various ways, both (1) on a neurological level and (2) with more subjective variables (e.g. quality of life).

Making music is an ideal tool in this context due to its role as a popular leisure activity. While neurological evidence shows that engaging with music can enhance the aging brain's cognitive abilities, qualitative research demonstrates an improvement of quality of life and an increase in self-fulfillment and wellbeing (VanderArk *et al.* 1983, Zelazny 2001, Hoyos *et al.* 2003, Bangert and Altenmüller 2003, Hays and Minichiello 2005, Cohen *et al.* 2006, Bugos *et al.* 2007, Perkins and Williamon in press). To test this in regards to learning a musical instrument, the current investigation was undertaken as a strand of the *Rhythm for Life* study at the Royal College of Music, London (RCM; see Perkins and Williamon in press). It explored: (1) does learning an instrument for a 10-week period have an influence on the subjective wellbeing of a group of older adults, and (2) in this setting, does making music influence (a) stress management, (b) flexibility (overall flexibility and flexibility of the fingers), and (c) intake of medication (prescription and over-the-counter).

## METHOD

### Participants

The study was conducted for a 10-week period (May 2011 to June 2011). Participants included 72 older adults between the ages of 54-90 ( $M=68.75$ ), divided into an experimental and a control group. Participants of the experimental group ( $n=40$ ) followed a program of free instrumental lessons on the guitar ( $n=9$ ), keyboard ( $n=18$ ), recorder ( $n=8$ ), or drums ( $n=5$ ), taught either one-to-one or in small groups by RCM students. Control group participants ( $n=32$ ) with a mean age of 64.90 were asked to simply follow their normal activities.

### Materials

Specially compiled teaching materials were provided by the RCM designed to ensure some continuity between different teachers and to enable the adult learners to finish their 10-week course with a semi-public concert. Musical instruments were provided free-of-charge by the RCM. Quantitative data were collected through questionnaires and comprised (1) demographical data, (2) the Short Warwick and Edinburgh Mental Health and Wellbeing Scale (SWEMWS; Stewart-Brown *et al.* 2009), and (3) the Health-Promoting Life-



Figure 1. Effects on learning an instrument as an older adult on perceived quality of life.

style Profile (HPPL-II; Walker *et al.* 1987; from the six subscales only stress management was considered). Four-point Likert scales gathered data for the variables (4) flexibility and (5) medicine intake. Qualitative data were obtained through observation of the keyboard group ( $n=6$ ) as well as an individual case study: a sixty-six year old participant with osteoarthritis.

## Procedure

Sixty-minute music lessons were offered on a weekly basis for a period of 10 weeks. Data were collected at base level and post intervention.

## RESULTS

The experimental group's mental wellbeing scores increased from pre- (median=23) to post-test (median=25.5), with a statistically significant difference in the keyboard sub-group ( $t_{17}=3.18$ ,  $p<0.05$ ; see Figures 2 and 3). Stress management improved significantly over time (pre-test  $M=2.20$ ,  $SD=0.52$ ; post-test  $M=2.3$ ,  $SD=0.54$ ;  $F_{1,58}=6.38$ ,  $p<0.05$ ). Hand flexibility improved significantly ( $Z=-3.69$ ,  $p<0.05$ ), which was supported with data from the keyboard group and case study. The positive trend for overall flexibility was too small to be significant. Data from both medicine intakes did not change.

No changes were detected in the control group (pre- and post-test), which consistently rated highly across all variables and was not overtaken in rating by the experimental group.

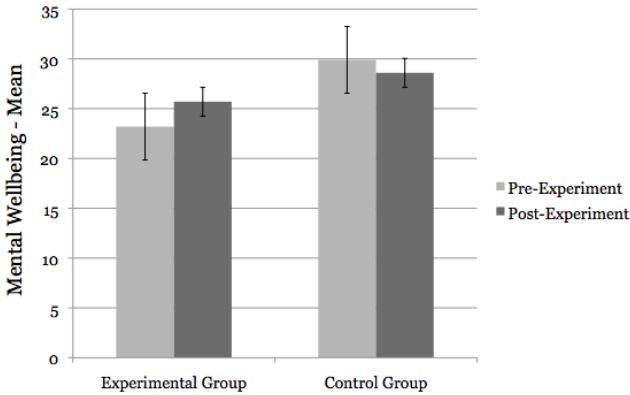


Figure 2. Mental wellbeing pre- and post-experiment.

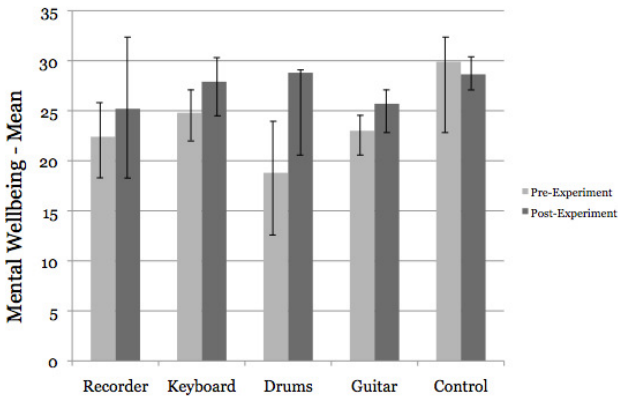


Figure 3. Mental wellbeing pre- and post-experiment (individual groups).

## DISCUSSION

It is reasonable to suggest that the improvement in wellbeing, hand flexibility, and stress management among the experimental group was connected to the fact that music lessons provide an enriched environment and active social life. This challenged participants into complex interpersonal exchanges and created a sense of purpose in old age as well as a meaningful social role (Burt-Perkins and Williamon 2011). Data from both groups suggest the importance

of social interaction in terms of wellbeing in old age, and observational data showed that pursuing lessons acted as a motivation that overcame even high pain thresholds. In turn, these mechanisms may relate to the maintenance or promotion of an efficient neural network and build a cognitive reserve (Hultsch *et al.* 1999), and may also have a neurohormonal influence on reducing stress (Fratiglioni *et al.* 2004). Further research is needed in these areas. The lack of improvement in overall flexibility might be attributed to the short timeframe or the lack of posture correction.

A limitation of the study was the assessment through self-report, which may be subject to recall bias or unwillingness of full disclosure as seen in the analysis of medicine intake data. Another limit was that the study did not take the long-term influence into account. Current changes in wellbeing might have partly been a result of life-long patterns. However, intervention trials show that an increase in health and wellbeing through social and other activities in older adults has shown promising results even over a short period of time. It appears very likely that the greatest effect is achieved through the accumulation of benefits over a lifetime, as also suggested by the data from the control group who were typically active and engaged in social activities (Fried *et al.* 2004, Carlson *et al.* 2008). Further studies on older musicians would be valuable to establish the cumulative effect. This study provides preliminary evidence that making music within a ten-week timeframe can help to improve wellbeing and aspects of health in older adults.

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# Flexibility in the use of shared and individual performance cues in duo performance

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We compared the *performance cues* (PCs), i.e. mental landmarks, reported by members of an established cello/piano duo in two concert performances of the F. Bridge *Cello Sonata*. We examined *overlap* between reports for *individual* and *shared* PCs and for both (*all* PCs). For the cellist, overlap across performances was higher for all and individual (35%) than for shared PCs (19%). For the pianist, overlap was highest for all (23%), lower for shared (15%), and lowest for individual PCs (6%). Both musicians prepared more PCs during practice than they actually used in any one performance, using them flexibly to achieve stability in performance. Differences between the musicians may have reflected differences in their musical roles or temperaments.

*Keywords:* Music performance; memory; performance cues; duo performance; performance stability

*Performance cues* (PCs) are the landmarks in a piece of music that a musician thinks about during performance. They provide a mental map of the piece that allows the performer to monitor the music as it unfolds. PCs are prepared during practice so that they come to mind automatically on stage, giving the musician the ability to focus on each aspect of the piece at the right moment, and providing the flexibility needed to cope with the varying demands of different performances. Musicians' use of PCs has been documented in longitudinal case studies in which experienced performers recorded themselves as they prepared new pieces for performance and then reported the PCs that they used. Their practice, performances, and written recall all suggested that PCs were prepared during practice and acted as memory retrieval

cues during performance (Chaffin *et al.* 2002, Chaffin 2011, Ginsborg *et al.* 2006).

We compared the PCs used by the two members of an established cello/piano duo for two concert performances of the same piece given eight days apart. The cellist had noted that, when playing with the pianist, performances tended to be more different from one time to the next than she was accustomed to with other duo partners that she played with regularly. The two musicians sought to understand this perceived variability by examining the overlap in their PCs, both across performances (*stability*) and with each other (*agreement*). If the pianist's PCs were less stable, this might explain the cellist's impression that their performances together were unusually variable.

We examined stability and agreement for both *individual* and for *shared* PCs. *Shared* PCs direct attention to coordination with other musicians. *Individual* PCs refer to aspects of the music that require attention (such as basic technique, interpretation, expression, structure), irrespective of the other musician. We expected agreement to be higher for shared than for individual PCs.

In the only previous study to examine the use of shared PCs, a singer and conductor reported the PCs they had each used in performing an ensemble chorale work (Ginsborg *et al.* 2006). The musicians first reported their individual PCs, and then jointly reported their shared PCs. This procedure naturally produced perfect agreement on shared PCs. Since one goal of the current study was to compare the overlap of individual and shared PCs, the musicians in our study reported their shared PCs separately, without first comparing their reports.

The one previous study to examine the stability of PCs across performances found that the individual PCs used by a singer in two performances overlapped by approximately 35% (Ginsborg and Chaffin 2012, Ginsborg *et al.* 2013). Although the degree of overlap was reliably greater than chance, it was far from perfect; most PCs in the two performances were different. This instability may have been due to the long interval between the two performances (18 months) and their different circumstances. The first, before a live audience, was thoroughly prepared, while the second, in the practice studio, occurred with minimal rehearsal. One goal of our study was to see whether such instability is a normal characteristic of PCs. Our second goal was to see whether stability was different for the two musicians.

## METHOD

### Participants

The two musicians had been performing together for several years. Tânia Lisboa, the cellist and first author, was trained in classical cello and piano in Brazil, England, and France, and currently lives in London performing as a cello soloist. Cristina Capparelli Gerling, the pianist and fourth author, was trained in classical piano in Brazil and the US, and is Professor of Music at the Federal University of Rio Grande do Sul (Brazil), where she performs regularly both as a soloist and as a chamber musician.

### Materials

The musicians selected the first movement (*Allegro ben moderato*) of the F. Bridge *Cello Sonata* (1917) from a program that they were currently playing together. Bridge's seldom-performed work is one of the greatest in the cello/piano literature. It expresses the desperate and tumultuous response of a pacifist to the Great War, alternating, with great mastery, between pastoral innocence and noble grandeur, between acerbic *scherzandos* and profound melancholy. These shifts in mood must be delineated by the musicians, chiefly through fluctuations of tempo. The movement is 291 bars in length, mostly in 2/2 time, and takes approximately 10 minutes to perform.

### Procedure

For this piece, the cellist played from memory and the pianist with the score. Following their usual practice, the musicians met prior to their first concert for a week of intensive rehearsal. In this case, they gave four concerts in the eastern US over a two-week period. On the day after the second and fourth concerts, a week apart, the musicians reported the PCs that they had attended to during the previous day's performance. The musicians completed their reports separately, without consulting each other. Using clean copies of the score, they marked the musical features they had attended to with arrows and annotated them to indicate which aspect(s) of the music were involved: basic (technique), interpretive, expressive, structural, or shared. Both musicians were accustomed to reporting PCs, having previously done so in other studies of their solo performances.

We tabulated the presence/absence of each type of PC in each bar. We tallied overlap by counting the number of bars where PCs were present in one, both, or neither report. Overlap between each musician's reports for the two performances reflected stability. Overlap between the two musicians for

the same performance reflected agreement. We tallied overlap separately for all PCs, individual PCs, and shared PCs. Fleiss' Kappa provided a numerical assessment of overlap, with values ranging from 0 to 1.

## RESULTS

There was a moderate degree of stability across performances (Figure 1, top rows) and somewhat less agreement between the two musicians (Figure 1, bottom rows). Agreement was higher for the second performance than the first. Both stability and agreement were generally highest for all PCs, intermediate for shared PCs, and lowest for individual PCs. The stability of the cellist's individual and all PCs was the exception: Kappa=0.35 for both. This is the same level of stability observed by Ginsborg *et al.* (in press), for whom Kappa=0.346, by our calculation.

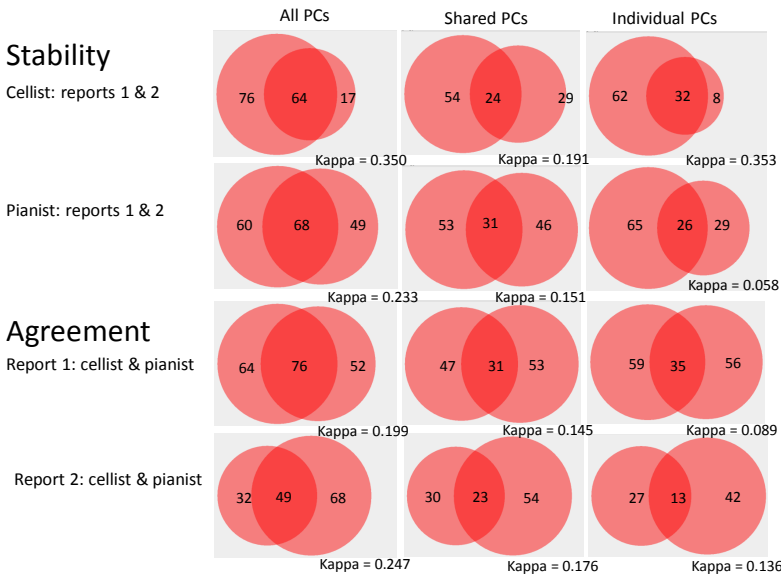


Figure 1. Overlap between PCs for two musicians and two performances for all PCs, individual PCs, and shared PCs, showing stability across performances and agreement between musicians. Areas represent number of PCs reported (Chow and Rodgers 2005). (See full color version at [www.performance-science.org](http://www.performance-science.org).)

## DISCUSSION

The stability of all PCs across performances was similar to that observed by Ginsborg *et al.* (in press). In both studies, the overlap of PCs across performances was well above chance levels, but many more PCs differed across the two performances than remained the same. In Ginsborg's study, this instability could have been due to the large differences in the setting and circumstances of the two performances. In our study, settings and circumstances were about as similar as any two performances are likely to be: one week apart, in similar settings, before similar audiences.

The moderate level of stability in the two studies suggests that substantial variation in PCs from one performance to another is normal. It seems that musicians routinely prepare substantially more PCs during practice than they actually use in any one performance and use them flexibly to achieve consistency in performance. PCs maintain the stability of the performance by allowing the musician to adapt to changes in circumstances, both large and small. In Ginsborg *et al.*'s (in press) study, the differences between the performances were substantial; in our study they were minor. Stability was similar in both cases, suggesting that this level of flexibility is a normal characteristic of PC use.

The pianist's PCs were less stable than the cellist's. The difference was smaller for shared and for all PCs (4% and 10% respectively) and largest for individual PCs (30%). The difference provides a possible explanation for the cellist's impression that performances with the pianist differed more from one time to the next than her performances with other duo partners. Other explanations for the difference between the two musicians cannot, of course, be ruled out by this one study.

As with stability, agreement between the two musicians was above chance levels, but far from unanimous. Agreement was higher for all than for shared or individual PCs. It appears that the two musicians often disagreed about which PCs were shared and which were individual; a PC that was shared for one was individual for the other, and vice versa. The lower agreement for shared and individual PCs may reflect the shifting roles of the two musicians as first one and then the other was assigned the musical focus by the composer. The musician taking the focal role might be more likely to think of a PC as individual, while her partner was more likely to think of it as shared.

The pianist reported more shared PCs than the cellist and this difference was more pronounced in the second performance (see Figure 1, column 3, rows 3 and 4). We speculate that this was because, by the last performance and having successfully completed three previous performances, the pianist

had a clearer idea of how the two instruments could work together to achieve the musical possibilities of the piece. If we are correct, then this provides an example of PCs changing in response to the conditions of the moment.

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# New limits of musical art expression: Serbian concept of interaction in the classical art form

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The communication between the performer and the audience is very rare on the Serbian classical music scene. This is why the steps in this direction, taken by a small number of artists, are very important. An interactive concept in this form means that the listener has to come rested to the concert in order to be able to participate. It is possible to achieve direct contact successfully with the audience on several communication levels by applying multiple instruments and theatrical elements. This results in the converging of elitist and populist aspects in the classical musical expression, thus expanding the limits of perception of artistic reality. The classical concert is facing a shrinking audience in the contemporary Serbian society. This results in the need of introducing elements from the global classical music scene in order to attract the audience back to the concert halls and acquaint the contemporary Serbian audience with the classical forms. The appearance of modern forms of performance on the classical music scene in Serbia marked the beginning of the twenty-first century. The newly acquired openness of this genre towards a variety of other arts led to a multidisciplinary approach to well-known musical forms. This resulted in direct contact between performers and listeners, on the audio as well as visual level.

*Keywords:* performing praxis; musical elitism; multiple instruments, interactive concept, interdisciplinary approach

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# The relation between the key and performance motion on the keyboard instrument

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We examined the performance motion of a professional pianist conveying Juslin's five emotions and an emotionless condition using a motion capture system. C major was used as the key for the performance task. We examined each center of gravity using the recorded trace. As a result, there was a difference in the emotional expression of the performance in the head and upper arm. In addition, movement conveying positive emotion was described as circular from the rear viewpoint.

*Keywords:* motion capture; emotion; keyboard instrument; body part; key

We examined performance on a keyboard instrument using a motion capture system. This study analyzed movement corresponding to each emotion during the performance. Davidson found that the movement of the head was important in pianists' performance expression (Davidson 1994). Castellano *et al.* (2008) examined emotion and motion by the pianists using video. In the results, the velocity of the head most significantly influenced the emotional expression. Thompson's (2012) study measured piano performances using optical motion capture. The study examined four different performance conditions. The results showed an association between performance intention and body part. In this research, we examined the performance motion of five emotions (as established by Juslin 2001) and an emotionless condition by a professional pianist using a motion capture system. The system allowed a detailed examination of correspondence between expressed emotion and physical motion through a trace of each center of gravity.

## METHOD

### Participants

Our subject was a professional pianist.

### Materials

We measured a keyboard performance in university classroom on a CASIO CTK-810 keyboard.

### Procedure

The performance task used simple music for beginners in the key of C major (see Figure 1). The pianist performed while expressing the five emotions (happiness, tenderness, anger, sadness, fear) used by Juslin (2001), as well as an emotionless performance. After a four beat count-in the pianist performed each condition at 90 bpm, playing the same melody in both hands.

In motion capture, reflective markers are attached to a person's upper body and multiple infrared cameras are used to detect the positions of these markers in three-dimensional space. These positions are output as a temporal series of absolute spatial coordinate values. The experimental apparatus was configured using a Motion Analysis MAC3D motion capture system with 6 Raptor-H cameras (frame rate=100 fps, shutter speed=0.5 ms). We used a total of 34 markers on the upper body and keyboard (see Figure 2).

The analysis section was from the beginning of the first sound to the end of the last sound. To investigate how the pianist moves the upper body, we calculated his center of gravity. This was calculated by modeling the upper body as a collection of 8 parts (head, torso, upper arms, forearms, hands), using the center of gravity position of each part, i.e.  $P_g(x_g[i], y_g[i], z_g[i]; i=1, 2, \dots, 8)$ , the mass-center ratio  $m(i)$ , and the position data of each part of the body obtained from the motion capture data. The center of gravity position of each body part was calculated using the equation in Figure 3.

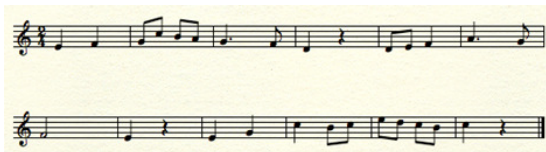


Figure 1. Performance task.

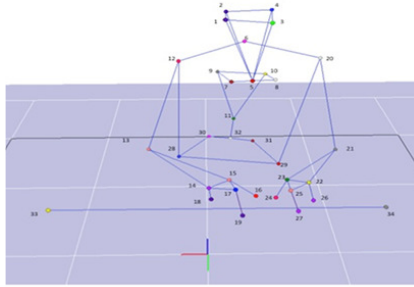


Figure 2. Marker adhesion position. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

$$\begin{bmatrix} x_g(i) \\ y_g(i) \\ z_g(i) \end{bmatrix} = (1 - m(i)) \begin{bmatrix} x_s(i) \\ y_s(i) \\ z_s(i) \end{bmatrix} + m(i) \begin{bmatrix} x_e(i) \\ y_e(i) \\ z_e(i) \end{bmatrix}$$

Figure 3. Calculation of center of gravity for each body part. The positions  $\text{Psi}(x_s[i], y_s[i], z_s[i])$  are the start positions of each body part, and the positions  $\text{Pei}(x_e[i], y_e[i], z_e[i])$  are the end positions of each body part.

## RESULTS

The traces for each condition are shown in 3D. The emotionless condition can be seen in Figure 4.

Movement during each expressed emotion can be seen from the lateral direction in Figure 5. As can be seen, the greatest movement was recorded during the happiness condition, followed by tenderness, anger, sadness, fear, and finally the emotionless condition. Positive emotions used big movements, while negative emotions used small movements. The head and upper arm showed the most movement across all conditions, while the forearm, hand, and torso showed the least.

The same movements can be seen from behind in Figure 6. The results mirror those from the lateral direction, though when viewed from behind the positive emotions were often conveyed via circular motions of the head and upper arm. Conversely, the negative emotions translated to sideways movement.

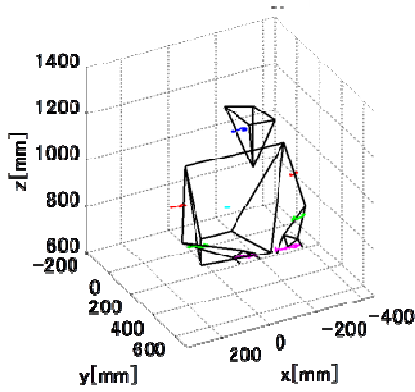


Figure 4. The trace of the emotionless playing in 3D.

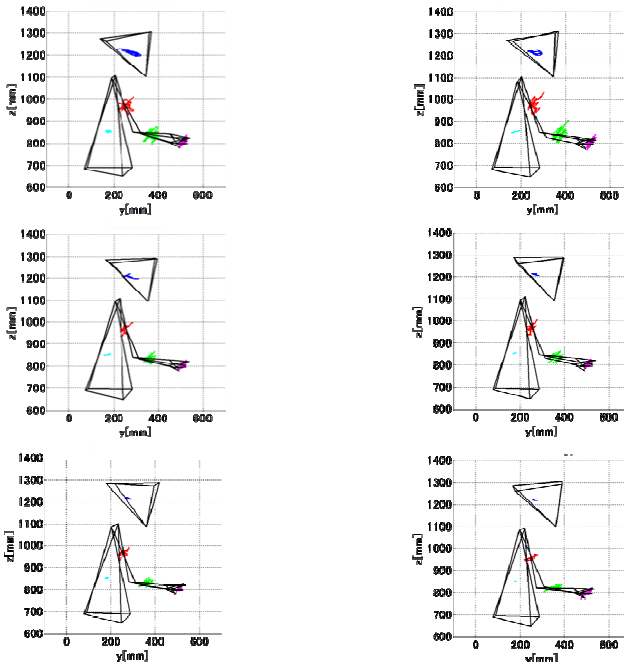


Figure 5. Lateral view: happiness (top left), tenderness (top right), anger (middle left), sadness (middle right), fear (bottom left), and no emotion (bottom right). (See full color versions at [www.performancescience.org](http://www.performancescience.org).)

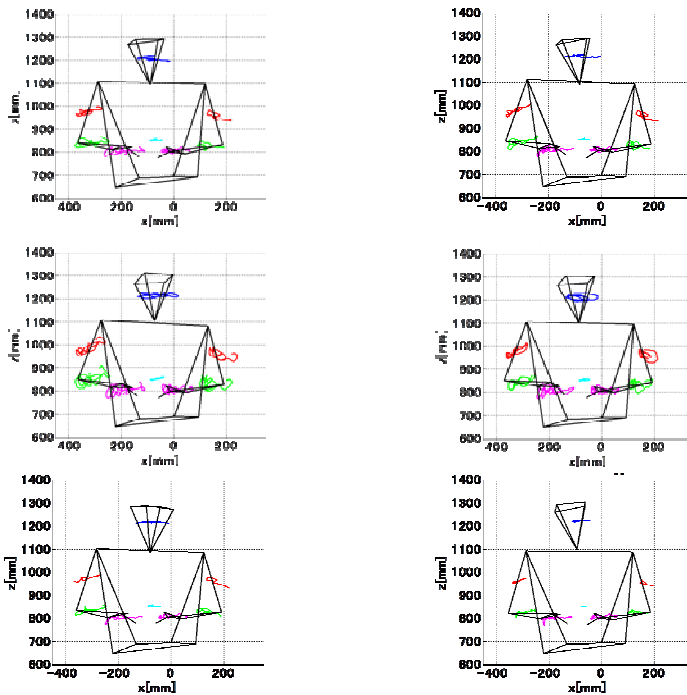


Figure 6. Rear view: happiness (top left), tenderness (top right), anger (middle left), sadness (middle right), fear (bottom left), and no emotion (bottom right). (See full color version at [www.performancescience.org](http://www.performancescience.org).)

## DISCUSSION

This study examined the association between emotion and movement of the body parts during a keyboard instrument performance. There was a difference in the emotional expression of the performance in the head and upper arm. In addition, movement conveying positive emotions could be described as circular when viewed from behind. However, as this result may be influenced by the music, future research will examine whether these movements can be replicated using different repertoire.

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# Embodying and learning individual creative methods: Sharing ideas and images for the interdisciplinary collaboration art project

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This ongoing art project is led by experts from a wide range of different academic disciplines who are normally teaching in separate departments of the College of Art, Nihon University. The project aims to realize artwork through deeper, substantial interdisciplinary collaboration. This year, as the first step, it is focusing on some forms of experimental performance, which are co-produced by external professional performers, such as dancers and actors. For this purpose the project emphasizes experimental workshops during the production until the final presentation. The workshops are based on unique and creative methods derived from the subtle perception and experiences in the creative processes of individual experts. All academic experts provide workshops with the performers for the other members. These workshops enable the various contributors to share and learn from each other's experience to find deeper ideas and contribute toward creative processes intensively and productively. It is important to record and describe processes, making use of various types of metadata: words, sounds, sketches, pictures, and video, so that participants can verify their own creative processes and methods objectively.

*Keywords:* interdisciplinary collaboration; cross-disciplinary production; workshop; learning creative methods; describing process

Today it is not always possible to define the style of artistic expression in a wide range of artistic fields, such as performing and fine arts. It is not uncommon that a creative expert passes above and beyond his own ordinary field and works together with others from different fields by sharing the same technology. Advanced technology makes it easier to share creative ideas. However, most of such cross-disciplinary collaborations concentrate first on audiovisual effects as provocative and spectacular approaches derived from technical aspects. Those often involve risks in sharing technical interpretation and its know-how. Such collaborations are often developed by cutting-and-pasting ideas.

However, creative methods are essentially rooted in subtle experiences and a unique understanding of the individual creator in each creative process. Such differences of experience determine concrete details and the meaning of the work. As it is not easy to visualize them, make them audible, make them tangible, or put them into words, it is very hard to explain how individual creators develop their imaginations or develop effective models for how different types of creators can share ideas to develop their imaginations under mutually respectful influences.

This project aims to explore the realization of high-quality experimental and controversial performance through deeper, substantial interdisciplinary collaboration. It shows how to develop the practical procedure from experimental workshops to the final performance as a public showing on the stage.

## **METHOD**

### **Participants**

This year seven professors from different departments of the College of Art, Nihon University, led this collaborative art project. This interdisciplinary team consisted of members from artistic fields such as spatial design with sequential images, music informatics, applied theater, cultural anthropology, performance photography, video art, and literary theory. Three or four professional performers (dancers and actors) co-produced the project. Each professor is teaching an experimental workshop for cross-disciplinary creation with performers. Young artists and students from various art fields can take part in all workshops. Young production managers as project participants also accompany the whole creative process under external professional supervision.



## **Materials**

The important part of the project consists of experimental workshops, which are organized from different creative fields. The results of the workshops will be presented in the exhibition of conceptual works and the pre-showing of the performance in the university gallery space. The final performance will be on the stage of university hall, followed by several public discussions.

Each experimental workshop aims to embody and teach individual creative methods. All of the participants from different fields should take part in all of the workshops, independently of their specialized areas. Thereby they can experience the individual artistic attitudes and creative methods of others. Through this process, they will develop a common vocabulary of words and images for the development of collaborative work.

The project emphasizes analyzing creative processes. Various kinds of metadata such as words, sounds, sketches, pictures, and video are gathered throughout, so that participants can verify their own creative processes and methods objectively. They also have to make some form of description of their perception, experiences, and development of ideas each time. They practice sharing topics, ideas, and images with utilization of metadata, and discuss them.

## **Procedure**

The project will follow the following procedure: (1) first experimental workshops, (2) exhibition and pre-showing, (3) second experimental workshops, (4) third experimental workshops, (5) final presentation as an experimental performance on stage, and (6) description of creative processes and discussion (see Figure 1).

The first experimental workshop consists of four different parts: three workshops for conceptual works and a lecture of theory of bodily expression. Those reflect aspects of dramaturge, visual and sequential images, and sound and acoustic images. Each creative expert co-operates in a workshop with performers, dancers (choreographers), and actors. It focuses especially on how to discover the themes and on how to share ideas for spatial experience based on visual and sound concepts and images. Young artists, creators, and performers from different artistic fields can participate. They attend all of the workshops to learn creative attitudes and methods, which experts provide from each field.

Materials of the conceptual works discovered in the first series of workshops will be exhibited in the gallery space of the university. During the exhibition fragmental short pieces of performance, which were developed from

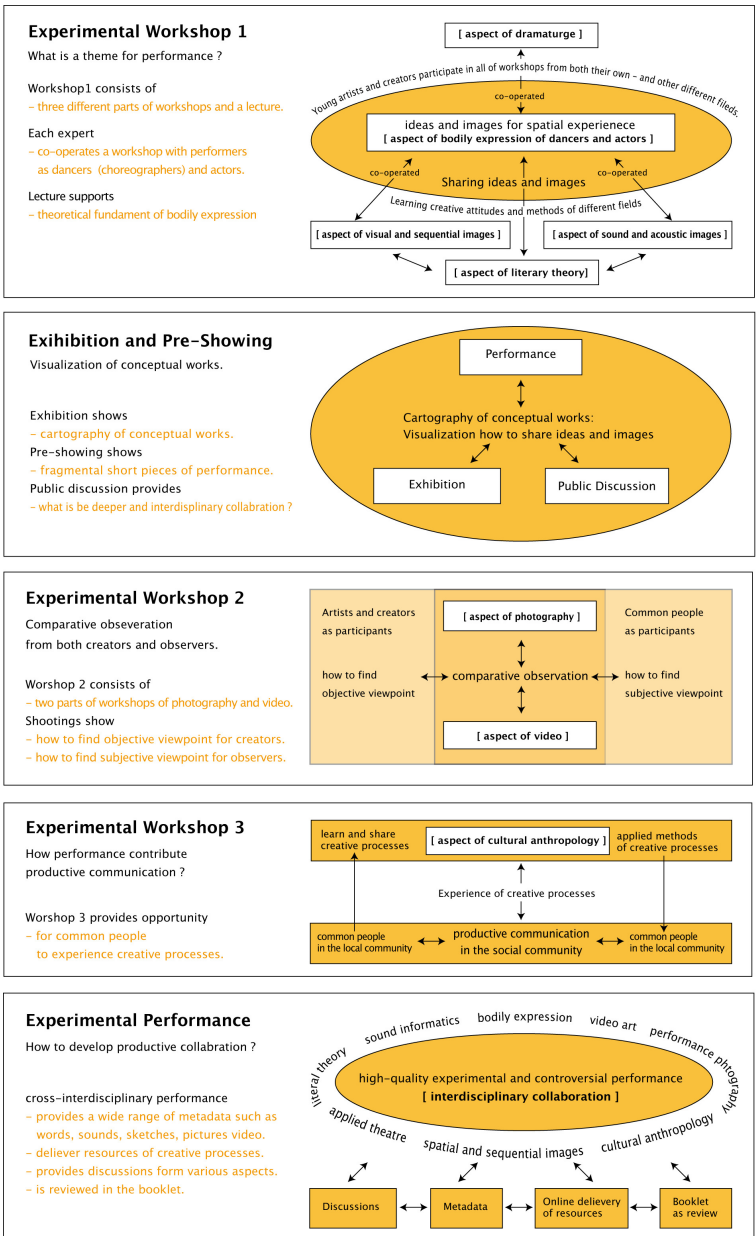


Figure 1. Project procedure. (See full color version at [www.performance-science.org](http://www.performance-science.org).)

conceptual works, will be shown and offer the opportunity for a public discussion about ongoing creative processes.

The second experimental workshop consists of workshops for video and photographic shooting of aspects of video art and performance photography. It focuses on observations from still and moving images of performers. Workshops will be given for creators and ordinary people. Performers and creators as participants can observe how bodily expressions of performance, which were developed from the first workshop, reflect on observers. Common people can compare various kinds of shooting images and discover their own viewpoints how to observe the performers and the performance.

The third experimental workshop will be held for ordinary people to experience creative processes which are derived from artists, creators, and performers. Some ideas from workshops 1 and 2 will be used. People can learn and share the background of productions, e.g. how creative experts find their ideas and images and integrate them into their artwork. By bringing together people from various backgrounds in a common creative process, the workshop reflects aspects of intercultural cities, as well as projects from the fields of sociology and cultural anthropology. People will have the opportunity to share their thinking and feelings in discussions. They can realize how to develop communication and collaborate with each other. This shows how performance focuses on creative processes and contributes to a productive communication between diverse people within a community.

Finally, the ideas realized within the workshops will be integrated into the experimental performance on the stage of the university hall, followed by a public discussion.

Each creative process will be captured as various kinds of metadata, such as words, sounds, sketches, pictures, and video during the production. Those resources will be delivered on the website and several social network systems. They are also going to be used in several public discussions. The overview of this year will be documented into a booklet.

## **RESULTS**

The production will end each year. In 2013 it will be integrated into an experimental performance on the stage for the first time. All materials and images for learning methods and sharing ideas will be presented in a public exhibition. A huge variety of metadata from the creative processes, production management, and discussions will be put online. People, both inside and outside, can refer to resources of this project. A booklet of each year will review the whole of production processes of one year.

## DISCUSSION

This project is scheduled to run for several years. As the project moves forward, the experience of previous years will feed into the following productions. We will explore the possibility of presentations and include other artistic contexts, e.g. museums and/or other cultural facilities. The new production should be developed in parallel. The final style of artistic expression does not always need to be a performance and shown on stage. The style and the emphasis of the field in this collaboration might shift organically each year.

The College of Art, Nihon University consists of eight Departments: Photography, Cinema, Fine Arts, Music, Literary Arts, Theatre, Broadcasting, and Design. Therefore the emphasis of the artistic field might change for this project. Nevertheless, it offers an art program as a role model, which enables flexible, concrete, and comprehensive approaches independently, on which artistic fields the project emphasizes. It is also possible to apply it to a wider range of collaborations between different types of universities.

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# Comprovisession: Improvisational real-time composing environment for multimedia session performance

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In this paper, a new idea called “Comprovisession” for multimedia performances with some improvisational performers is explored. An investigation of the problems of past systems is carried out with the aim of supporting improvisations not only for performances but also for compositions reflected on the structure of music. In addition to this, the improvisational performers will be able to grasp the interactions visually as well as by listening. As a concrete example, the special project “Jami-Girls’ Band,” and the system of this performance will be introduced.

*Keywords:* improvisation; live computer music; multimedia performance; interaction; real-time composition

In this paper, a new idea called “Comprovisession” for multimedia performances with some improvisational performers is explored. The author has been interested in improvisational real-time performances and in live computer music for over 20 years. As a composer/performer of computer music, he has been not only composing scores/programs, but also developing new instruments/systems as a part of his compositions. Touched off by previous research (Chadabe 1983, Chen 1994), the author advocated the compositional environment with intersection and interaction between musical model and graphic model, with chaotic algorithm and the keyword: “listen to the graphics, watch the music” (Nagashima 1995a, Nagashima 1995b, Nagashima 1998). In “Improvisession” which was developed/reported on previously (Nagashima 2002), the music department students who faced 24 computers (connected via network) enjoyed the improvisatorial music session by operating a mouse using RMCP (Goto *et al.* 1997). Next, the author advocated a new idea called GDS (global delayed session) music. With “Improvisession-II” which was developed/reported on previously (Nagashima 2003), people

connected via network using OSC (Wright and Freed 1997) and enjoyed the improvisatorial music session by operating their PCs in spite of a global delay (over 15 seconds). Next, an investigation of the problems of these past systems will take place focusing on the following two points: (1) the improvisation was limited to simple ad-libs in the framework of the fixed-style music, and (2) performers could not grasp the situation of each improvisation by listening to the mixed music only. Thus, one aim of this research is to support improvisations not only for performances, but also for compositions reflected on the structure of music. Another aim is to all improvisational performers to grasp the interactions visually as well as by listening.

### MAIN CONTRIBUTION

A new project was organized in 2011 with five students, and we collaborated to develop special musical instruments. For students (performers), making instruments by themselves supported the freedom of thinking in musical improvisation. Next, we discussed the style of the performance, and decided that the five performers will each have a theme-color on the screen and each will also have a main part (instrument) sound in the space of sound. As a programmer (not composer) of this work, the author developed a new system (environment) which assigns graphic/musical elements to the screen/PA in real-time, by arranging information from all instruments (sensors) of the performers. On stage, the performers created the live performance with interactions by each improvisational control, and they easily recognized the situation by the screen.

### Analysis and arrangement of the “Jaminators”

The “Jami-Girls’ Band” (see Figure 1) was a special collaboration-education project of five 1st year students and the author in 2011-2012. Firstly, many “junk” Jaminators were purchased in e-auctions at very low prices. Then, the students (Ayano Kazuma, Chika Suzuki, Yuriko Tosaya, Mai Morikawa, and Akiho Yamada) and the author opened the Jaminators, removed the parts and analyzed the system. Then, we arranged and remodeled the Jaminator (see Figure 2). We removed the mother board and replaced the CPU with Arduino. The scan/detect lines of the keyboards/switches were connected to Arduino’s I/O ports, and we set the small high-power RGB-LED (PWM controlled) at the top of the neck. We added the 2-D acceleration sensors inside, and a MIDI interface to send information to the host system. Students did not have sufficient knowledge of electronics, so they could only assist, but

they studied and learned a great deal. All MIDI outputs of the five Jaminators were merged by a special machine produced by the author.

### **Production of graphics/sound parts**

The title was “Revolution-J”, and Figure 3 (left) shows a conceptual sketch. As creators, students produced movies and images for the graphic part of the performance, and recorded many sounds from mobile phones as sonic materials (see Figure 3, right). Next, they discussed the style of the performance and decided that the five performers each have a theme-color on the screen, and each have a main part (instrument) sound in the sound space. The performance was a kind of battle-session game of sounds and graphics on stage.

They premiered this work in the “Inter-College Computer Music Concert” (Tokyo Metropolitan University) in December 2011. The second performance was in the “Make Ogaki Meeting 2012.”

As a programmer (not composer) of this work, the author developed a new system (environment) with a Max5/MSP/jitter environment. This patch assigns graphic/musical elements to screen/PA in real-time by arranging information from all instruments (sensors) of the performers. On stage, the performers created the live performance with interactions by each improvisational control, and they easily recognized the situation by the screen.

Figure 4 (left) shows a screenshot of the main patch. As a PA staff, the author checked these indicators beside the stage. If some trouble occurred, buttons/sliders which are normally controlled by MIDI could be adjusted. Figure 4 (right) shows a screenshot of the graphic-master subpatch. With jitter, the screen was divided into 4 areas with 1 small area in the center. Each of these 4 areas grows bigger when its performer makes a sound, and the center area moves slowly and grows bigger when its performer makes a sound. Performers knew well the relation between the sound and the graphics in the rehearsal, and changed them as creators.

Figure 5 (left) shows a screenshot of one of the performers’ subpatch. Each performer creates their own sounds, images, and movies, so this composition is not a “fixed program,” but only an “assign system” for contents with their performance. This Max5 patch is only the environment in which five creators/performers act freely. Figure 5 (right) shows a screenshot of the graphic mixing subpatch with jitter.

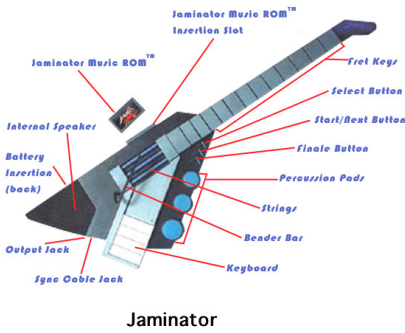


Figure 1. Jaminator (left) and “Jami-Girls’ Band” (right).

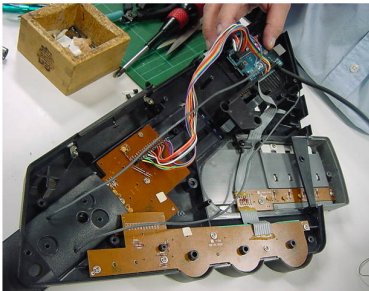


Figure 2. Arranging and remodeling of the Jaminator.

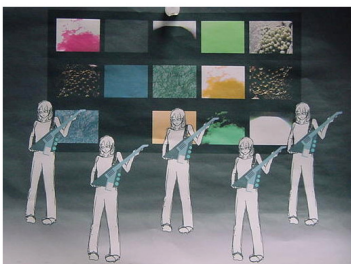


Figure 3. Conceptual sketch (left) and the recording of sounds (right). (See full color versions at [www.performance-science.org](http://www.performance-science.org).)



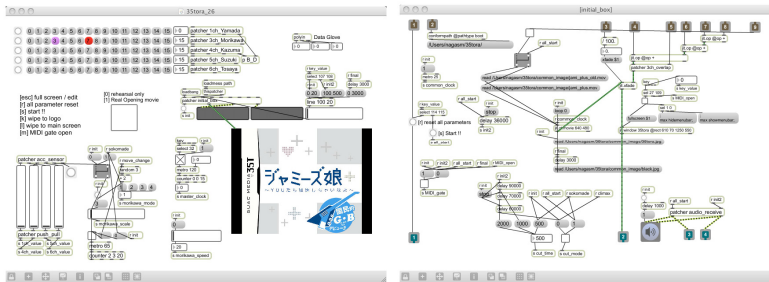


Figure 4. Main patch (left) and the graphic master subpatch (right).

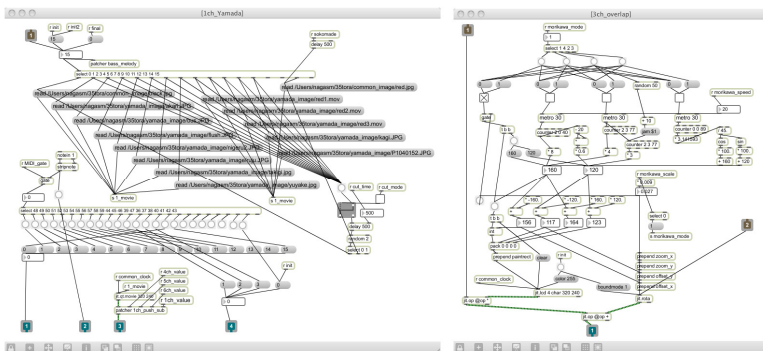


Figure 5. One of the performers' subpatches (left) and the graphic mixing subpatch (right).

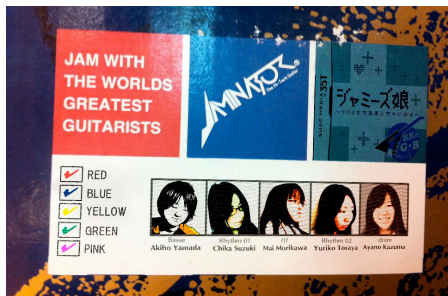


Figure 6. Original poster of “Jami-Girls’ Band,” given by the engineer who originally designed the Jaminator in the famous design studio IDEO (See full color versions at [www.performancescience.org](http://www.performancescience.org).)

## IMPLICATIONS

The “making” ([www.youtube.com/watch?v=aXv-NAnt6iw](http://www.youtube.com/watch?v=aXv-NAnt6iw)) and the “performance” ([www.youtube.com/watch?v=Midqvqej-hw](http://www.youtube.com/watch?v=Midqvqej-hw)) videos of this project were uploaded to YouTube. Many specialists and musicians gave positive evaluations. We were able to benefit from many useful arguments and new possibilities. Figure 6 shows the poster of this project.

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# Exercise physiology of piano playing

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Eleven pianists performed four octave, bilateral scales at each of five tempi (60, 80, 100, 120, and 138 bpm) at three sound-pressure levels (83.0, 87.0, and 90.0 dB). They also played a self-selected favorite classical piece of a tempo at around 120 bpm with full emotions. Oxygen uptake ( $\text{VO}_2$ ), carbon dioxide production ( $\text{VCO}_2$ ), energy expenditure (EE), minute ventilation (VE), tidal volume (VT), respiration rate (RR), and heart rate (HR) were evaluated using gas analyzing system. Mean HR,  $\text{VO}_2$ , and EE increased curvilinearly with tempo. At the fastest tempo at the strong dynamics, HR was elevated to 103 bpm, and  $\text{VO}_2$  was 360 ml/min with EE of 2.6 kcal/min. VE was also increased with tempo, which was accounted for by RR (64%) and very little by VT (8%). Mean HR when playing a favorite musical piece was 100.8 bpm, which was significantly higher than 90.6 bpm during scales played at a similar tempo.  $\text{VO}_2$  did not differ between these conditions. Physiological measures examined indicated that piano playing was a relatively light physical work, and RR plays an important role in ventilation. Cognitive load of emotional playing of their favorite music modulates autonomic nerve activity independent of energy cost of performance.

*Keywords:* piano performance; physiology; oxygen uptake; heart rate; energy expenditure

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# An electromyographic study of the left hand in violin playing

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Surface electromyogram was obtained from the left flexor digitorum superficialis (FDS), extensor digitorum communis (EDC), fourth dorsal interosseous (DI4), opponens pollicis (OP), biceps brachii (BB), triceps brachii, and brachialis anticus muscles to investigate muscle activity during single and vibrato tone production on the violin. Six trained violinists performed successive A4 and D5 tone production using the ring finger at varied tempi and dynamics with and without vibrato. String clamping force and 3D kinematics of the finger were also recorded. The mean activity of DI4, OP, EDC, and FDS increased with tempo, but not with dynamics. The finger's upward and downward velocity was also increased with tempo while string clamping force was decreased. Subjective evaluation of effort and strenuousness increased with tempo. The findings suggest that the speed of finger movement is related to the discomfort of the arm and hand in violin playing, and less to the clamping force. There was a reciprocal activity in the sets of flexor and extensor muscles during vibrato. The findings suggest that the synergistic use of wrist flexion and extension play an important role in both string clamping and shaking force productions during vibrato.

*Keywords:* violin; EMG; muscle; left hand; string clamping force

We recorded string clamping force on the violin during simple tone production (Kinoshita and Obata 2009, Kinoshita *et al.* 2012). Findings showed that the peak force exceeded 4.5 N at slow tempi, and decreased to 1.7 N at fast tempi. Subjective assessment of playing effort indicated an opposite trend:

the players were feeling more strenuous at faster tempi. Measurement of muscular activity along with finger kinematics may help in the understanding of this discrepancy (Chan *et al.* 2000). The fingers of the left hand play an important role in producing a vibrato on stringed instruments. This requires wobbling of the fingertip by the forces generated longitudinally and vertically on the fingerboard (Obata *et al.* 2009, 2012). Vibrato thus demands left finger/hand/arm muscle coordination, which is different from a non-vibrato tone production. Particularly, the importance of wrist joint relaxation allows swinging of the hand freely and has been suggested as a key element to a successful vibrato. Details of this skill can be better understood from the examination of forearm muscular activity (Bejjani *et al.* 1989). The aim of this study was to investigate the activities of string clamping-related muscles in the left hand and arm during single (non-vibrato) and vibrato-tone productions. Surface electromyography (EMG), 3D kinematics, and string clamping force were measured for this purpose.

## METHOD

### Participants

Four female and two male trained violinists (mean age $\pm$ SD=28.5 $\pm$ 4.7 years) served as subjects.

### Materials

Under the A string at the D5 position of the neck of a Yamaha V10G violin a 3D miniature force transducer was installed to measure string clamping force (Kinoshita and Obata 2009). Radiated sound was sampled using a Rion sound-level meter. Surface EMGs amplified ( $\times 1000$ ) and filtered between 10 and 500 kHz were collected from the flexor digitorum superficialis (FDS), extensor digitorum communis (EDC), fourth dorsal interosseous (DI4), opponens pollicis (OP), biceps brachii (BB), triceps brachii (TB), and brachialis anticus (BR) on the left side of the arm and hand. Using high-speed infrared cameras (200 Hz), 3D kinematics of the left ring finger, wrist, and the violin were recorded. All electrical signals were simultaneously A/D converted and stored on a PC (sample frequency=1 kHz).

### Procedure

The single tone task was successive A4 (440 Hz, open) and D5 (587 Hz) tone productions without vibrato, which were performed at a combination of metronome-guided tempi (60, 120, 240, 480, and 840 bpm) at pre-determined

sound dynamics ( $p=70-72$  dB,  $mf=75-77$  dB, and  $f=80-82$  dB). This task was continued until data from 30 successive tone productions were attained for each of the tempo and dynamics combinations. For the vibrato task, a D5 tone was produced for 30 sec at 6 Hz vibrato rate at  $mf$ . A 30-bpm single tone ( $mf$ ) production without vibrato was also performed to make a comparison with the vibrato performance. Maximum isometric voluntary contraction (MVC) EMG data for each muscle was used to normalize the root mean square values of EMG signals. Subjective evaluation using a 7-point scale (1=not at all, 7=very much so) for their effort and strenuousness was also performed.

## RESULTS

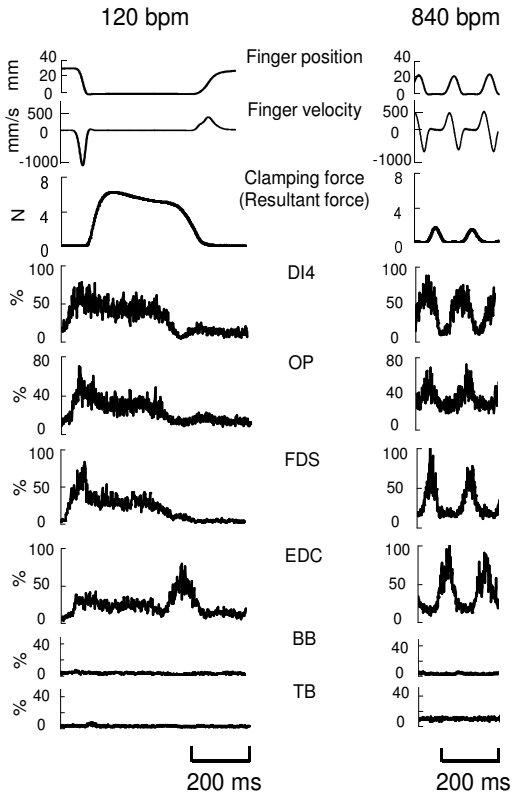
EMG, force, and kinematic variables were computed for each of the 30 sound productions. The EMG variable was mean values for each D5 tone production, and the string clamping force variables were peak and mean forces from the resultant force for the single tone, and those from the longitudinal force for the vibrato. The repeated measures ANOVA was significant ( $p<0.05$ ). Figure 1 shows representative mean time-history curves of kinematics, string clamping force, and EMG data for 120 and 840 bpm at  $mf$ .

The amplitudes of ring finger movement and its string clamping force were much larger at 120 bpm compared with those at 840 bpm. The mean normalized EMGs of DI4, OP, EDC, and FDS were clearly larger at the faster tempo. A two-way ANOVA showed a significant tempo effect for the DI4, OP, EDC, and FDS, but not for BB, BR, and TB. Neither the dynamics effect nor tempo x dynamics interaction effect was significant for all muscles. We therefore pooled three dynamics conditions to show the effect of tempo on the EMGs and resultant clamping force (see Figure 2). The mean values of the subjective evaluation scale for effort at the 60 and 840 bpm tempi were 1.3 and 5.2 points, respectively, and those for strenuousness were 1.3 and 5.7 points, respectively.

Figure 3 shows string clamping force (vertical and longitudinal components) and EMGs during vibrato. Reciprocal activation of the flexor-extensor muscles was readily discernible. A comparison of mean EMG between vibrato and non-vibrato trials revealed that DI4, FDS, EDC, BB, and BR had a significantly larger level of activity during vibrato.

## DISCUSSION

Consistent with our previous findings (Kinoshita *et al.* 2009, Kinoshita and Obata 2012), the string clamping force decreased with tempo. This study



*Figure 1.* Time history curves of ring finger position, velocity, string clamping force (resultant vector), and muscular activity (%MVC) in one subject.

demonstrated that with an increase in tempo, amplitude of fingertip movement decreased, and its downward velocity for clamping the string also decreased. Upward peak velocity for releasing the string, on the other hand, was higher at faster tempi. The EMGs demonstrated that the mean activity of the flexor and extensor muscles increased with tempo. Indeed, their activity exceeded 40% MVC for the flexors of the intrinsic and extrinsic muscles, and 30% MVC for the extrinsic finger extensor muscle at 840 bpm. These values were nearly twice as large as those observed at 60 bpm. The present observations suggest that the feeling of strenuousness in the left hand/arm at fast tempi is due to the increased level of muscular activity associated with the



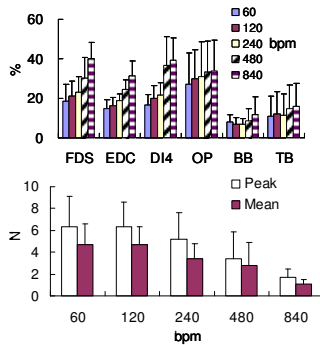


Figure 2. Mean and SD (vertical bars) values of normalized EMGs and string clamping force for all subjects at five tempi. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

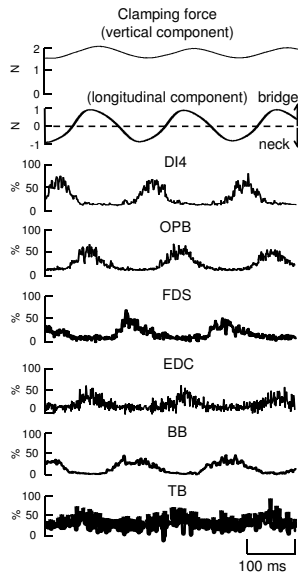


Figure 3. Vertical and longitudinal components of string clamping force, and muscular activity (% MVC) during vibrato in one subject.

successive lifting and dropping of the finger, and less with force for clamping the string steadily. The muscular activity of the finger flexor and extensor and kinematic data at fast tempi suggests that the pulse-like clamping force was

generated by the inertia resulting from fast downward and upward finger movement as if tapping the fingerboard. Consistent with previous findings (Obata *et al.* 2009, 2011), during vibrato string clamping (vertical) force was kept at the level similar to the non-vibrato tone production though it contained some oscillations. There was a notable oscillating longitudinal force during vibrato, which corresponded with previous findings (Obata *et al.* 2009). The EMG data showed a clear periodic vibrato-rate-related burst of activity in the flexors and extensors of the hand and arm. Between the bursts of activity there was always a phase with a quite low level or nearly no-activity of the flexor muscles. During this period the string clamping force must originate from other sources. Our data suggests that the extensor muscle, such as EDC, which also extends the wrist and tilt the finger, plays a role in the pressing of the string on the fingerboard. This may also be the case for the FDS. Forceful wrist action may contribute to the production of both vertical and longitudinal forces during vibrato.

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# Music and speech performance: Music characteristics of Serbian accents

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There is a close connection between speech and music, i.e. the spoken accent and musical features of speech. The Serbian system of accentuation is extremely melodious. The main musical characteristics are: duration (two shorts and two longs), intonation (two upwards and two downwards), tempo (three shorts and one fast), and intensity (of minor importance). There are four main accents in the Serbian language including short-downward, short-upward, long-downward, and long-upward. In polysyllabic Serbian words, each syllable can be stressed except for the last one. Downward accents appear on the first syllable and in monosyllables, while only upward accents appear freely on each syllable, except on the last one. A great number of scientists and theoreticians have researched music characteristics of Serbian accents trying to realize their music transpositions: downward intervals in downward accents are larger than upward intervals in upward accents (both long and short); the major interval for short downward accents being approximately a major sixth, while the major interval for long downward accents is approximately the interval of a seventh. The size of interval in speech depends on the meaning of the word as well as on the emotional level of the interpretation.

*Keywords:* accent; interval; emotion; vowels; expression

Nineteenth century scientists noticed a difference between long and short syllables and felt the nuances between upward and downward accents in Serbian language (Peco 1971). The question of transposing words into music and intonative projection of Serbian accents is a narrow and unexplored area in relevant Serbian literature (Milojevic 2003). Scientists investigated the correlation between linguistic and musical accent: accent intonation (upward and downward) influences the speech melody. Long accents require larger intervals and vice versa (Despic 1986). Sunjic was the first to use music sym-

bols to describe accents and their music characteristics in 1853 (Djordjevic 1987). Mazing, however, was the first to determine the difference between long and short accents according to the ascending and descending nature of the accented syllable in 1876 (Peco 1971). Both Mazing and Florsic discovered that the syllable is higher in pitch after an upward accent; Florsic used the interval of the sixth downward to show downward accents, and the interval of the third upward to present an upward accent (Lehiste 1961). Nevertheless, the interval relationship between the accented and non-accented syllables is difficult to display accurately, because the differences are individual and depend on dialects. Linguists frequently failed to notice the degree to which tempo and expiration influence the accent pronunciation. The results showed individual accent pronunciation of some representatives of different dialect zones. The true picture of Serbian standard accents' nature is rather descriptive (Peco 1971). Miletic showed in 1926 that in downward accents the interval between the accented and non-accented syllables usually oscillates between the intervals of a second and a fifth. In upward accents, those two syllables have the same pitch position and the interval between them can be relatively small (Peco 1971). Both Belic in 1948 and Miletic in 1952 found that downward intervals in words with downward accents are larger than upward intervals in words with upward accents. The largest interval used to present the short downward accents was the major sixth, while the largest interval presenting the long downward accents was a seventh (Ivic and Lehiste 2002). The first aim of this paper is to show that the contrast between upward and downward accent intonation corresponds to music intonation. The second aim is to investigate any regularities in music notation of Serbian accents made by linguists, theoreticians, and composers.

### MAIN CONTRIBUTION

Many scientists have studied music characteristics of Serbian accents. Serbian accents, represented by the interval between the accented and non-accented syllable, have specific musical characteristics including duration, intonation, tempo, and intensity. The findings of linguists, composers, and music theoreticians, who researched the field of musical transposition of Serbian accents, will be summarized below.

#### **Serbian accents viewed by linguists and musicians**

Among four main accents, Serbian language uses the so-called fifth accent: the length after the main accent in the word. It offers special musical and metrical qualities to the language (Telebak 2004, Djordjevic 1987). Its ap-

pearance dates back to ancient times, when language was closely connected to singing and prosody. Although today this accent is almost lost in speech, writing, and literacy, in nineteenth century Serbian music—especially in romantic Lied—the fifth accent appears. This shows its frequent appearance during the period of Serbian literacy language affirmation. While pronouncing the length, the speech melody is rather flat, but its contour is similar to that of the long upward accent (Despic 1986).

Music parameters can be used for music transposition of all four Serbian accents as well as the fifth accent or the length after the accent. Musicians thought that intervals presenting linguistic accents underscore emotional expression of lyrics (Milojevic 2003) and emphasize the speech melody and the intonation of the sentence (Peco 1971). Lyrics and music are connected with technical (meter, rhythm, and melody) and expressive (psychological and descriptive) elements (Despic 1986). While upward and downward accents show voice direction and speech melody, the size of intervals in speech varies and depends on the emotional level of the interpretation: long accents require larger melodic intervals and vice versa. On one hand there is the accented syllable pronounced with the higher intonation, and on the other hand there is the non-accented syllable in words with upward accents higher in pitch than the syllable with the main accent (Despic 1986). When it comes to the accented syllable, we must not overlook the importance of dynamic, melodic, and agogic characteristics, such as intensity, pitch, and duration in music (Djordjevic 1987).

### **Music transposition of Serbian accents by linguists and musicians**

The short downward accent is shown either by the repetition of the tone or with the interval of the second between accented and non-accented syllable (Peco 1971; see Figure 1).

The same music transposition of the short downward accent in the word *tico* (*bird*) is notated by the tone repetition of the fifth and sixth eighth notes in the first bar (see Figure 2).

Similarly, the interval of the downward second is used for music transposition of the short downward accent, presenting the difference between accented and non-accented syllable in the word *zvona* (*bells*) at the beginning of the bar in the Lied in Figure 3.

The long downward accent is expressed by a downward interval: the octave downward is frequently used for following Serbian dissyllable words (see Figure 4).

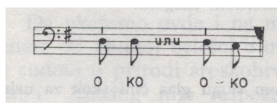


Figure 1. Storm: the repetition of a tone or the interval of the second downward in the short downward accent.



Figure 2. Composer Stevan Hristic, *Swallow*.



Figure 3. Josif Marinkovic: *Prayer*.



Figure 4. Storm: the octave as the range of the long downward accent.

Serbian romantic Lied composers also used the octave downwards to present the intonation of the long downwards accent in the dissyllable word *svijam* (see Figure 5).

The range of three to five tones (the interval of a third, fourth or fifth) presents the intonative framework of the short upward accent (Djordjevic 1987). Linguists used either tone repetition or the interval of a second/third downwards to display dissyllable words with the short upward accent on the first syllable (see Figures 6 and 7).

Linguists and music theoreticians assume that the range of the long upward accent includes six or eight tones, and the interval representing this type of accent oscillates from a sixth to a second (Djordjevic 1987). A gradually rising tone until the appearance of the non-accented syllable is the main characteristic of the long upward accent. This ascending melody heard on the first syllable is shown by the interval of a third (see Figure 8).

To present the intonation of the first accented syllable in the long upward accent some linguists used larger intervals. In their music transpositions, the intonation of the non-accented second syllable returns to the initial tone (see Figure 9).

In the same way composers use large intervals to present and transpose the long upward accent. For example, a fifth upward on the second accented syllable in the trisyllable word *gitara* (guitar) is used to show the intonation of the long upward accent. On the third non-accented syllable, the intonation is still relatively high (see Figure 10).

Similarly, in the trisyllable word *opelo* (requiem), linguists used the sixth and fifth upward on the second syllables with the long upward accent (see Figure 11).



Figure 5. Miloje Milojevic: *The eagle song*.

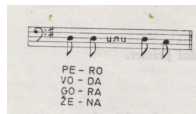


Figure 6. Storm: tone repetition or the interval of second downward expressing the short upward accent.

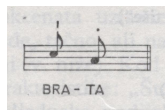


Figure 7. Mazing: the interval of third downward represents the short upward accent.

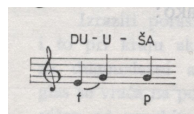


Figure 8. Mazing: the interval of third on the first syllable with the long upward accent.

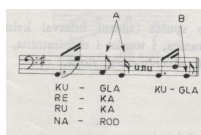


Figure 9. Storm: the octave on the first syllable with the long upward accent.

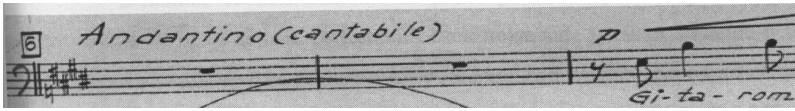


Figure 10. Stevan Hristic: Spanish song.

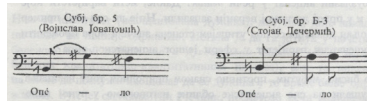


Figure 11. Djordjevic: the interval of a sixth between the first and the second syllable.

## IMPLICATIONS

Future research will investigate two questions: (1) the relationships between facial expression of affects and emotions and mouth expression during vowel pronunciation and (2) do accented syllables, followed by unaccented syllables, represent a particular semantic meaning due to their different interval size and how does this translate into music (duration, tempo, and intensity).

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# Infrared thermography as diagnostic tool for physiotherapeutic taping support of musicians

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Players of asymmetrical instruments, like the violin or flute, often suffer from health problems through the required unnatural body positions. The risk for overuse symptoms partly depends on the type of instrument but is also very individual. That is why all kinds of ergonomic support or therapeutic help have to be adjusted and customized. To detect individual critical areas, this pilot study presents non-invasive infrared thermography imaging of the bodies of eight different players. The assumption is that hot regions (i.e. more active and more vascularized areas) correspond with regions of higher risk for overuse and pain. The presented results show temperature change after 90 minutes of practicing the instruments. The measurements at 21 points could reveal many asymmetric and individual differences before and after playing. In addition, it was demonstrated that thermocam measurements with applied K-Tapes are also possible, since the material approximates the temperature of the skin below. The objective of a follow up study will be to determine whether the use of K-Taping—often used by sports therapists—could support pain relief for musicians with muscular problems or could be used as individual prevention opportunity.

*Keywords:* performing artists; health; infrared thermography; prevention; taping

Research shows that up to 85% of professional musicians suffer from pain, fatigue or musculoskeletal disorders (Spahn *et al.* 2010). This often results in the loss of strength, endurance, dexterity, and control. The figures of health complaints from music students look quite similar. About 25% of music students in instrumental classes at the University of Music in Vienna suffer from occasional or regular violent pain; another 25% of discomfort from playing related activities (Bertsch 2011). Some studies show that pain can occur even

in children and younger people while practicing and playing music (Ranelli *et al.* 2011). During performing or any other activity, muscle contractions and increased blood flow result in a higher temperature of the overlying skin. This effect can be visualized and quantified by infrared-thermography. Documentations of different playing techniques and variability between student and professional brass players were provided in earlier studies. Temperature changes have been measured at several points. Simple visual inspections have shown less effort and more symmetric patterns for advanced players (Bertsch and Maca 1997, 2001).

As other studies have shown, computer-assisted skin video-thermography (thermography) is also a highly sensitive tool in the diagnosis and monitoring of complex regional pain syndromes (Huygen *et al.* 2004). Changes in the blood-supply to the skin, resulting in an altered skin temperature and characteristics such as reduced mobility and on-going pain, have been demonstrated. In pilot-studies this method also applied the technology for pain-evaluation of musicians and proved that “thermography can be effective in diagnosing muscular pain, providing a relatively inexpensive and non-invasive imaging diagnostic tool” (Lourenço *et al.* 2011, p. 188).

In physiotherapeutic rehabilitation, taping is used both as a treatment and as prevention of sport-related injuries. K-Tapes could be placed on almost any muscle or joint in the body and should be applied with a special technique on the skin. Throughout lifting the tissue, better blood flow in the sore or damaged tissue would be possible, which could result with reduction in pain and sensitivity. The healing process could be stimulated, and the pain receptors might be relieved (Kumbrink 2012). A first meta-study on the basis of evidence-based medicine (EBM) came to an ambivalent result, because the method is new and only a few studies exist (Willbacher and Maringer 2011). K-Taping has been tested on its mode of action especially for shoulder and back pain in several clinical studies (Kalichman *et al.* 2010). Supplemented by medical diagnosis and the evaluation of individual complaints, further studies are supported (Thelen *et al.* 2008). If further studies can confirm positive effects, this technique could be documented as a new method to prevent and to cure health problems of performing artists.

The first aim of this study was to determine which muscles would activate the most during violin, viola and flute practice by thermography. The second aim was to see whether K-Tape application interferes with thermographic evaluation. This interdisciplinary research is possible through the experience of the first author as professional flautist, trained physiotherapist, and a certified K-Taping practitioner.

## METHOD

### Participants

All subjects in this pre-study were healthy college students enrolled at the University of Music and Performing Arts Vienna, Austria. Eight (six female and two male; one student with and without shoulder rest) students (instrumental players of viola [ $n=2$ ], violin [ $n=4$ ], and flute [ $n=2$ ]) took part between September and November 2012. Screenings with infrared thermography were performed at the Medical University Clinic for Internal Medicine II. In a survey, fatigue symptoms were mentioned and most of subjects reported taking part in recreational sports. No player mentioned the importance of warm-up or cool-down, and none of them included a relaxation and invigoration program during their musical practicing sessions.

### Materials

Recordings have been done with a FLIR® T335 Thermal Imaging Camera, showing exact skin temperature at the time. A FLIR R&D software 1.2. QuickPlot analysis system has been used for visual and quantitative temperature analysis. As far as possible, the distance from the camera and the position(s) of the players has been controlled.

### Procedure

Participants were introduced to the camera and had around 20 minutes to acclimatize in the room. Since measurements focus on the skin temperatures, they had to undress the upper part of the body, except the bra of female players. Hair had to be tied up. The Flir® T335 Camera was mounted on a tripod and the thermographs were obtained for each participant in twelve clockwise positions. Pictures were taken with adducted arms, and also with arms 90 degrees up. Positions of the feet and the head were marked, so the distance was kept as similar as possible.

Data acquisition was done before playing ( $T_0$ ), after 30 minutes ( $T_1$ ), and after 90 minutes ( $T_2$ ) of practicing the instruments. There was no instruction to play specific pieces. Temperature values were obtained symmetrically from 21 points, and one large area.

For quick visual analysis, the hot areas were marked in dark (see Figure 1). The effect of differently applied K-tapes on skin temperature was tested on one person by infrared thermography camera (see Figure 2).

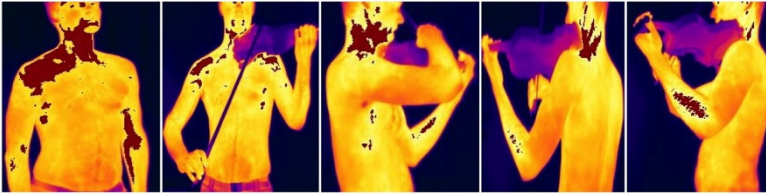


Figure 1. Subject 6JT after playing violin with shoulder rest (images 2 and 3) and without shoulder rest on images 4 and 5.

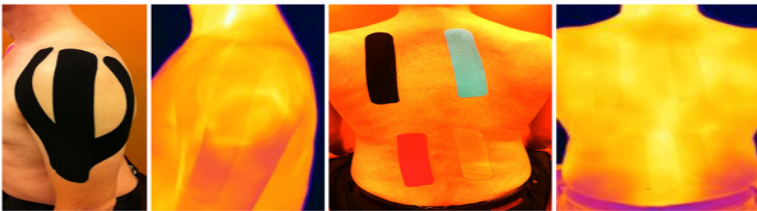


Figure 2. Pictures of K-Tapes with Canon IXUS Camera and Thermal imaging Camera FLIR T335. (See full color versions at [www.performancescience.org](http://www.performancescience.org).)

## RESULTS

The presented results demonstrate individual and instrument-specific activation patterns. It is easy to see asymmetric "hot areas" of muscle activation, especially how it progresses after a longer period of time combined with repetitive actions. Figures 3 and 4 show the different temperatures before ( $T_0$ ) and after playing ( $T_2$ ). For each point the values for left and right sides are next to each other, so asymmetric activation can be determined. Increased temperature from playing is superimposed with the acclimating effect of the room temperature and the undressed playing condition. For detection of asymmetries and relative values, this does not affect the analysis.

For string players, on the right side (bowing arm) the most activated muscles are M. Sternocleidomastoideus (upper and lower part), M. Pectoralis major, and M. Deltoideus (ventral, pars clavicularis, and pars acromialis). At the left side (holding side) the most activated muscles are Platysma, M. Sternocleidomastoideus (lower part with deep M. Scaleni), M. Pectoralis major (pars clavicularis), and M. Deltoideus (ventral und pars clavicularis).

For flautists, the most active muscles on the both sides are M. Deltoideus (ventral, pars clavicularis) and the M. Buccinator, which is essential for tone generation. Asymmetrically heated regions for the flautists were found espe-

	A01DEK (J0BMIN)	A01SIN (J0BMIN)	A02DEK (J0BMAX)	A02SIN (J0BMAX)	A03DEK (J0BAVR)	A03SIN (J0BAVR)	P01DEK (TR0ES UP)	P01SIN (TR0ES UP)	P02DEK (TR0ES MD)	P02SIN (TR0ES MD)	P03DEK (TR0ES LW)	P03SIN (TR0ES LW)	P04DEK (TR0TRANS UP)	P04SIN (TR0TRANS UP)	P05DEK (TR0TRANS LW)	P05SIN (TR0TRANS LW)	P06DEK (TR0ASB)	P06SIN (TR0ASB)	P07DEK (LAT0ADD)	P07SIN (LAT0ADD)	P08DEK (AB0BUC)	P08SIN (AB0BUC)	P09DEK (AC0BUC)	P09SIN (AC0BUC)	P10DEK (PT1TS H)	P10SIN (PT1TS H)	P11DEK (PT1TS H)	P11SIN (PT1TS H)	P12DEK (PT1TS H)	P12SIN (PT1TS H)	P13DEK (PT1TS H)	P13SIN (PT1TS H)	
VP1MP-flute	-1.2	-1.2	-0.4	0.3	-0.1	-0.2			0.0	0.0	0.0	0.0	-0.2	-0.1	-0.4	-0.2	0.3	0.1	1.1	1.1	-0.2	2.1	3.6	0.1	1.0	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.1
VP7SO-flute	-1.1	-1.3	-0.5	-0.8	-0.8	-0.9	-0.8	-0.1	-0.4	-0.9	-0.2	-1.0	-0.9	-1.0	-1.2	-0.7	-1.4	-1.0	0.7	-1.3	-0.9	-1.7	-1.2	-0.9	-0.3	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
VP2AN-violin	-1.6	-1.5	-1.3	-1.6	-1.2	-1.8	-1.4	-0.5	-1.0	-0.7	-0.8	-1.2	-0.9	-1.9	-1.4	-2.3	-1.7	-2.2	-3.1	-2.0	-1.4	-3.2	-0.7	-0.7	-0.7	-1.3	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
VP34SA-violin	1.1	-0.8	-0.8	-0.1	-0.7	-0.9	-0.8	-0.6	-0.3	-1.3	-0.9	-2.0	-0.8	-1.4	-0.4	-0.4	-0.8	-0.2	-2.4	-3.0	-0.8	-1.7	-0.6	0.8	-1.3	-0.4							
VP8JP-violin	0.1	0.1	0.6	0.1	0.9	0.3	0.2	0.3	0.7	0.7	1.0	0.1	0.9	0.6	1.0				0.9	1.1	-1.1	-0.5	0.0	0.0									
VP6JT-violin-w	-0.7	-2.4	0.2	0.0	-0.1	0.6	0.5	0.1	0.2	0.4	0.4	0.4	0.4	0.4	0.9	0.3	0.1	-0.2	-0.2	-0.4	0.0	0.2	-0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
VP8JT-violin	1.5	-1.5	-3.0	-0.2	-0.4	-0.9	-0.3	0.0	0.2	0.0	0.0	0.0	-0.5	-0.7	-0.2	-1.0	-0.8	-1.1	-1.8	-2.3	0.7	0.7	-0.4	0.6	-0.4	-0.5							
VP4JS-violia	-0.6	-1.0	-0.2	-0.8	-0.2	-0.9	-0.4	-1.2	-0.3	-0.4	-1.1	-0.3	0.0	-0.6	0.4	-1.2	-0.9	-1.2	-1.1	-1.1	-0.4	-2.0	-1.5	-1.4	-1.0	0.2							
VP5SH-violia	-0.3	-0.3	-0.1	0.0	0.0	-0.3	-2.3	0.1	0.5	0.1	0.2	-0.2	-0.2	0.0	0.1	-0.4	1.1	0.0	0.1	0.2	-0.5	-0.2	0.2	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	

Figure 3. Individual Temperature Differences after Performing ( $\Delta^{\circ}\text{C}$ ).

	P04-DEK (PE0CLW)	P04-SIN (PE0CLW)	P05-DEK (PE0STERN)	P05-SIN (PE0STERN)	P06-DEK (DELTA FRONT)	P06-SIN (DELTA FRONT)	P07-DEK (STERUP)	P07-SIN (STERUP)	P08-DEK (STERLW)	P08-SIN (STERLW)	P09-DEK (DELTA-PARS_SP)	P09-SIN (DELTA-PARS_SP)	P10-DEK (DELTA-PARS_CL)	P10-SIN (DELTA-PARS_CL)	P11-DEK (DELTA-PARS_CJ)	P11-SIN (DELTA-PARS_CJ)	P12-DEK (DELTA-PARS_AC)	P12-SIN (DELTA-PARS_AC)	P13-DEK (FLE0DIG-DIST)	P13-SIN (FLE0DIG-DIST)	P14-DEK (FLE0DIG-PROX)	P14-SIN (FLE0DIG-PROX)	P15-DEK (FLE0CARP)	P15-SIN (FLE0CARP)
VP1MP-flute	-0.3	0.2	-1.0	-0.4	0.5	1.1	-0.4	-0.3	0.2	0.1	-0.9	-0.5	1.0	1.8	-0.3	0.0			-1.0	-0.2	-1.1	-0.3	-2.4	-0.9
VP7SO-flute	-0.4	-0.4	-0.7	0.7	0.7	1.0	-0.4	-1.1	-0.5	-0.7	0.5	-1.3	1.3	0.5	0.8	-0.7								
VP2AN-violin	0.4	0.3	-1.0	-1.2	1.0	0.3	-1.2	-1.1	-0.8	-0.5	-1.1	-2.6	0.2	0.9	-1.9	-2.0								
VP34SA-violin	0.3	-1.3	0.4	0.6	0.7	-1.5	-0.2	0.0	-0.4	-0.1	-3.2	-4.0	-0.7	-0.6	-2.9	-1.6			0.0		0.0		0.0	
VP8JP-violin							0.2	0.3	0.1	1.5	-1.0	-0.2	1.3	2.2	1.8	-0.1								
VP6JT-violin-w	1.0	0.8	0.0	0.6	0.5	0.8	0.5	2.0	0.2	1.0	0.6	0.3	1.0	0.0	1.2	-0.3	2.1				2.6			
VP6JT-violin	0.7	-1.4	-0.2	-1.1	1.2	-0.9	0.2	-0.1	0.1	0.5	0.0	-0.8	1.2	-0.8	-0.3	-1.2								
VP4JS-violia	-0.4	-0.1	-0.3	-1.0	1.1	0.3	-0.2		0.1		-0.6	0.4	-0.7								-1.1	1.0		
VP5SH-violia	0.5	0.5	0.5	0.5	1.0	0.2	-0.4	-0.7	0.3	0.4	0.3	1.2	1.6	-1.0	0.0	-0.5								

Figure 4. Individual temperature differences after performing ( $\Delta^{\circ}\text{C}$ ). (See full color versions at [www.performancescience.org](http://www.performancescience.org).)

cially at the right side (more abducted holding arm), that is the lower parts of M. Trapezius and M. Sternocleidomastoideus.

Thermocam measurements with applied K-Tapes are possible, since the material approximates the temperature of the skin below (see Figure 2).

## DISCUSSION

This study has shown that asymmetric activation patterns can be detected with thermocams, and that thermography can also be used when K-Tapes are applied. The results are essential for the second part of the study, in which the activity levels and areas are evaluated individually by thermocam and by means of electromyography (EMG) when players perform with and without K-Tapes. The target of the follow-up studies is to evaluate whether K-Taping can be used for the prevention and treatment of musicians' complaints.

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# An exploration of the pianist's multiple roles within the duo chamber ensemble

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The current research explores the multiple roles of the pianist within the traditional Western art solo-accompaniment duo chamber ensemble. Based on a survey of existing literature, including historical, pedagogical, and empirical texts on chamber ensemble practice (specifically piano accompaniment), five roles are identified for the pianist in a solo-accompaniment duo ensemble: (1) co-performer, (2) soloist, (3) coach, (4) accompanist, and (5) collaborator. An overview of these roles is provided through consideration of their functional and socio-emotional qualities. The importance of understanding the multiple roles of the pianist in chamber ensemble practice is revealed along with implications for further research.

*Keywords:* pianist; co-performer; soloist; coach; accompanist and collaborator

Studies on chamber ensemble practice have developed significantly in recent years. Researchers and practitioners alike have enriched knowledge by revealing important information about various different aspects of chamber ensemble rehearsal and performance, such as rehearsal strategies (e.g. Davidson and King 2004), the structure and organization of practice (e.g. Ginsborg *et al.* 2006), musical interaction and negotiation techniques (e.g. Davidson and Good 2002, Davidson and King 2004), musician's roles in rehearsal (e.g. King 2006), co-ordination (e.g. Williamon and Davidson 2002, Keller 2008), modes of communication including visual, aural, gestural, verbal, and non-verbal modes (e.g. King and Ginsborg 2011), and social interaction (e.g. Ford and Davidson 2003, King 2006, King in press). Kokotsaki (2007) provides a theoretical framework about the pianist's role within the chamber ensemble which develops an earlier model of the pianist as accompanist and coach (Adler 1965). Other research focusing specifically on the

pianist in chamber ensembles highlights issues of leadership, dominance, methods of compromise, and resolving conflict such as in the piano duo context (Blank and Davidson 2007). Deon Nielsen Price (2005) and Martin Katz (2009) target the pedagogical aspect of piano accompaniment and collaboration. Price (2005) provided a manual of accompaniment techniques and skills which has become a successful textbook especially for university students. Katz's (2009) book offers advice on how pianists can "achieve a complete fusion" with their partners. The most hands-on guidance for piano accompanists is evident in texts by practitioners such as Gerald Moore (1943), who share their experiences in the field.

In order to develop our understanding of piano accompaniment within chamber ensemble practice, this paper aims to investigate the potential multiple roles of the pianist within the traditional Western art solo-accompaniment duo ensemble as identified via an in-depth survey of existing literature.

### MAIN CONTRIBUTION

Five roles can be identified in the literature when considering the functional and socio-emotional behavior of the pianist in the solo-accompaniment duo: the pianist as co-performer, soloist, coach, accompanist, and collaborator. These roles have musical, pedagogical, and social implications which are interlinked. Taken at face value, these roles could be interpreted in the following ways: (1) a co-performer, implying a fellow musical performer; (2) the pianist emerging as a soloist during specific "solo" passages within a work; (3) a coach, seeing the pianist working in a directing role, such as in rehearsal; (4) an accompanist, with the pianist acting in a supporting role; and (5) a collaborator, signifying equality between the two performers. Closer consideration of each of these roles is given below so as to reveal more detailed insight about the pianist. For the purpose of this study the instrumentalist or singer who has the single-line melody part will be referred to as the "instrumental soloist."

#### **The pianist as co-performer**

In duo chamber ensembles the term co-performer implies two performers which are part of the same ensemble partnership, therefore partners, but not necessarily on equal terms. Traditionally, melody instruments are regarded hierarchically superior to the accompaniment instruments as far as the equality of roles is concerned. However, pre-existing studies indicate that the "stereotypical hierarchy" of the solo-accompaniment duo is not necessarily upheld in practice (Davidson and King 2004). Blank and Davidson (2007)



use the term duo instead of duet to underline the equality between the two performers in the piano duo collaboration. Both Moore (1943) and Cranmer (1970) refer to the accompanist as an equal partner with their soloist. Adler (1965) refers to teamwork as being the greatest accomplishment between instrumental soloist and accompanist, which once again has the implication of equality. Both melody and accompaniment are conceived by the composers as a joint affair which complete and complement one another. Therefore the piano part is not written “as an afterthought” (Moore 1943, Zeckendorf 1953) but as part of the original composition, hence it should be regarded as equal.

Coaching and accompanying are two different specializations that overlap in many ways (Adler 1965). Coaching is a pedagogical term which encompasses elements of the pianist being in an instructor’s/director’s role. It involves dealing with both the musical aspects of learning a piece of music and the social aspects of dealing with a fellow performer. In this role, the pianist might contribute significantly to interpretative decision-making.

An accompanist, according to Grove’s *Dictionary of Music and Musicians* (fifth edition) is:

the performer playing as a rule with a single singer or instrumentalist usually on the pianoforte, whose part is nominally subsidiary, but who, in all music that matters and especially in music dating later than the 17th [and] mid-18th century accompaniment from a thorough-bass, should be regarded as an equal partner in the interpretation of a type of music which in a broad sense appertains to the category of chamber music (Adler 1965, p.5).

Literature reveals that the accompanist was perceived as an inferior type of musician (Cranmer 1970, Kokotsaki 2007) or one who perhaps failed to succeed as a concert pianist (Moore 1943, Zeckendorf 1953). Also, that the accompanist’s contribution was often not appreciated (Zeckendorf 1953) or taken for granted (Katz 2009). However, Cranmer (1970) claimed that people’s attitudes had changed and that accompanists are considered on many occasions better musicians than their partners.

Katz (2009) states that in recent years the term “collaborator” has more or less replaced the term “accompanist” and that “collaborative pianist” is nowadays more commonly used, although there is no empirical evidence to support this claim. Arguably, the term accompanist is still widespread even though Moore (1943) referred to the act of accompaniment as “collaboration” in the early part of the twentieth century. Katz claims that the word “accompanist” has a derogatory connotation whereas the word “collaborator,”

meaning working with others, denotes that the pianist is on an equal footing with the soloist. Moreover, Katz supports the fact that there is growing appreciation towards collaboration by pointing out that nowadays more and more courses on collaborative piano are available at the university level. Both “accompanist” and “collaborator” seem to refer to the pianist when serving similar functions, although the latter perhaps implies a broader musical and socio-emotional role. For the purpose of this research, the term “accompanist” will be used as it is more commonly employed by the majority of authors and researchers encountered in this investigation.

### **Understanding the piano accompanist’s multiple roles**

A pianist in a solo-accompaniment duo ensemble is therefore a musician who may act in one or more of the following ways during rehearsal and performance: as a co-performer, as a soloist, as a coach, as an accompanist (in the literal sense), and as a collaborator. The term “piano accompanist” embraces all of these roles together. Each role can be regarded as primarily functional, i.e. to ensure the success of the musical partnership, but also entails specific socio-emotional behavior.

Indeed, the socio-emotional contribution of the piano accompanist in chamber ensemble practice is recognized in the literature, for the accompanist is described as inspiring confidence (Katz 2009) and making the soloist feel comfortable and secure (Moore 1943) by looking after their emotional (Katz 2009), physical, and psychological needs (Adler 1965). In particular, in their roles as co-performer, coach, and collaborator, piano accompanists nurture the socio-emotional behavior of the instrumental soloist in the ensemble. At the same time, a piano accompanist needs to be musically functional, notably in their roles as a soloist and accompanist: an accompanist should respect and follow the instrumental soloist’s wishes during performance (Adami 1952), is able to adjust the balance accordingly and supply the correct tone color to match the instrumental soloist’s (Moore 1943, Cranmer 1970, Price 2005), is flexible and versatile, is supportive without being overpowering (Price 2005), is relied upon by the instrumental soloist as being their “second pair of ears” (Ginsborg *et al.* 2006), mentally anticipates, detects, compensates and prevents possible errors (Adler 1965, Kokotsaki 2007), is ready to deal with any possible incident (Moore 1943, Price 2005), and is a pianist with unquestionable musicianship (Adler 1965, Price 2005) and piano technique (Moore 1943, Adler 1965, Price 2005).

In order to successfully contribute to a duo ensemble, an accompanist thus exhibits numerous attributes that reflects the pianist in multiple roles.

## IMPLICATIONS

This research aimed to present the piano accompanist in a clearer light in an effort to encourage both practitioners and researchers to revise, reinstate and re-think the role of the pianist within the solo-accompaniment duo chamber ensemble. In the contemporary Western art tradition, the pianist's roles as "accompanist" and "collaborator" are the most common by far, and have become synonymous with particular functions that the pianist is expected to provide when paired with a solo instrumentalist or singer. This doctoral research endeavors to explore the piano accompanist's multiple roles in more depth via observational case-study.

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# Classification and visualization of dance movements of Nihon Buyo using motion capture system

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Using an optical motion capture system to examine the center of gravity of dance movements for dancers in various age groups belonging to five major schools of Nihon Buyo, we constructed a system for visualizing a dancer's center of gravity and studied the classification of dance movements using feature quantities describing center-of-gravity motion. In this paper, we report on the construction of a visualization system that can display the dance movement and center-of-gravity motion of dancers from multiple schools simultaneously. We use this system to uncover the feature quantities of a dancer's center-of-gravity motion and to classify the schools of Nihon Buyo accordingly.

*Keywords:* motion capture system; Nihon Buyo; physical skills; motion analysis; educational support system

The passing on and preserving of advanced skills is becoming an important issue in a variety of fields. Motion capture is being used in research to analyze movements in advanced skills that the body remembers through practice, which can be referred to as physical skills (Furukawa *et al.* 2005, Yoshimura *et al.* 2001). There are many schools of Nihon Buyo dance, a traditional art form in Japan, and it is important that means are found to objectively evaluate the features of each school. It is also thought that introducing a science-based educational system to pass on traditional techniques and skills can help promote the further development of Nihon Buyo into the future.

The objectives of our research are to classify Nihon Buyo according to style, school, and degree of proficiency through motion analysis (Yoshimura

*et al.* 2004, Shinoda *et al.* 2012), and to construct a system for visualizing dancers at sites where Nihon Buyo dance is taught. Using an optical motion capture system, we have previously obtained dance movements of 20 dancers in their 20s to 50s from five major schools of Nihon Buyo and have constructed a visualization system for analyzing those dance movements.

## METHOD

### Participants

To carry out the experiment, we obtained the cooperation of 20 female dancers (age group=20-50 years) from five schools of Nihon Buyo (Fujima, Nishikawa, Hanayagi, Wakayagi, and Bando).

### Materials

The program selected for motion analysis was the latter half of the *kudoki* segment (200 seconds) in *Museme Dojoji*. The main reason for selecting this program is that *Museme Dojoji* is highly representative of Nihon Buyo on the whole, which means that core differences in styles and manner among the different schools would not be apparent.

### Procedure

We used an optical motion capture system (MAC3D System, Motion Analysis Corporation) to conduct our experiment using 12 cameras (HAWK) directed on a 5 m(x) by 5 m(y) by 2 m(z) measurement space. Camera frame speed was set to 1/60 seconds and shutter speed to 1 ms. Each dancer was asked to repeat this program five times for motion capture purposes. In the motion analysis that we conducted, we focused on the interval in the program having the most demanding movements.

In this experiment, using an optical motion capture system, each dancer wore a black body suit on which a total of 42 reflective markers were attached corresponding to various parts of the dancer's body. The motion capture system obtained a time series of three-dimensional positions for each of these 42 markers. The coordinate system used here for specifying these positions was a right-handed system consisting of an x-axis and y-axis on the horizontal plane and the z-axis in the vertical direction.

The dancer's center-of-gravity position was calculated from the position data of these various body parts obtained from motion capture. Specifically, it was calculated from the center of gravity and mass ratio of each of 14 body parts, namely, the head, torso, upper arms, forearms, hands, thighs, shanks,

and feet. To begin with, center-of-gravity positions  $P_{gi}(x_g(i), y_g(i), z_g(i))$  ( $i=1,2,\dots,14$ ) of each body part were calculated using position data of each body part obtained by motion capture and the center-of-mass ratios  $m(i)$  ( $i=1,2,\dots,14$ ) of each body part. Next, the body's center of gravity  $P_G(x_G, y_G, z_G)$  was calculated using the above center-of-gravity positions  $P_{gi}(x_g(i), y_g(i), z_g(i))$  and mass ratios  $n(i)$  ( $i=1,2,\dots,14$ ) of each body part.

## RESULTS

To present dance movements to dancers in a visually easy-to-understand manner, this visualization system was designed to dynamically display the positions of body parts and the body's center of gravity without being affected by certain types of dance movements. A screenshot of this center-of-gravity visualization system is shown in Figure 1. This system can dynamically display the movements of a dancer as well as the movements of up to five dancers simultaneously for comparison purposes. The display portion of this visualization system uses a coordinate system that compensates for the motion of the dancer obtained in the three-dimensional xyz coordinate system used for motion capture. First, at the top of the screen in Figure 1, the system presents three-dimensional displays of dancers in their 30s from the Fujima, Nishikawa, Hanayagi, Wakayagi, and Bando schools, while compensating only for horizontal motion of the body. The position of each dancer's center of gravity is also displayed on their bodies in these three-dimensional displays. A convenient feature of these dynamic displays is that the user can change the viewpoint as desired by a drag operation using the computer's mouse.

Next, in the middle of the screen in Figure 1, the system uses an XYZ coordinate system that compensates for both horizontal and rotational movements of the body to present two two-dimensional displays, one showing the dancers from the front (Y-axis) and the other from the right side (X-axis). In each dancer's display, solid lines are used to depict the dancer's arm and leg on the right side of the body and broken lines to depict the dancer's arm and leg on the left side of the body. This scheme makes it easy to distinguish between the two even if left and right arms and legs should cross each other while dancing. In addition, the dancer's center-of-gravity position and its locus are displayed simultaneously with each dancer's display. This XYZ coordinate system compensates for movement in the horizontal (xy) plane by performing a rotation about the height-indicating z-axis (Z-axis) so that the hips of the dancer are always facing the front.

Finally, at the bottom of the screen in Figure 1, the system presents a time-series display of height  $Z_G$  of each dancer's center of gravity and a dis-

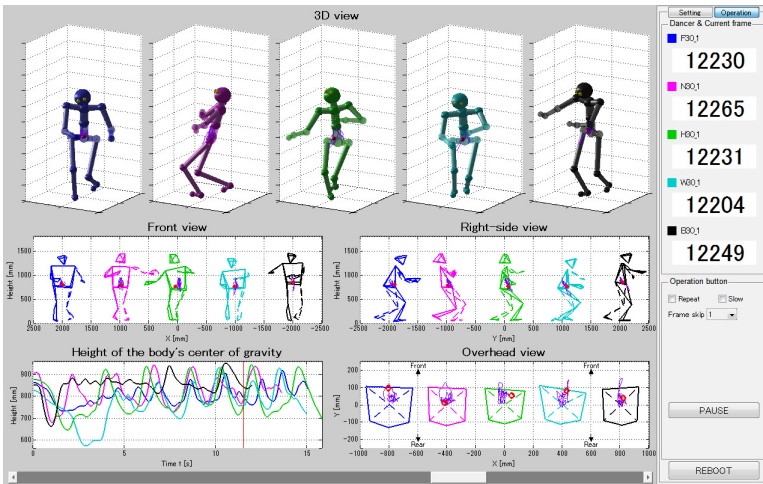


Figure 1. Screenshot of visualization system. (See full color version at [www.performance-science.org](http://www.performance-science.org).)

play of each dancer's center of gravity and its locus on the horizontal plane (overhead view). Here, compensating for horizontal and rotational movements of the body fixes the hips and enables the position of the center of gravity ( $X_G$ ,  $Y_G$ ) and its locus to be displayed with respect to the hips

This ability to present the performances of more than one dancer at a time makes it possible to observe differences in dance movements not only between schools, but also between dancers in different age groups in the same school. It also enables center-of-gravity movements to be compared. Furthermore, the fact that this system uses digital data obtained by motion capture means that changes over time in the dance movements of an individual dancer can be visualized, which should increase a dancer's desire to improve his or her Nihon Buyo dance skills through self-study while contributing greatly to preserving and passing on the technical skills of Nihon Buyo.

We therefore proceeded to classify dance movements by hierarchical cluster analysis (Ward's method) using the number of frames  $N_f$  of motion capture and the COG feature quantities of the variation in the longitudinal ( $Y$ ) direction  $\Delta Y_G$ , and the variation in COG height  $\Delta Z_G/L$  ( $\Delta Z_G$  normalized by the height  $L$  of the dancer) in a coordinate system that compensates for horizontal and rotational movements of the body.

The results of drawing a tree diagram from this hierarchical cluster analysis are shown in Figure 2. In this diagram, dividing the vertical axis (distance)



at the three mark enables dance movements to be classified into four groups. Here, groups I, II, and IV include all four age groups from the Fujima, Nishikawa, and Bando schools, respectively, while group III includes three of the four age groups of dancers from the Hanayagi school. The Wakayagi school, moreover, is distributed across all groups, which means that it cannot really be classified as a unique school. Nevertheless, four of the five schools targeted in this study could be classified from their dance movements based on the number of frames  $N_f$  and COG feature quantities of  $\Delta Y_G$  and  $\Delta Z_G/L$ . This result demonstrates the potential of classifying the dance movements of a Nihon Buyo dancer according to that dancer's school regardless of the dancer's age group for the program interval targeted for motion analysis here.

## DISCUSSION

The virtualization system that we constructed for analyzing the body's center of gravity can provide a three-dimensional display of a dancer's movements compensating for horizontal movements and can visualize the dancer's body parts and center of gravity in various planes compensating for horizontal and rotational movements of the body. The system can also display the dance movements of multiple dancers from different schools at the same time for comparison purposes. The proposed system therefore shows promise as an

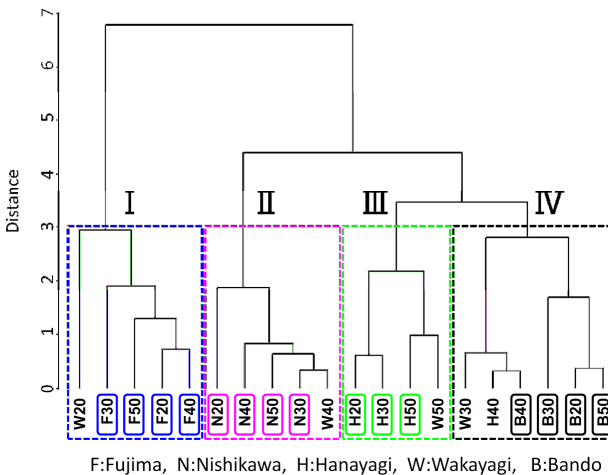


Figure 2. Results of classification of dance movements. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

educational support system that can visualize changes over time in the dance movements of an individual dancer and that can therefore help to stimulate a dancer's desire to improve his or her dance skills through self-study.

By using the number of frames of motion capture and the two-dimensional range of movement of a dancer's center of gravity into feature quantities while compensating for horizontal and rotational movements, we demonstrated the potential of classifying dance movements according to the dancer's school regardless of the dancer's age group for four of the five major schools of Japan's traditional Nihon Buyo dance for the program interval subjected to motion analysis in this study.

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# Performing Together? A case study of physiological stress between soloist and audience

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Several studies looked at psychological or emotional interaction between musicians and audience while performing. Little scholarly information, however, is available regarding the physiological communication between musicians and audience. By using non-invasive immunoassay salivary cortisol testing, this study examined the physiological stress levels in a solo oboe performer and four audience members. The study was realized within the context of three live performances in two different venues and two different musical contexts in order to determine possible correlations between performer and public. Recitals 1 and 3 had the same solo program performed at the same venue of a university at the same hour of the day, while Recital 2, consisting of contemporary chamber music, was performed at a prestigious concert hall in a major European city. The results of this pilot study could demonstrate that exaggerated physiological stress of the performer was not communicated to the audience, but had rather the opposite relaxing effect on the audience, thus attesting to the professionalism of the musician in controlling the stress while maintaining a high level of performance.

*Keywords:* stress; cortisol-salivary testing; musician-audience interaction; performer-public; oboe

Several studies looked at the performer/audience relationship from various points of view, particularly the psychological or emotional (Brand *et al.* 2012, Broughton and Stevens 2009, Pitts 2005, Gabrielsson and Juslin 1996, Ken-

dall and Caterette 1990). Little scholarly information is available in terms of the physiological interaction between musician and the audience, especially regarding stress levels measured by salivary cortisol testing. Bohnen *et al.* (1991) studied individual factors of coping and trait anxiety during mental stress, while positive emotions and their relationship to stress were examined in singers by Beck (2006). Various ways of studying the efficiency of salivary cortisol testing has been done using Salimetrics (Adam and Kumari 2009, Aardal and Holm 1995). Alfano (2008) looked at salivary alpha-amylase as a biomarker for stress, while Clements and Parker (1988) considered the efficiency of frozen versus mailed salivary cortisol samples as methods of handling.

## METHOD

### Participants

The participants included a professional male solo oboist, as well as 4 non-musician audience members.

### Materials

A non-invasive high sensitivity Salivary Cortisol Enzyme Immunoassay test (Salimetrics) was applied to all participants, on a normal day and on each day of the three recitals.

### Procedure

Three normal-length recitals were performed—two of them were including the same solo recital at the same venue and same time of day while the third was a chamber music recital at a different venue and a different time of day. To increase the level of stress, difficult contemporary repertoire was chosen, including John Cage's *4'33"*, a piece with no sound performed by the musician and where both musician and audience must maintain a unique kind of concentration. In order to determine whether the level of stress in the oboist was conveyed to the members of the audience, cortisol was measured (High Sensitivity Salivary Cortisol Enzyme Immunoassay test, Salimetrics) during the performances. To fulfill the criteria of a valid comparison, cortisol was also assessed after two days without a stressful event. The time interval of the assessment remained on each occasion, starting with the first measurement after awaking, 45 minutes afterwards, 11 am, 2 pm, 4:30 pm, 6 pm, 9 pm and before going to bed. Further measurements were taken at the start, finish, and 30 minutes after each recital.

## RESULTS

All subjects had a dramatic increase of cortisol levels 45 minutes after awakening (see Figure 1). The oboist showed the highest increase of all participants. All members of the audience showed no significant difference in their cortisol level in each condition (recital versus baseline), while the oboist revealed noticeable differences between his normal day cortisol levels and the days of recitals, with the highest peaks occurring at the point of performance. This peak was, however, consistently less than his peak at 45 minutes after awakening in every case.

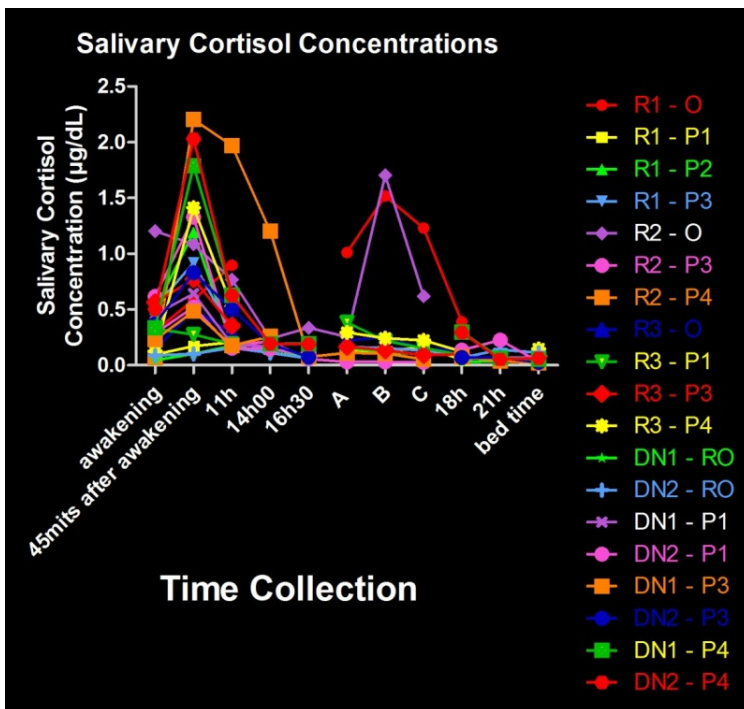


Figure 1. Average cortisol levels of public and performer during different times of the day. DN=normal day; A=beginning of recital; B=end of recital; C=30 minutes after end of recital; R1=1st recital; R2=recital 2; R3=recital 3; O=oboist during performance; RO=oboist during normal day; P1=audience member no. 1; P2=audience member no. 2; P3=audience member no. 3; P4=audience member no. 4. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

## DISCUSSION

Regarding Point A in Figure 1, immediately before the beginning of the recitals cortisol levels had not yet visibly increased. The absence of this rise can be justified by particular mechanisms associated with the glands of internal secretion. It is important to note that changes in cortisol levels in stress situations take about ten minutes to become visible in the saliva samples. In addition to the peak of waking, another peak in the cortisol curve was detected, which appears to be associated with the moments of performance by the musician. This leads to the conclusion of a correspondence to a physiological stress response, which, in this case, is the public presentation of the musical pieces. Moreover, after this stressful situation, there was also observed a decrease to normal values of cortisol levels (approximately 30 minutes after exposure to a stressful situation), which seems to indicate a return to normal by the musician.

The most significant differences are found at Point B—just after the end of the recitals—in which the inference response to stress is the highest in each of the performances and which implies an increase of stress throughout the recitals. Because of the differences of the times of the recitals (R1 and R3 began at 13:00 while R2 began at 18:30) the cortisol levels were higher in R1 and R3 at Points A and C (the beginning and 30 minutes after the end of recitals). Cortisol levels were higher near lunch time in all subjects.

The stress levels in R2 are the highest for the soloist. In spite of being a recital with other musicians in contemporary chamber music (and with an unconventional work by John Cage), the importance of this recital may have been the underlying factor for raising the stress level. The need to maintain a high level of performance that was simultaneously “judged” by performing colleagues may have been a factor for high stress.

Finally, R3, the repeated solo recital at the same venue, did not show a peak as in R1, but rather showed overall lower levels of cortisol that are close to ND levels. This fact may be related not only to intrinsic/extrinsic factors in the performer, such as emotional stability arising from a known, and therefore less stressful, environment and performance situation compared to R1 due to its repetition. In all cases, the audience members did not mirror the performer’s stress and had the opposite reaction to the performer.

To conclude, a certain amount of stress is necessary in order to maintain consciousness. Between performer and public, this preliminary physiological hormonal study shows that audience members do not reflect stress levels related to performance and that the professional musician was able to control the performance without communicating his own stress to the audience. The

results of the other tests of this multi-disciplinary study will confirm or deny these findings.

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# A comparison of practice on a MIDI wind controller to practice on single-reed instruments

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In the study of piano performance, the use of MIDI keyboards and computer software has improved measurement efficiency and accuracy of data analysis. MIDI wind controllers have existed for over 20 years, but their feasibility as a tool in wind instrument research has received little attention. The purpose of this investigation was to determine the validity and practicality of using a MIDI wind controller in instrumental performance research. Specifically, this study examined performances of the same passages, played by the same performers on a wind controller and played on a saxophone or clarinet, for pitch and rhythmic accuracy. The final phase of the study replicated procedures from previous research comparing the effectiveness of practice strategies on woodwind instruments.

*Keywords:* MIDI wind controller; practice; cognition; instrument; technology

The advent of the MIDI keyboard in 1983 (MIDI Manufacturer's Association) made available a new tool for studying musical performance. Soon after, researchers began using MIDI keyboards and computers to examine temporal and other aspects of skilled piano performance (Lee 1989, Palmer 1989b, Salmon and Newmark 1989). Since then, it has become common practice to use MIDI keyboards in piano research and music-motor learning research because they facilitate data collection and analysis. Wilson (1992) charged the music research community with using keyboards and MIDI technology to further our understanding of performance movement. While the keyboard community has embraced that charge, the wind community has not. MIDI wind controllers have existed for over 20 years, but their feasibility as a tool in wind performance research has not been studied. The purpose of this study

was to determine if a MIDI wind controller is suitable for performance research.

There are compelling reasons for examining the potential of MIDI wind controllers in research settings. First, computer-monitored musical instruments collect data without the perceptual biases that may unintentionally occur in humans (Large 1993, Lee 1989). Similarly, digital sound analysis is more discriminating than human perception. In addition, the performance specifications of MIDI wind controllers enable data collection for parameters such as air speed that are unavailable through conventional wind performance. Sequencing software used in conjunction with MIDI wind controllers provides a rich array of performance information in both numerical and graphic formats. Individual pitches are indicated by frequency or pitch name, and duration can be indicated in milliseconds. Graphic outputs enable data analysis that is unavailable with conventional methodology (Salmon and Newmark 1989). Palmer (1989a) noted that the advantages of graphic notation include the ability to compare multiple excerpts concurrently, the representation of a temporally evolving performance in its entirety, and the possibility of examining performance details not easily heard. Furthermore, she stated that traditional notation “cannot display the number of dimensions or the precision of each dimension adequately for research on musical performance” (p. 266).

Finally, data generated by MIDI wind controllers can significantly reduce the amount of time required to score acoustic sound files. To score performances in conventional wind research, the performances must be randomized, expert listeners must be trained to use the scoring criteria, experts must listen repeatedly to each performance to achieve the highest level of accuracy possible, and reliability between scorers must be determined. When studies may have thousands of acoustic files (e.g. Stambaugh 2011), this is a very time-consuming process. The numerical data generated by MIDI wind controllers in sequencing software eliminates the need to randomize certain kinds of files (“right or wrong” parameters, including pitch). Software generates lists of pitches and durations. These will still need to be compared to the intended performance scores, but the overall labor time will be considerably reduced.

The study is part of a series of studies examining the feasibility of using MIDI wind controllers in performance research. A pilot study informed the design of this study. The purpose of this repeated-measures design was to compare performance on clarinet or saxophone to performance of the same material on wind controller.

## METHOD

### Participants

Participants (N=9) were undergraduate (n=7) and graduate (n=2), clarinet (n=3) and saxophone (n=9) majors and one minor. Eight participants were music majors and one participant was a music minor at a large university in the southeast United States.

### Materials

The most widely used MIDI wind controllers (MWC) are manufactured by Akai and Yamaha. They use a recorder or saxophone/clarinet style mouthpiece with a manufacturer-designed synthetic reed, are about 600 mm/24 inches long, and weigh about 520 grams/1.2 pounds. The key system is Boehm-style and can be set to saxophone, flute, oboe, recorder, or brass fingerings, depending on the model. True electronic instruments, MWC generate no tone but instead are connected to a sound generating module or computer that enables sound production. For research purposes, the controller and the module need to be connected to computer software which records the digital performance data. When using an MWC in this way, the researcher can collect data about pitch, duration, and breath pressure (volume).

The Yamaha WX5 MIDI Wind Controller was used in this study. It retails for about \$700 US. It has two mouthpiece styles: clarinet/saxophone with a composite reed and recorder. Although it is lightweight, it does come with a neck strap. It can be used with an AC adaptor, batteries, or phantom power. Several performance parameters may be adjusted, including tight or loose lip mode, sensitivity of wind pressure, and fingering mode (three saxophone systems and one flute system). The most significant difference in key set up between the WX5 and a flute, clarinet, or saxophone is that there are four octave keys operated by the left thumb. The wind controller was connected to a Yamaha VL70-m, a virtual acoustic tone generator, which retailed for about \$800 US. The unit is a half-rack mount (220 mm x 212 mm x 46 mm) and weighs almost 3 pounds/1.3 kg. The tone generator was connected to a MacBook Pro laptop using a USB MIDI interface (UM-1G from Cakewalk, retails about \$40 US). This device transmits the MIDI data to notation or sequencing software. In this study, Cubase LE4 was used.

Music notation was created for two-octave major scales in C, D, and Eb. A short “etude” in the key of C was transposed from a violin piece.

## Procedure

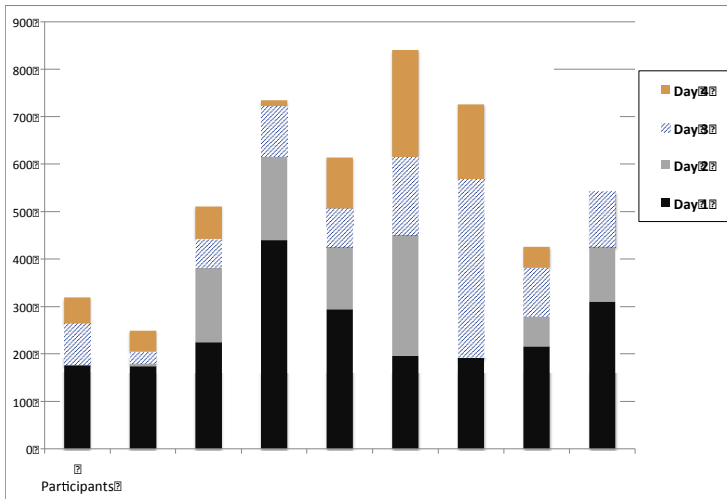
All procedures were approved by the Institutional Review Board and participants received \$40 for completing the four-session study. Sessions were conducted individually in a small room with the researcher present. In a repeated measures design, each participant played the same music on his or her clarinet/saxophone and on an MWC. MWC performance was recorded directly into Cubase software. Acoustic performances were recorded using a QC1 microphone and Audacity software. Participants practiced a warm-up sheet for the MWC that included long tones, octave leaps, and two measures of tongued sixteenth notes, for as long as they wanted to. Then they practiced the C, Eb, and D major scales until they could play each scale at metronome marking 88. Next, participants practiced the etude until they decided they were able to play it accurately as written. On their primary instrument, participants warmed up in any manner they chose and then prepared the scale and etude tasks.

## Scoring

Timelines were prepared for each participant's performance on the MWC and on their primary instrument. These detailed the start and stop times for each study task, such as practicing the Eb scale. The final trial of each scale and etude on the MWC was located and the MIDI pitch, duration, and volume data exported. The final trials of the acoustic performances were cut and pasted into a new sound file. They were randomized and then scored using procedures established in previous research (Stambaugh 2012). The duration of each trial was measured by highlighting each trial for Audacity to calculate the time. Pitch accuracy was determined by repeatedly listening to each trial and using a point deduction system. Perfect scores were 29 for each scale and 55 for the etude. Incorrect, skipped, repeated, or added pitches incurred a 1-point deduction each.

## RESULTS

On Day 1, the amount of time participants warmed up ranged from almost 3 minutes to over 7 minutes ( $M=247$  seconds,  $SD=82$ ). On Days 2, 3, and 4, participants played shorter warm-up sessions (Day 2,  $M=97$ ,  $SD=81$ ; Day 3,  $M=121$ ,  $SD=92$ ; Day 4,  $M=84$ ,  $SD=66$ ; see Figure 1). However, the reduced warm-up time was not a good indicator of skill improvement. Pitch accuracy for the etude remained largely unchanged across days (Day 1,  $M=38.71$ ,  $SD=4.95$ , out of 55; Day 2,  $M=41.67$ ,  $SD=4$ ; Day 3,  $M=41$ ,  $SD=6.39$ ; Day 3,



*Figure 1.* Participant warm-up time in seconds on a MIDI wind controller. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

$M=37.78$ ,  $SD=13.16$ ). The one area in which participants showed success was speed. Participants were instructed to perform at the same metronome marking each day. The speed scores across days were quite similar (Day 1,  $M=17.83$ ,  $SD=10.3$ ; Day 2,  $M=22.33$ ,  $SD=1.68$ ; Day 3,  $M=21.96$ ,  $SD=1.69$ ; Day 4,  $M=22.11$ ,  $SD=1.91$ ).

## DISCUSSION

MIDI wind controllers may be useful for research questions that demand highly precise measurement. However, that same sensitivity leads to brief (and, for some participants, frequent) repeated notes. The mechanical configuration of the octave keys may also lead to octave errors. Therefore, musical tasks should be designed to stay within a 1-octave range. Future research should continue to define parameters that enable MIDI wind controllers to be used validly and reliably.

## Acknowledgments

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# Trumpet and marimba: Combining sounds in Brazilian music

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The main purpose of this article is to provide information regarding Brazilian music for trumpet and marimba duo. *In Tempori Duo*, formed by the authors of this paper, started performing chamber music for trumpet and percussion in Brazil from 1990 onwards. As a result, many Brazilian composers wrote for this duo. About twelve pieces have been composed for *In Tempori Duo*, mostly for trumpet and marimba.

*Keywords:* trumpet; marimba; percussion; Brazilian music; duets

“Trumpet and percussion instruments have histories and centuries-old relationship [sic] with one another” (Foster 2007, p. 140). Several ancient societies used these instruments in battles as a form of communication. In the Renaissance, they were partners in different kinds of ensembles, and during the twentieth century, they integrated together various chamber ensembles (Gleason 2008, 2009). However, their combination in duos and trios is relatively new. According to Dunn, music for trumpet and percussion can be considered a new genre of chamber music:

During the last four decades of the 20th century, over [one] hundred works were composed for trumpet and percussion in chamber music settings for two or three players. This body of literature represents the beginning of a new genre of chamber music that is gaining momentum at the turn of the 21st century (Dunn 2001, p. 1).

Trumpet and percussion chamber music began to appear by 1963. Trumpet player and composer William A. Billingsley, in order to expand his trumpet recital repertoire, composed and performed *Brief Encounters* (Dunn 2001). The family of percussion instruments ranges widely, and the marimba is only

one instrument in this context. During the last century marimba has been growing both in manufacturing aspects and technical approaches, and it is possible to say that this development permitted new prospects for the instrument, such as the very new combination with the trumpet.

In recent decades, numerous works have been composed for an unusual combination—the trumpet and marimba. These works have often been by prominent composers, yet are rarely performed and most have never been recorded (Foster 2007, p. 1).

Foster (2007, p. 44) presents a list containing seventeen works for trumpet and marimba. We add one more piece to this list: *Recital music for marimba and trumpet* by Don Kuen, a Canadian composer. *In Tempori Duo* has commissioned music for trumpet and marimba since 1995 in Brazil, and the main objective here is to present these works.

### MAIN CONTRIBUTION

Even though the writing possibilities for trumpet and marimba chamber music are very diverse, we intend to introduce this subject, to present the Brazilian repertoire for trumpet and marimba duo, and to stimulate new compositions for trumpet and marimba as well as for trumpet and percussion. All of the works for trumpet and marimba selected below were written by Brazilian composers and commissioned by *In Tempori Duo*. They use typical notation, and most are written for trumpet in C and low A marimba. The music excerpts and composers are briefly cited.

- *Tema Expresso* (1995; see Figure 1) by Alex Guerra. The music alternates between 3/4, 4/4, 5/8, and 6/8 bars and the marimba part requires four mallets.
- Eliana G. Sulpicio, one of the paper's authors, wrote three pieces: *Divertimento* (1997; see Figure 2), *Vernal* (1998; see Figure 3), and *Cirandas* (2003; see Figure 4). *Divertimento* alternates between two and four marimba mallets. *Cirandas* are variations on Brazilian folk music and the trumpeter needs mutes for some passages.
- *TPM I* (2005; see Figure 5) by Marcos Battistuzzi. It requires four mallets, and the most difficult aspect for the trumpet is endurance.
- *Peça para Trompete e Marimba* (2006; see Figure 6) by Sergio Igor Chnee, a Brazilian composer and conductor. The marimba part alternates between two and four mallets.



- *Porto Belo* (2011; see Figure 7) by José Gustavo Julião de Camargo. It is a doubled melody and requires four marimba mallets.
- *Cançoneta I* (2011; see Figure 8) by Osvaldo Lacerda, an important Brazilian composer. This is one of his last pieces. He died on July 18, 2011.
- *Cinco introduções a uma música inexistente* (2012; see Figure 9) by Matheus Bitondi. It starts with the trumpet alone and the marimba has challenging passages.
- *Amor nunca diálogo* (2012; see Figure 10) by Leonardo Martinelli. The trumpeter plays offstage.
- *Interiores* (2013; see Figure 11) by Valdeci Faggioli. It presents a Brazilian atmosphere with jazz articulation in a serial process.
- *De que são feitos os dias?* (2008; see Figure 12) by Silvia Berg. It is for vibraphone, percussion (one player), and trumpet and is based on a poem by Cecília Meireles, a Brazilian writer.

The image shows a musical score excerpt for two instruments: Trumpet in C and Marimba. The music is in 4/4 time and marked *mf* (mezzo-forte). The trumpet part consists of a series of eighth and quarter notes, while the marimba part features a rhythmic pattern of eighth notes with a steady bass line.

Figure 1. Excerpt of Guerra's *Tema Expresso*.

The image shows a musical score excerpt for two instruments: Trumpet (T) and Marimba (M). The music is in 3/4 time. The trumpet part has a melodic line with some grace notes, and the marimba part has a more rhythmic, eighth-note pattern. The score includes dynamic markings and articulation symbols.

Figure 2. Excerpt of Sulpicio's *Divertimento*.

The image shows a musical score excerpt for two instruments: Trumpet (T) and Marimba (M). The music is in 3/4 time and marked *mf*. The trumpet part has a melodic line with some grace notes, and the marimba part has a rhythmic pattern of eighth notes. The score includes dynamic markings and articulation symbols.

Figure 3. Excerpt of Sulpicio's *Vernal*.

Figure 4 shows an excerpt from Sulpicio's *Cirandas*. The score is for Trumpet in C and Marimba. The tempo is marked "Faster". The Trumpet part begins with a melodic line in 3/4 time, marked *mf*. The Marimba part provides a rhythmic accompaniment with chords and single notes, also marked *mf*.

Figure 4. Excerpt of Sulpicio's *Cirandas*.

Figure 5 shows an excerpt from Battistuzzi's *TPM I*. The score is for Trompetta C and Marimba. The Trompetta part features a melodic line with slurs and accents, marked *mp*. The Marimba part provides a rhythmic accompaniment with chords and single notes, also marked *mp*.

Figure 5. Excerpt of Battistuzzi's *TPM I*.

Figure 6 shows an excerpt from Chnee's *Peça Para tompete e Marimba*. The score is for Trumpet in C and Marimba. Both parts feature a complex, rhythmic pattern with many accents, marked *mf*.

Figure 6. Excerpt of Chnee's *Peça Para tompete e Marimba*.

Figure 7 shows an excerpt from Camargo's *Porto Belo*. The score is for Tpt. (Trumpet) and Mar. (Marimba). The Tpt. part begins at measure 109 with a melodic line, marked *mf*. The Mar. part provides a rhythmic accompaniment with chords and single notes, also marked *mf*.

Figure 7. Excerpt of Camargo's *Porto Belo*.

Figure 8 shows the opening bars of Lacerda's *Cançoneta*. The score is for Trombeta em Dó and Marimba. The tempo is marked "Andantino ( $\text{♩} = 92$ )" and the mood is "cantabile". The Trombeta part begins with a melodic line, marked *mf*. The Marimba part provides a rhythmic accompaniment with chords and single notes, marked *mp*.

Figure 8. The opening bars of Lacerda's *Cançoneta*.

Introdução no.3

Figure 9. Excerpt of Bitondi's *Cinco introduções a uma música inexistente*.

Figure 10. Excerpt of Martinelli's *Amor nunca diálogo*.

Figure 11. The opening bars of Faggioli's *Interiores*.

Figure 12. Excerpt of Berg's *De que são feitos os dias*

## IMPLICATIONS

*In Tempori Duo* is in the process of recording the above music. We feel that it will be of value to musicians, composers, students, and teachers (and even to those who appreciate music) to know the possibilities of this uncommon combination. All the works above are currently unpublished. The scores are in possession of the composers and the authors of this paper.

## Acknowledgments

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# Effects of physical training on the stability of operatic singing: Acoustical analyses and physical measurements after isometrics

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To investigate the effectiveness of a new type of training for singing, i.e. isometric training for the muscles to maintain the steady posture of the upper half of the body, nine undergraduates of Kyoto City University of Arts, majoring in vocal music, provided samples of singing before and after isometric training spanning nine months. The isometric training improved the physical achievement of each participant. The total durations of maintaining body posture became significantly longer than at the very beginning of the training. Three undergraduates, majoring in vocal music, provided samples of singing as a control group. Acoustic analyses revealed that the physically trained participants could modulate the fundamental frequency more prominently than the control group. On the other hand, the fluctuations in intensities and spectral patterns were suppressed more effectively in the training group than the untrained group. These results indicated that the isometric training affected the way of controlling the singing or phonation. The changes caused by the physical training can be assumed to improve the stability of singing voices.

*Keywords:* vocal performance; isometric exercise; voice quality; acoustic measure; training method

When people sing, they need to control their speech organs differently from when they speak. This fact tends to be ignored, because people generally believe that they can sing as easily as they speak. However, there are some “poor” singers who we cannot distinguish from good or normal singers based on the way they speak. One of the differences between speech and singing is that singing requires we stabilize the voice, especially in the fundamental

frequencies, longer than speech (Sundberg 1987). To maintain a steady state of a voiced segment, it is required to keep the subglottic pressure at a certain value, which enables the vocal folds to vibrate periodically. This appropriate subglottic pressure varies depending on several physical characteristics of the vocal cords, i.e. the tension, length, and thickness, as well as the pitch and loudness of the vocal sound. Two main forces are engaged in determining the subglottic pressure: (1) a passive recoiling force of the lung and (2) an active muscular force to change the costal volume. Because the recoiling force varies depending on the lung volume, the active muscular force should change during a single vocalization. This might be a reason for many professional singers and instructors to pay attention to the method of respiration in singing. However, active control of relevant muscles is more complex than average singers can imagine (Sundberg 1987, Friberg and Sundberg 1995).

While it might seem to be too straightforward to expect that reinforcing the strength of muscles would improve the vocal quality, the experiences of the third and fourth authors of this paper, who are professional opera singers, indicate that some of their young students had difficulties which might be related to the weakness of their basic physical strength. The current study investigated whether isometric training would be effective in improving vocal performances by measuring several acoustic features of vocal sounds.

## METHOD

### Participants

Twenty-eight undergraduates completed the measurement of the physical performances, both at the beginning and the end of the first semester. Nine undergraduates majoring in vocal music, who completed the isometric exercise class, provided recordings of the vocal performance for the trained group. Three undergraduates in the vocal music course, who did not take the isometric exercise class, provided vocal recordings for the untrained group.

### Materials

The vowel “a” was sung at the three pitches and the three dynamics by each participant and then submitted to acoustic analyses. Pre- and post-recordings were analyzed (81 samples for the trained group and 27 samples for the untrained group).

## Procedure

Isometric training was imposed for two semesters as a part of gymnastics classes, including three poses as depicted in Figure 1: (1) plank bridge, (2) side bridge, and (3) isometric squat. One class lasted 90 minutes, and 12 classes were given per semester. The maximum durations participants were able to hold the poses were measured at the beginning and the end of the first semester.

Each participant was required to sing a vowel "a" as long and stable as possible in three pitches (the base tonic of each participant, the tonic higher by an octave, and the highest pitch which he/she could sing) and three dynamics (*mf*, *p*, *pp*). Pre- and post-recordings were done in May 2012 and March 2013, respectively, in a sound-treated classroom for musical performance at Kyoto City University of Arts. Each participant wore a headset-type wireless microphone (Sennheiser ME). Vocal sounds were digitally recorded with an audio interface (Edirol FireWire AudioCapture FA-101) connected to a laptop computer (Apple MacBook Pro) by a transmitter (Sennheiser SK 100) and a receiver (Sennheiser EM 100).

## RESULTS

Two types of limit durations to keep each of the three poses were measured. The first type was the limit at which a noticeable tremor was observed. The second type was the limit at which each participant gave up keeping each pose (maximum=180 seconds). A two-way ANOVA was performed for the logarithm of each duration with the test date and the measure type as main factors. Both of the main factors were significant ( $F_{1,432}=102.8$ ,  $p<0.0001$ ;  $F_{7,432}=2.76$ ,  $p<0.01$ , respectively). Their interaction was also significant ( $F_{7,432}=2.76$ ,  $p<0.01$ ). The test date factor was tested with the interaction term as a random error and it became significant again ( $F_{1,7}=37.28$ ,  $p<0.0005$ ).

To obtain acoustic features, a fundamental frequency (FO) estimation, a spectral estimation by a smoothing reflecting the FO information, and an

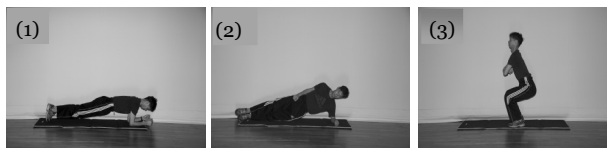


Figure 1. Three poses of the isometric exercise: (1) plank bridge, (2) side bridge, and (3) isometric squat.

estimation of the aperiodicity excluding the factors by Fo and spectral fluctuations (STRAIGHT) were applied to the waveform data of the vocal samples (Kawahara *et al.* 2008). Because the estimation of acoustic features for the initial and final transient parts of each vocal sample tends to become unreliable, these transient parts were excluded automatically using the Fo trajectory information. Fourteen parameters described below were estimated as candidates for the stability of the vocal sounds. The stability of logarithmic Fo trajectory was measured using five features: (1) a standard deviation from the mean Fo, (2) a root mean square (RMS) of the difference between each pair of consecutive frames, (3) a frequency of the most prominent temporal modulation component, (4) an amplitude of the most prominent temporal modulation component, and (5) a strength of the harmonic structure of the temporal modulation waveform (Indices 1–5).

These five measures were also obtained for the intensity contour. The first two measures were obtained for the spectral temporal pattern as well (Indices 6–10). The difference between each frame from the mean spectrum and the difference between each pair of two consecutive frames were calculated while keeping the frequency structure at the first step, and they were pooled over the frequency axis (Indices 11–12). The aperiodicity measure was estimated as amplitudes of random components excluding the influences of the Fo modulation and the spectral modulation for each frequency bin of each frame. They were summed up by pooling over the frequency and frames (Index 13). The duration of the stable segment was also used as a candidate of the stability index (Index 14).

Paired t-tests between the pre- and post-recordings were performed for each acoustic measure to compare groups (see Figure 2). Significant effects of the isometric training (IT) were observed for the acoustic measures as follows: (1) the amplitude of Fo modulation increased more prominently in the trained group than in the untrained group ( $t=-2.118$ ,  $p<0.05$ ); (2) the intensity fluctuation between two consecutive frames reduced more prominently in the trained group ( $t=3.187$ ,  $p<0.005$ ); (3) the amplitude of intensity modulation increased clearly in the trained group, while it did not appear to change in the untrained group ( $t=-2.667$ ,  $p<0.01$ ); (4) the spectral fluctuation between two consecutive frames increased in the untrained group, while it stayed at almost the same level in the trained group ( $t=-2.320$ ,  $p<0.05$ ); and (5) the aperiodicity reduced more prominently in the trained group ( $t=-3.054$ ,  $p<0.005$ ).



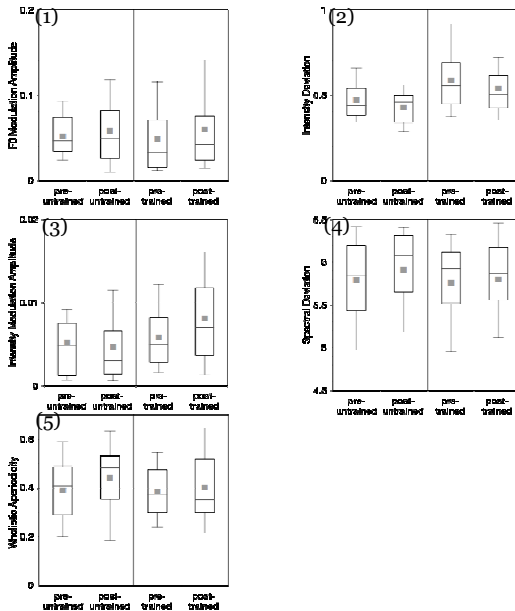


Figure 2. Boxplots of the acoustic measure for which significant differences of the isometric training was observed between the trained and untrained group: (1) amplitudes of FO modulation; (2) RMS differences of intensities between each pair of consecutive frames; (3) amplitudes of the intensity modulation; (4) spectral RMS differences between each pair of consecutive frames; and (5) aperiodicities.

## DISCUSSION

The acoustic analyses revealed that the isometric training affected the degree of improvement in vocal performances. Generally, the participants tended to use the deeper vibrato (FO modulation) while reducing the intensity fluctuation. The depth of vibrato increased more prominently in the trained group than in the untrained group. Simultaneously, the intensity fluctuation reduced more clearly in the trained group. The deepened modulation in the fundamental frequency was accompanied by an increase of the spectral fluctuation in the untrained group. The trained group, however, succeeded in keeping it at the same level. A similar tendency was observed for the aperiodicity index. While the amplitude of intensity modulation increased in the trained group, it tended to decrease in the untrained group. It appeared to be incongruent with the fact that the intensity fluctuation reduced in the trained

group. It is worthwhile to note that the amplitude of intensity modulation reflects the regular intensity change of vocals while the between-frame intensity fluctuation can increase as a result of irregular perturbation. It has been observed that singing higher pitches requires generally higher subglottic pressure, and might result in the increment in intensities (Sundberg 1978). The observed tendency indicates that the participants tried to sing with deeper FO modulation after 8 months. They managed to suppress the intensity fluctuation as much as possible. This compensatory suppression was done more successfully in the trained group than in the untrained group. The trained group also seemed to minimize the spectral fluctuation, which might be also caused by the deeper FO modulation. The isometric training seemed to be effective in controlling such compensatory or coordinated controls on the muscles involved in singing. It could be an interesting question to ask whether these coordinative operations improved simply by the augmented muscular strength, which might be trained by the dynamic training as well, or by any other factor improved by the isometric training.

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# Simulating and stimulating performance: Designing and validating simulated music performance settings

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Musicians typically rehearse far away from their audiences and in practice rooms that differ significantly from the concert venues in which they aspire to perform. Due to high costs and the inaccessibility of such venues, much current international music training lacks repeated exposure to realistic performance situations, with students learning all too late (or not at all) how to manage the challenges of performing and the demands of their audiences. Simulation has been shown to be an effective tool for training students in the fields of medicine, clinical therapy, and sport, offering practitioners access to real-life performance scenarios but with much lower risk of negative outcomes and evaluation. Only few attempts have been made to apply simulation training to music. The aim of this project was to design simulated performance environments in which the conditions of “real” performance could be recreated as authentically as possible. Advanced violin students (N=12) were recruited to perform in two distinct simulations: (1) a solo recital with 24 virtual audience members and (2) an audition situation with three “expert” virtual judges. Each simulation contained back-stage and on-stage areas (complete with CCTV footage of the audience/audition panel, spot-lights, and stage curtains), life-sized virtual audiences who were interactive (controlled from back-stage), and pre- and post-performance protocols designed to match those found at leading international performance venues (e.g. entrance to a “green room” for warm-up, stage calls at regular intervals, and procedures for entering, bowing, and exiting the stage). Participants were then asked to complete a questionnaire on their experiences of using the simulations and take part in a semi-structured interview. The results show that both simulated environments offered sufficiently realistic experience of performance contexts to enable musicians to practice their performing. The musicians reported numerous training and educational applica-

tions of the technology, from preparing for important recitals and auditions to delivering higher quality performances.

*Keywords:* simulation; music education; professional training; performance anxiety; performance quality

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# Preferences in practicing chamber music

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This research aimed to develop and apply an online, qualitative-quantitative questionnaire to 66 music students in their practice of chamber music. The participants were enrolled as students in the Music Department (UFRGS) with different levels of musical instruction, years of musical practice, and instruments. The questionnaire aimed to identify periodicity of rehearsals, criteria for ensemble partner selection, motivation for performing in an ensemble, leadership establishment, and rehearsal techniques used by students in their activities. Results showed a preference for personal choices over partners' choices, with flexibility in rehearsals when necessary. The main advantage of practicing chamber music, according to the participants, was the opportunity to exchange knowledge and experiences and to develop concentration, a sense of responsibility, and respect for one another. Reported challenges included the construction of similar interpretations and understandings of the music, overcoming self-centrism and individual personalities, differences in level of study and experience, achieving rhythmic synchronicity, adapting to the kind of repertoire and style of playing, and forming a schedule of rehearsals. Rhythmic inaccuracies and structural mismatches were reported as the main reasons to interrupt a rehearsal.

*Keywords:* music performance; chamber music; music students; deliberate practice; rehearsal techniques

Chamber music performance is both a musical practice and a social gathering in which people need to be motivated in order to collaborate. In previous decades an increasing interest in research on chamber music can be observed. The increased number of articles and publications addressing aspects of the practice of chamber music has focused on group constitution, organization, leadership, strategies, and performance. King (2006) cites authors who researched "music ensembles, including piano duos (e.g. Williamon and Da-

vidson 2002), cello-piano duos (e.g. Waterman 1996, Goodman 2000, 2002, Davidson and King 2004), string quartets (e.g. Young and Colman 1979, Butterworth 1990, Murnighan and Conlon 1991, Tovstiga *et al.* 2004), wind quintets (e.g. Ford and Davidson 2003), choirs (e.g. Yarbrough 1975, Cox 1989) and orchestras (e.g. Faulkner 1973, Weeks 1996)” (King 2006, pp. 262). Davidson and King (2004) address aspects such as group dynamics, rehearsal planning and strategies, verbal and nonverbal communication, social interaction, and rehearsal methods among performers. The authors suggest that there is no “best” method or strategy for rehearsing a piece of music; rather, each ensemble will find their own “best” way to rehearse and that alternative approaches and different strategies could achieve the same goal. The authors emphasize the necessity of greater awareness of the social-psychological principles to improve interaction and cohesion within an ensemble. Price and Byo (2002) researched conductors and their influence on ensembles, emphasizing the influence of rehearsal atmosphere, feedback, pacing, error detection, conductor demeanor, organization of the rehearsal structure, and verbal and nonverbal proceedings to help conductors cope with ensembles. King’s (2006) research examining roles of leadership in quartets concluded that those with a regular leader exhibited more stable team role behavior, a consistently focused group dynamic, and better progress than those without one, thus highlighting the impact of leadership on the success of a group. Ford and Davidson (2003), comparing string quartets with wind quintets, found features in common, and also identified distinctive characteristic aspects of leadership, time management, rehearsal procedures, and organization within each ensemble, suggesting that each developed their own characteristics and functionality. The research presented here aimed to develop and apply an online, qualitative-quantitative questionnaire to better understand these inter-ensemble interactions.

## METHOD

### Participants

An online questionnaire was initially applied to 12 participants of different instruments (2 singers, 2 pianists, 3 flutists, 1 recorder player, 1 trombonist, 1 violinist, 1 guitarist, and 1 contrabassist). The data were collected between October and December of 2012. A paper version of the questionnaire was also applied to 54 additional first-year music students during an introductory music class. All participants were enrolled as students in the Music Department of the Federal University of Rio Grande do Sul (UFRGS) and

*Table 1.* Demographic data from participants (N=66).

	<i>Age</i>	<i>Musical training</i>	<i>Weekly practice time</i>
Maximum	52 years	40 years	40 hours
Average	24.2 (SD 7.56)	12.7 (SD 9.35)	11.3 (SD 8.27)
Median	22 years	10 years	10 hours
Minimum	17 years	1 year	1 hour

presented different levels of musical instruction (conservatory, graduate, and post-graduate students) as well as years of musical practice (see Table 1).

## **Materials**

Question 1 (Q1) investigated the amount of practice time and nature of ensemble activity engaged by each participant. Q2 dealt with the identification of individual criteria for selecting partners. It allowed multiple answers (casual choice, personal affinity, personal choice, repertoire, opportunity, proximity, audition or contest, other). Q3 recorded the periodicity of rehearsals, and Q4 the objectives for practicing in ensemble groups (musical development, financial, repertoire, fun, social, other). Q5 and Q6 identified advantages and difficulties in playing within an ensemble, Q7 how leadership is established in ensemble practice, and Q8 the causes of rehearsal interruptions (wrong notes, articulation, rhythm, structural mismatch, individual concept about the music, balance, mistuning, other).

## **Procedure**

The questionnaire was presented in two versions. The online version was answered by 12 students, and the paper based version by 54 students. Data were analyzed using  $\chi^2$  (frequency data) and ANOVA (scale from 0 to 10). The qualitative analysis is in its initial stage, and the results reflect the answers from the initial 12 participants from the online version of the questionnaire. Additionally, tests comparing age, years of musical training, and weekly practice time were conducted.

## **RESULTS**

Differences in frequency of answers to Q2, *ensemble membership selection*, were statistically significant ( $\chi^2=32.76$ ,  $df=7$ ,  $p<0.001$ ). The most common answers were *personal affinity with the other players* (20.3%), *repertoire*

(14.7%), *opportunity* (14.2%), and *proximity* (13.6%). Answers to Q4, *reasons for performing chamber music*, did not present statistically significant differences save for *musical development* (35.1%) and *social* (9.2%), the highest and lowest frequencies ( $p < 0.001$ ).

$X^2$  tests that divided subjects into two groups in relation to years of musical training and weekly practice were non-significant. Subjects older than the median age (22) reported playing for social reasons 6.29% more often than the younger subjects. Conversely, the younger subjects reported playing for fun 6.40% more often ( $X^2=5.65$ ,  $df=1$ ,  $p < 0.017$ ).

One-way ANOVA was conducted for comparing differences of means of answers to Q8, *reasons for interrupting rehearsals*. Results are highly significant ( $F_{6,441}=13.584$ ,  $p < 0.001$ ). Three groups of homogeneous subsets (with non-significant differences among their means) are presented in Table 2. Subset 3 includes the three main motives for interrupting rehearsals according to 59 subjects who marked from 0 to 10 in all 7 items.

The initial qualitative analyses of Q5, Q6, and Q7 have been conducted on the 12 subjects who answered the online questionnaire in 2012. Its results helped in the decision to continue the research with more subjects.

The exchange of ideas and experiences, the opportunity to learn the repertoire for collective formations, the development of concentration, the collective construction of interpretation, and the understanding of musical structures were referred to by participants as advantages to chamber music practice. Also mentioned were the improvement of the concept and sound of the ensemble and developing individual tuning. Participants also reported perceived difficulties in playing together, including the construction of similar

Table 2. Reasons for interrupting rehearsals. Tukey's HSD homogeneous subsets.

	N	Subset for $\alpha=0.05$			SD
		1	2	3	
Conception of the music	59	5.73	-	-	2.840
Wrong notes	59	5.76	-	-	2.855
Differences in articulation	59	5.80	-	-	2.420
Balance	59	6.15	6.15	-	2.476
Mistuning	59	-	7.39	7.39	2.252
Rhythm	59	-	-	7.90	2.280
Structural mismatch	59	-	-	8.59	2.035
Significance	-	0.967	0.095	0.114	-



interpretations and understandings of the music, overcoming self-centrism and individual personalities, differences in the level of study and experience, achieving rhythmic synchronicity, the kind of repertoire and style of playing, and scheduling rehearsals. Concerning leadership and the decision-making process, participants reported that decisions tended to be collective and democratic, except when leadership is conferred by the group to one of its members.

## DISCUSSION

Three primary conclusions can be inferred from the analysis. Structural mismatch and rhythmic inaccuracy were considered more likely to interrupt rehearsals than disagreement on the conception of the musical work, balance, and articulation. This may reflect the stage of musical development of the students; more experienced, professional performers may report different reasons.

The combination of *personal affinity* (with the other players) as a reason for engaging in a chamber music practice with *musical development* as the main objective for ensemble practicing may reflect an underlying relationship between *personal affinity* and *musical development* in general. This could extend beyond chamber music practice and be a general preference for learning music. It also may reflect the origins of chamber music as an interaction between family and friends in social gatherings for performing music.

Finally, differences in years of musical training, as well as in hours of weekly practice, did not influence reported reasons for playing chamber music. Nevertheless, age differences may have influenced the reason as *social* versus *fun*. This result may indicate a natural change of musical goals that comes with aging.

This research is in its initial stage and the authors will be very thankful for inquiries and suggestions.

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**Thematic session:  
Ensemble synchronization**



# Patterns of entrainment: Being out of sync, in sync, and in between

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In order to investigate a previously uncharted range of dyadic entrainment behaviors, we conducted a dyadic tapping study on resisting entrainment. Participants were asked to maintain their own tempo while interacting with their tapping partner. Different patterns of entrainment emerged, but trials were often either highly entrained or not at all. As expected, initial tempo difference between the participants was the main factor determining whether a trial was entrained or not, but a clear threshold was not found. Musical training, but not individual rhythmic skill or personality traits, had an effect. Surprisingly, participants with musical training were more likely to entrain even over a large tempo difference, perhaps owing to their training in playing together and learned aesthetic preferences.

*Keywords:* entrainment; interaction; synchronization; non-musician; tapping

Entrainment is often automatic and fundamental to human interaction and communication. Previous studies have explored unintentional and intentional entrainment (reviews in Repp 2005, Schmidt and Richardson 2008), while few studies have explored resistance to entrainment (Lucas *et al.* 2011). Previously, automatic phase attraction to distractors (Repp 2004), and preference of human partners over mechanical metronomes (Himberg 2006) have been demonstrated. Since the previous focus of tapping studies has been on extremely high synchronization, we performed an experiment on resisting entrainment to explore how people move in and out of sync. Participants were

asked to play and sustain their own tempo against the other participant, whose tempo was either same or different.

Our aims were to investigate (1) whether participants can maintain their own tempo or whether they entrain with their partner, (2) whether there is a threshold of tempo difference below which participants cannot help but entrain, and (3) the types of changes in the relationship between the tappers: are they gradual or sudden and are they symmetrical or asymmetrical?

In doing so, we explored which factors influence the extent to which participants can resist entrainment. We focused on two possibly highly correlated factors: musical training and the participants' solo tempo stability.

## METHOD

### Participants

In Experiment 1, 36 participants (20 musicians with an average 12.35 years of active musicianship and 16 non-musicians with <2 years of formal musical training) performed the experiment in pairs matching in musical experience and age. In Experiment 2, 38 non-musicians (<5 years of formal musical training) took part.

### Procedure

Participants performed synchronization-continuation trials (45 seconds/trial, finger-tapping on a MIDI drum) at 5 tempi (93.5-126.5 bpm) in three conditions: solo, same tempo duet, and different tempo duet. In duet trials, participants did not hear each other until 4 seconds into the continuation part so that they had time to establish their own tempo. Their instruction was to maintain their original tempo as well as possible, regardless of the distraction of the other participant. In the different tempi duets the participants had smaller or larger tempo differences (5-33 bpm), depending on the combination of starting tempi.

## RESULTS

### Experiment 1

Our analysis focuses on the duet section of the trials. Relative phase of the participants' taps were calculated, and the concentration index of the phase angle distribution  $R$  was used as an entrainment measure (Fisher 1993). Trials seemed to be either highly entrained or not entrained at all—the histogram of  $R$ -values in the trials was bimodal with the extreme values dominat-

ing and fewer values in between (see Figure 1). Unsurprisingly, musicians were the better tappers and their tap-to-tap stability was better in all tasks. However, it is somewhat surprising that musicians were also more likely to entrain even when the initial tempo difference was large. This could reflect their ensemble training and preference for synchronized rhythms.

Figure 2 illustrates how, even within one pair (musicians in this case), performance could vary greatly between trials. Panels A and B show inter-tap interval data from experiments in which the initial tempo difference was large. In A, both participants sped up slightly relative to their metronome tempo (dashed straight lines mark the metronome IOI) but they did not entrain, instead maintaining their tempo difference to the end (they finished at the same time; the blue tapper had longer beat length so performed fewer taps). However, in B the red tapper quickly sped up and caught the blue one, and they became entrained for the rest of the trial (while having similar ITI's is not yet sufficient evidence for entrainment; this was confirmed in separate analysis).

In panels C and D the participants had the same metronome and started the duet section at a very similar tempo. However, only in C were they entrained, as in D they quickly separated. The blue tapper in particular behaved differently in these two trials, as in C s/he sped up with the red tapper, while in D s/he resisted not only entrainment, but also the natural tendency to speed up during the trial. Perhaps in an effort to resist entrainment, s/he actually slowed down slightly—a rare behavior in this study.

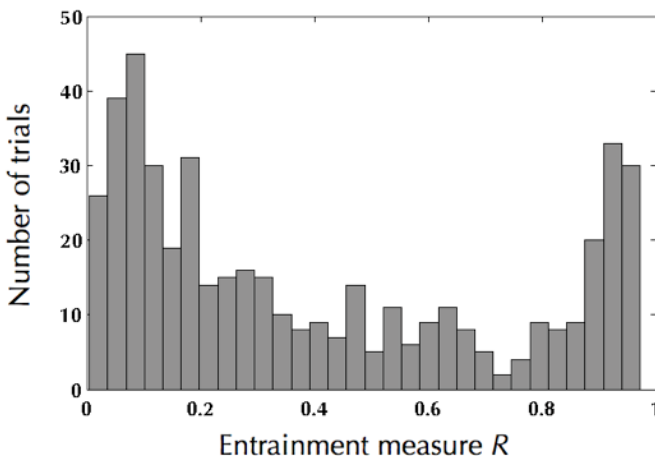


Figure 1. Histogram of the entrainment measure in the trials of Experiment 1.

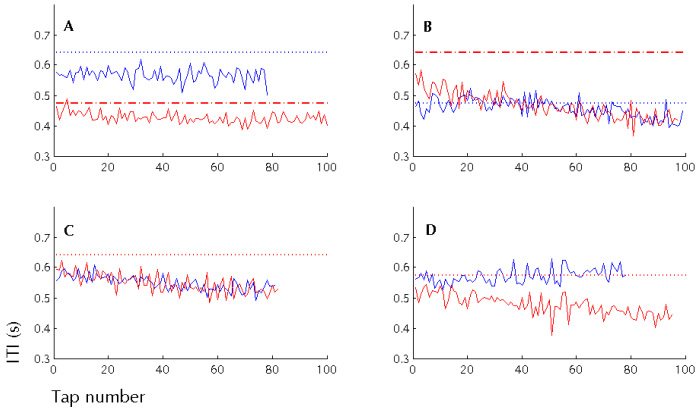


Figure 2. Inter-tap interval patterns for one pair (musicians) in four trials of Experiment 1. Dashed straight lines mark the original metronome tempi.

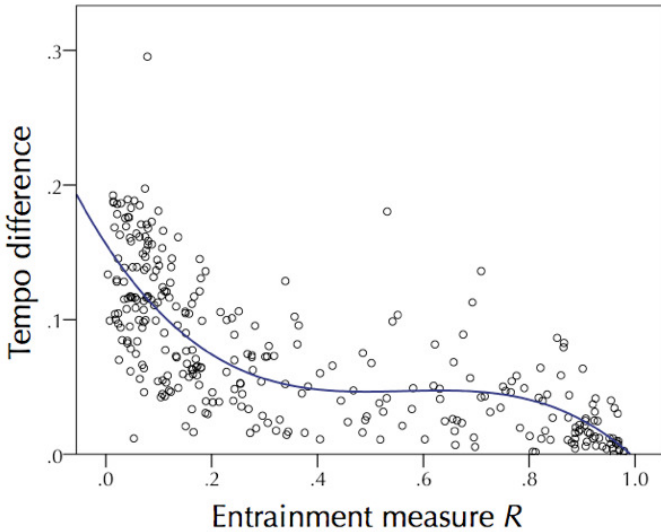


Figure 3. Cubic line fit for tempo difference versus entrainment in Experiment 2. (See full color versions at [www.performance-science.org](http://www.performance-science.org).)



## Experiment 2

We made minor changes to the setup for the second experiment. The focus was changed to non-musicians only and tempo difference conditions were added so that we could formally investigate whether there is a threshold for resisting entrainment.

The example discussed above already suggests that it may not be possible to identify a clear threshold, as the same participants engaged in “opposite” behaviors when a trial was repeated. In Figure 3 the entrainment measure and tempo difference of the trials are plotted. A cubic line is fitted to the data, with a relatively good fit ( $R^2=0.568$ ). It can be seen that trials are clearly clustered to the right bottom corner (high entrainment, small tempo difference) and towards the left top corner (low entrainment, large tempo difference). The long, horizontal middle part of the line illustrates that, for trials with small tempo differences, virtually any outcome was possible.

We also looked at entrainment patterns within the trials at this middle ground. About a quarter of these were trials where the participants started not entrained but entrained during the trial. This transition was usually very quick, but in some cases the shift was slightly more gradual and in others there were multiple transitions between the two extremes. There were also trials where the opposite transition occurred—from entrained to not entrained. Again, multiple transitions could occur, but these were rare.

Tempo drifts were observed in most trials. There was a general tendency to speed up, apart from the fastest tempo, but interestingly the amount of tempo drift did not affect the amount of entrainment in the trial—even in perfectly entrained trials large tempo drifts were observed and vice versa.

## DISCUSSION

We conducted a dyadic tapping trial where participants were required to maintain their original tempi, in most cases resist entraining with their partner. We found that entrainment was often a yes/no affair, with fewer trials with mixed outcomes. Even of these mixed trials, most of the transitions between these two states were fast. The initial tempo difference was the main predictor of entrainment, but participants, and especially musicians, both resisted entraining even when in the same tempo and entrained even across a large tempo difference.

Our future research will apply these results to our work on entrainment and rhythmic behaviors in music therapy interactions. This involves exploring the links between entrainment and various psychological factors, such as

empathy, and analyzing therapist-client interactions in music therapy improvisations.

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# Multidimensional analysis of interdependence in a string quartet

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In a musical ensemble such as a string quartet, the performers can influence each other's actions in several aspects of the performance simultaneously. Based on a set of recorded string quartet exercises, we carried out a quantitative analysis of ensemble interdependence in four distinct dimensions of the performance: dynamics, intonation, tempo, and timbre. We investigated the fluctuations of interdependence across these four dimensions, and in relation to the exercise being performed. Our findings suggest that, although certain differences can be observed between the four dimensions, the most influential factor on ensemble interdependence is the musical task, shaped by the underlying score.

*Keywords:* interdependence; string quartet; ensemble performance; signal processing; motion capture

Studying the inner workings of joint music performance is a complex task. Previous research (Keller 2008) points out some important characteristics of ensemble performance: the sharing of a common goal among performers, the implicit (i.e. non-verbal) communication between performers, and specific “ensemble skills” which are required for ensemble cohesion to be achieved.

Previous research on musical collaboration has been carried out for tapping tasks (Repp 2005) and piano duets (Goebel and Palmer 2009), among others. On the subject of interdependence (as opposed to synchronization), different computational approaches for intonation and dynamics have been evaluated (Papiotis *et al.* 2012).

In this study, we analyzed several recordings of a professional string quartet in terms of ensemble interdependence: the degree to which the musicians are influencing each other's performance. We extracted numerical features that characterized the produced sound in terms of four performance dimensions (*dynamics, intonation, tempo, and timbre*), and quantified the

amount of interdependence between these features for each pair of musicians. Finally, we aggregated the obtained results to investigate relationships between dimensions, and the effect of the underlying musical score on the overall amount of interdependence.

## METHOD

### Experimental material

The experimental recordings are based on an exercise handbook for string quartets (Heimann 1958) specifically designed to assist in improving the ensemble's capabilities for collaborative expression. This material is divided into six categories: dynamics, intonation, phrasing, rhythm, unity of execution, and timbre. We analyzed nine of the recorded exercises; a brief description of each exercise is provided in Table 1.

Each exercise was recorded in two experimental conditions: *solo* and *ensemble*. In the first condition (*solo*), each musician performed their part alone without having access to the full ensemble score. In the second condition (*ensemble*), the quartet performed the exercise together following a brief rehearsal period (~10 minutes).

### Data acquisition and processing

All exercises were recorded by the same group of professional musicians. Individual audio for each musician was acquired through the use of piezoelectric pickups attached to the bridge of the instrument while motion capture data were acquired through the use of a wired MOCAP system that tracked the movement of the bow in relation to the instrument strings. Instrumental (sound-producing) gestures were computed from the raw motion capture data as described in Maestre (2009). For every recording, a semi-automatic alignment between the performance and the music score was performed using a dynamic programming routine that combined audio and instrumental gesture features to detect note change events.

### Interdependence estimation

The general framework for estimating interdependence in a single performance dimension was the following: first, four continuous features (one time series for each musician) were extracted from the recorded performances. Then, using a sliding window analysis, we sequentially calculated the Mutual Information between each pair of features for every window. Finally, a single

Table 1. Description of the recorded exercises per category and exercise focus. (U of E=unity of execution.)

<i>ID</i>	<i>Category</i>	<i>Exercise focus</i>	<i>Duration</i>
D1	Dynamics	<i>Vertical listening</i> : the ability to adjust one's intonation according to the intonation of the rest of the ensemble.	2:00
D2	Dynamics	Immediate ( <i>subito</i> ) changes in dynamics.	2:00
I1	Intonation	Gradual ( <i>crescendo/diminuendo</i> ) changes in dynamics.	5:00
P1	Phrasing	Synchronous bow strokes of slurred notes ( <i>legato</i> ).	3:00
R1	Rhythm	Small changes in tempo ( <i>poco piu/meno mosso</i> ).	3:00
R2	Rhythm	Different degrees of rhythmic syncopation.	3:00
U1	U of E	Sound as one instrument (chords).	2:00
U2	U of E	Sound as one instrument (ascending/descending scales).	2:00
T1	Timbre	Similar tone quality for different bow/string contact points ( <i>sul tasto/sul ponticello</i> ) and different dynamics levels.	2:00

overall interdependence value was obtained by averaging across all musician pairs and analysis windows (Papiotis *et al.* 2012).

For the *Dynamics* dimension, we extracted the Root Mean Square (RMS) energy of each musician's individual pickup signal, mapped to a logarithmic scale. For exercises with score-imposed changes in dynamics (D1, D2, and T2), we applied a note-by-note detrending to the logRMS feature in order to remove any bias introduced by dynamics-related indications appearing in the score. For the *Intonation* dimension, we extracted the so-called "Intonation deviations"—the difference between the estimated pitch from the recordings and the "reference pitch" that is obtained by the aligned score (according to equal temperament). For the *Tempo* dimension, we computed a tempo curve for each musician using the note onset times provided by the score-performance alignment. Given the relatively short duration of the exercises, Mutual Information was applied to the entire tempo curves instead of windowing them. For the *Timbre* dimension, we used two separate features—the *bow-bridge* distance, the distance (in cm) of the point of contact between bow and string from the instrument's bridge, and the *Spectral Crest*, a descriptor of spectral "peakiness" that has low values for noisy signals (and therefore "flat" spectrums) and high values for tonal signals; after computing the amount of interdependence for both features, we averaged the two results to obtain a single value.

The above procedure was carried out in each recorded exercise, both for the *ensemble* as well as the (artificially synchronized) *solo* recordings; in this way, “*solo* interdependence” was used as a baseline that was subtracted from the “*ensemble* interdependence,” removing any bias introduced by the score. As a final post-processing step, we normalized the obtained Mutual Information values per dimension, according to the Euclidean norm, across all exercise categories.

## RESULTS

Figure 1 shows the mean normalized values for Mutual Information per exercise and performance dimension.

One can first observe that the estimated Mutual Information values for each exercise type varied according to the exercise goal: the *Dynamics* exercises demonstrated highest interdependence for the Dynamics dimension, the *Intonation* exercise for the Intonation dimension, the *Rhythm* exercises for the Tempo dimension, and the *Timbre* exercise for the Timbre dimension; moreover, the *Unity of execution* exercises demonstrated highest interdependence for the Dynamics and Tempo dimensions. The sole exception is the *Phrasing* exercise, which demonstrated highest amounts of interdependence for the Intonation and Timbre dimensions but notably lacked interdependence in the Dynamics dimension. Mean interdependence per dimension across all exercises was as follows (from highest to lowest): Tempo (0.385), Dynamics (0.349), Timbre (0.340), and Intonation (0.306). The small differences across dimensions suggest that each dimension was of equal importance to the overall ensemble interdependence.

In addition to interdependence, we calculated two statistics for each exercise: the *Mean Absolute Asynchrony* between each pair of simultaneous notes in the score, and the *Mean Note Duration*. The obtained values for each exercise can be seen in Table 2.

It can be seen that across all exercises, the asynchrony between musicians varied from small values (~20 milliseconds, U2) to quite large values (~120 milliseconds, T1). The fact that the *Dynamics*, *Intonation*, and *Timbre* exercises sustained high amounts of interdependence despite the large asynchronies supports the notion that synchronization and interdependence are two separate qualities, each describing a different aspect of ensemble performance. A correlation analysis between Mean Note Duration and each performance dimension revealed a positive correlation for the Dynamics (0.86,  $p < 0.05$ ) and Intonation (0.79,  $p < 0.05$ ) dimensions.

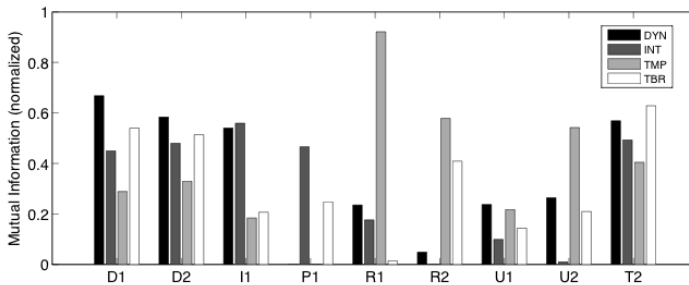


Figure 1. Normalized values of Mutual Information per exercise and performance dimension (DYN=Dynamics, INT = Intonation, TMP = Tempo, and TBR = Timbre).

Table 2. Mean Absolute Asynchrony and Mean Note Duration for each exercise.

	<i>D1</i>	<i>D2</i>	<i>I1</i>	<i>P1</i>	<i>R1</i>	<i>R2</i>	<i>U1</i>	<i>U2</i>	<i>T1</i>
MAA (seconds)	0.100	0.091	0.114	0.036	0.042	0.037	0.054	0.022	0.118
MND (seconds)	4.535	4.419	6.555	0.972	0.939	0.572	1.485	0.309	4.624

Finally, Figure 2 shows the overall amount of interdependence per exercise, averaged across all four dimensions.

One can see that the highest interdependence values occurred for the exercises that were based on simpler concepts (*Dynamics*, *Intonation*, *Rhythm*, and *Timbre*), while the *Phrasing* and *Unity of Execution* exercises, which require coordination in multiple aspects simultaneously, sustained lower amounts of interdependence. From the above figure, it can be observed that ensemble interdependence was not an ever-present quality, but rather a varying quantity that was strongly influenced by the underlying musical score.

## DISCUSSION

We directed our focus on a little-researched topic in ensemble music performance: the concept of interdependence between musicians. While some dimensions appeared to sustain higher levels of interdependence more commonly than others, it was seen that the underlying musical task is ultimately the most influential factor, as a common goal shared by the musicians. We believe that through the analysis of more recordings, the inclusion of musical pieces besides exercises, and a more sophisticated analysis of the musical score, such a methodology can yield important conclusions on the complex subject of joint musical performance.

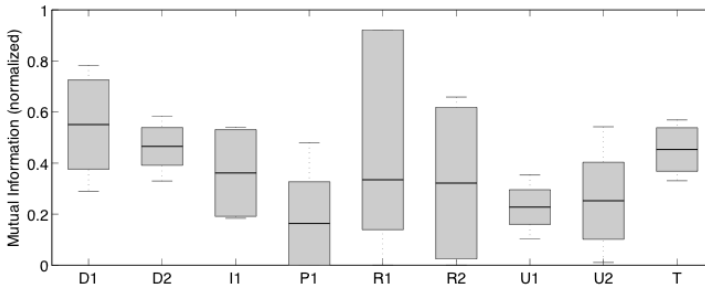


Figure 2. Mutual Information values averaged across performance dimensions for each exercise.

### Acknowledgments

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# Temporal coordination in string quartet performance

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Temporal coordination between members of a string quartet performing an excerpt of a Haydn string quartet was characterized in terms of patterns of dependence between player note onset times estimated from acoustic data, and compared to self-reported patterns of dependence between players. Audio onsets revealed temporal dependencies indicative of a leading-following relationship between the first and second violin and a relationship of mutual adaptation between the first violin and both the viola and cello. This relationship of mutual adaptation was not reflected in the self-reported dependencies, which predominantly ascribed a leadership role to the first violin.

*Keywords:* timing; synchronization; string quartet; self-report; measurement

Investigations of group dynamics in chamber music ensembles have suggested the relevance of leadership as well as democracy for the successful operation of such groups (Murnighan and Conlon 1991). Within string quartets, artistic leadership is often attributed to the first violin, while other members may take up other roles, organizational or social, or may function as “deputy” leader (King 2006). The second violin may seem to have the least significant role by primarily supporting the melody; it is nevertheless essential to the success of the group, a phenomenon known as the paradox of the second violin (Mullighan and Conlon 1991).

These dynamics between ensemble members concern their musical roles and social relationships, and may be indicative of processes of decision-making. It is likely, however, that similar patterns of interaction operate during performance and influence the way in which string quartet members coordinate with each other over time.

There may be a single “leader” of an ensemble who the other members follow to assure ensemble synchronization, or synchronization may be a more reciprocal process in which timing adaptation is bidirectional across ensemble members. For duo performances, evidence for reciprocal rather than uni-directional adaptation has been found (Goebel and Palmer 2009). Evidence also exists that accurate prediction of a partner is more beneficial to temporal synchronization than leadership, with optimal results being obtained if a duo consists of two predictors (Pecenka and Keller 2011). The case may be different, however, for larger ensembles. As Rasch (1979) demonstrated, larger ensembles may need a clearly uniting point of reference, such as a conductor, for successful synchronization.

Even if ensembles have a leader who provides a primary reference for temporal coordination, it is still likely that individuals distribute attention and respond to and correct for asynchronies with other members of the ensemble. The degree of allocation of attention to timing across players is of particular interest (Keller 2001) and may vary depending on such factors as the perceptual salience of the instrument or the similarity in musical function between players.

The aim of this study was to investigate how members of a string quartet adjust their timing to each other and, in particular, to investigate patterns of uni-directional or bi-directional dependencies. We estimated timing dependencies from inter-response interval data (intervals between note onsets) and compared these with self-reported dependencies between pairs of performers in order to evaluate the usefulness of self-report in exploring synchronization strategies in string quartets.

## METHOD

### Participants

An existing string quartet of professional musicians participated who had played together for 5 years at the time of the study.

### Materials

The musicians performed the first eight bars of the *String Quartet in G Major, Op. 77 No. 1* by Joseph Haydn (see Figure 1). This excerpt was selected because of the relatively high proportion of synchronous notes across the two lower instruments. Violin I states a simple ornamented theme, echoed by Violin II, while Viola and Cello provide steady accompanying pulses.

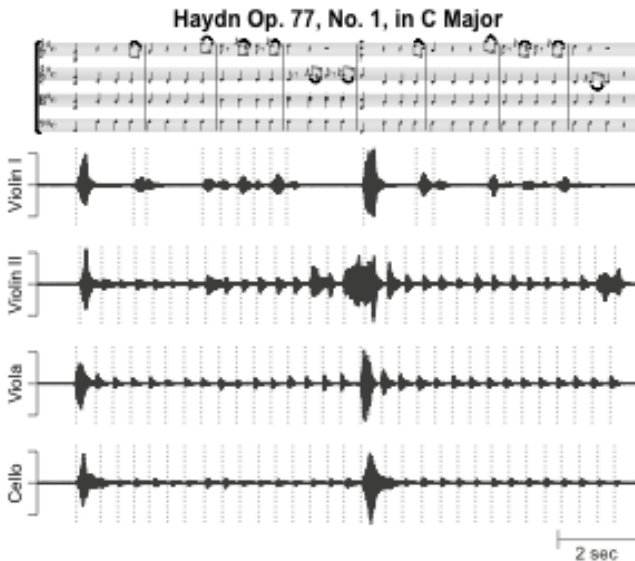


Figure 1. The excerpt and a single trial example of audio data of the quartet. The vertical dotted lines indicate the note onset detected from their respective audio signal.

## Procedure

The quartet was seated in a circle of radius approximately 2 m with, from stage right to left, Violin I, Violin II, Viola, and Cello. They performed the musical excerpt 15 times, endeavoring to make each repeat an individual performance with some variation in interpretation. At the end of the block, participants indicated their subjective estimates of temporal dependencies between pairs of performers using a questionnaire: firstly, the players reported the dependence on each player including him/herself in a percentage (the sum of the score across the quartet summed to 100%). Secondly, they indicated the dependence that they expected each of the other players would report.

Audio data were recorded at 41 kHz using an omnidirectional miniature condenser microphone attached below the strings between bridge and tail-piece using a rubber clip. The audio data for each instrument were rectified and then smoothed using a bi-directional 2nd-order Butterworth low-pass filter with a cut-off frequency of 50 Hz. Local maxima of the signal, corresponding to successive notes were detected (see Figure 1), and note onsets were determined using an adaptive threshold applied to the “valley” preced-

ing each maximum. The inter-response intervals (IRI) of note onsets were then calculated for each player.

## RESULTS

The timing dependency between pairs of instruments was calculated by cross-correlating IRI variability between players after removal of changes in tempo estimated from the average of the 15 repetitions. The correlation was calculated at the bar level to allow for missing onsets due to rests in Violin I.

Figure 2 shows an overview of the correlations, including auto-correlations along the diagonal. Within each box, correlations at different lags are given from a negative to a positive lag of four positions. In case of negative lags, the voice in rows is shifted 1, 2, 3, or 4 bars backwards with respect to the voice in columns. In case of positive lags, the voice in rows is shifted forwards.

Positive cross-correlations at lag 1 indicate that the instrument of the column follows variations in IRI of the instrument in rows. This is the case for the Viola (third column) and Cello (right column) adapting to the second Violin (second row). The second Violin (second column) followed the first Violin (top row). Mutual adaptation (positive correlations at lag 1 and lag -1) can be seen between the first Violin and Cello at lag 1, and between the first Violin and the Viola at lag 2. Negative values at lag 0 support the idea of a 1st order linear correction between instruments. Interestingly, all cells have a negative coefficient at lag 0, although the coefficients are especially strong for correlations with Violin I, and for the correlation between the Cello and Violin II.

Turning from cross-correlations to autocorrelations, these were negative at lag 1, which is consistent with the Wing and Kristofferson (1973) model of internal timing control.

Figure 3 shows the self-reported dependencies between pairs of instruments. The left panel shows the indications of players of the extent to which their own timing depends on the timing of others or on themselves. The right panel shows the means of the ratings by others of the timing dependency between voices other than themselves.

The left panel shows that ratings of dependence were highest for self in the case of Violin I and II. The Viola and Cello indicated to depend in particular on Violin I and II. The right panel shows that expected ratings of dependence by other players were highest for self with the expected rating for Violin I next highest. The inter-rater reliability in terms of Pearson's coefficient was  $r=0.63 (\pm 0.163)$ .

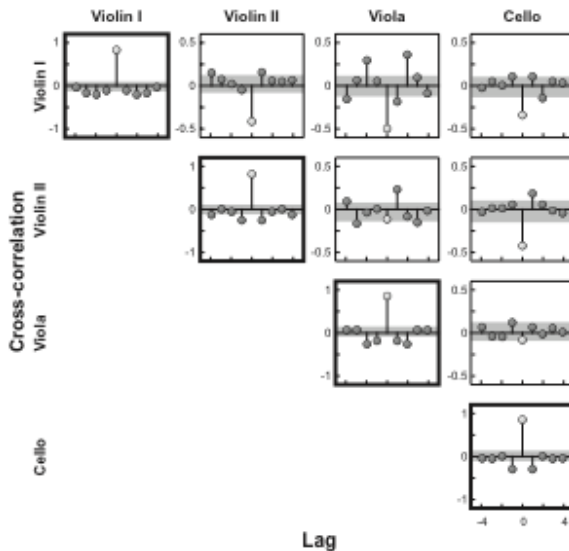


Figure 2. A matrix of cross-correlation coefficients of IRIs between players. In the diagonal axis (bold squares), the autocorrelations are shown. Shaded areas indicate one standard error.

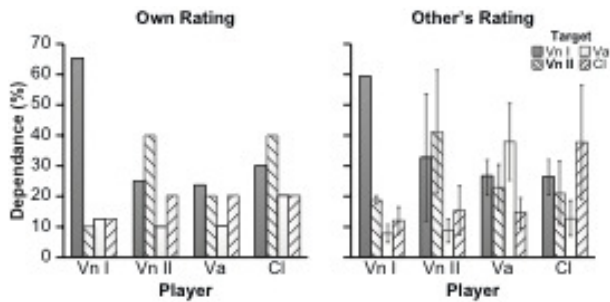


Figure 3. Subjective ratings for timing dependency of own performance and the averaged ratings by the other players. The error bar represents one standard deviation.

## DISCUSSION

The measured timing dependencies (see Figure 2) suggested several leading-following relationships with Violin II following Violin I and the Viola and Cello following Violin II. Mutual adaptation was observed between Violin I

and the Viola and Cello. In contrast, the expected dependence patterns (see Figure 2, right panel) emphasized the first violin as the leader. Although the data is limited and the results preliminary, the apparent discrepancy between self-report and observed timing dependence may not be a surprise. Correction of timing errors operates at a subconscious level (Repp 2001) and may not be accessible for reflection. While this may cast doubt on the usefulness of self-report in uncovering strategies of ensemble synchronization, a combination of methods may nevertheless prove most informative in uncovering explicit and implicit strategies of temporal coordination.

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**Thematic session:  
Analyzing musical movement**





# Is emotional drumming realized in both sound and movement?

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In order to investigate the contribution of body movement and sound on emotion expression, snare drum performances of a simple etude with posing of six basic emotions by three percussion students were captured using motion capture. Body parameters characterizing emotional movements were calculated from motion data and were fed into a machine learning system so as to rate which emotion was expressed during performance. Analysis was done using normalized (stretched) motion data in order to standardize the length of time for all recorded patterns. The contribution of impact and contact duration on emotional expression was obtained from the velocities of the tips of the drumsticks, of which the position was calculated from reference markers put on the middle of the drumsticks. Extracted parameters were then compressed by principle component analysis. The number of obtained parameters was 45 for body motion and 3 for sound. A naive Bayesian estimation with 10-fold cross validation was conducted. Here, the recognition rates were 77.8% (body), 85.6% (sound), and 88.9% (body and sound), which implies that both body movements and sound quality are effective for expressing emotion during snare drum performance.

*Keywords:* emotion; body movement; motion capture; cue; machine learning

Emotions have been extensively studied in vocal, facial, musical, and gestural expressions (e.g. Scherer 2003, Ekman 1992, Juslin and Sloboda 2001, Heenan and Troje 2012) in order to gain knowledge of the usage of cues to convey emotions. However, the combination of multiple cues, for example in sound features and body movements, has not been well investigated. Since we be-

lieve that multimodal communication of emotions in musical performance is important, we focused our research on the role and interplay of two different modalities: the acoustic and body movements (gestural). The aim is to extract the relevant features which contribute to expression of different emotions in body movements during drumming, and to investigate the validity of the parameters.

## METHOD

### Participants

Three drummers majoring in percussion at Hanover University of Music, Drama, and Media participated in our experiment. They gave informed consent for the purpose of our experiment, which was conducted in accordance with the rules of the declaration of Helsinki.

### Materials

Drummers had to play a simple snare drum etude with a maple-based concert snare drum (Ludwig LS401). Four markers for motion capture were attached to each of the drumsticks in order to calculate the location of the tip, and six markers were attached to the snare drum to calculate the center of the drumhead. The tip trajectory was then calculated by referring the markers to the snare drum utilizing motion capture software (Qualisys track manager). Furthermore, 26 motion markers were attached to the players' bodies in the same position previously reported (Konishi *et al.* 2011). The etude was also the same as in the previous study, requiring <30 seconds for performance.

Movements during drumming were captured by a motion capture system (Qualisys corp), with a sampling rate of 480 Hz. The impacts of the tips of the drumsticks were assessed by observing changes of velocity in the tip. Zero-crossings of the velocity curve were obtained from the tip trajectories and were used to calculate the impact time of each of the drumsticks. This corresponded to the impact time of the drumsticks. The impact velocity of each impact was calculated by observing the local peaks of the trajectories before and after impact. The difference of the velocities was extracted as a parameter defining the impact. Figure 1 (a, b, and c, respectively) shows the location of the tip from motion data, the calculated velocity curves of each drumstick, and the location of markers on each drumstick. In Figure 1(a), zero determines the head of the snare drum, calculated by the reference markers on the drum. As can be seen in Figure 1(a) and (b), the zero-crossings of the velocity

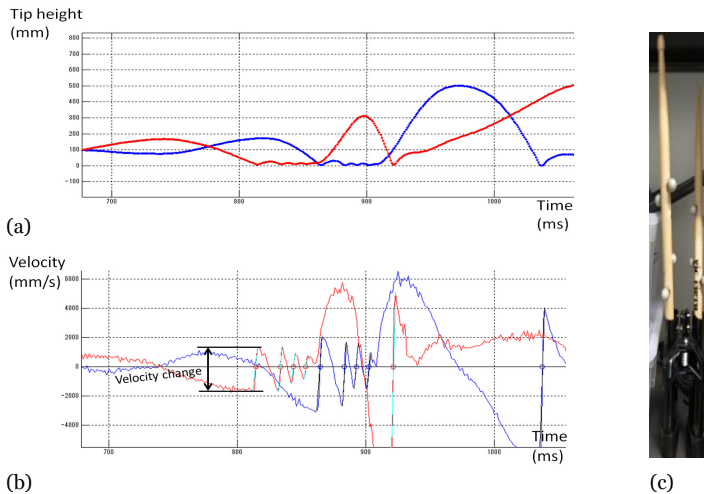


Figure 1. Drumstick and tip trajectory: (a) tip trajectory, (b) velocity change of the tip, and (c) drumstick. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

curves were robust even though the curve of the height of the tip was unclear. The obtained impact times were used when normalizing the motion data.

## Procedure

Participants were asked to play a snare drum etude expressing each of six basic emotions (anger, fear, happiness, sadness, tenderness, neutral). Five trials for each emotion were recorded. Participants were asked to play the given score, but were free to decide on tempo and dynamics. All obtained motion data for the players' upper body were anchored by the impacts on time, and were adjusted to an identical inter-onset-interval (IOI) sequence of the respective drumming patterns in order to better compare patterns played at different tempi. Several features of upper body movements were indirectly contributing to sound production, such as the tilt of the back, head tilt of sagittal and coronal directions, angle between body and arm, and angle between upper arm and forearm. These measures were compared and related to the emotions expressed. Furthermore, parameters directly related to sound production, such as the change of velocity in the tip at impact, sound level, IOI, and global tempo, were analyzed. Basic statistics, such as mean, SD, maximum, minimum, and difference, were obtained for each parameter. Table 1

Table 1. List of parameters to be used on machine learning. LBA=LeftBodyArm; RBA=RightBodyArm; LAF=LeftArmForearm; RAF=RightArmForearm.

<i>Sound</i>	<i>Back</i>	<i>Head</i>	<i>Body-arm</i>	<i>Arm-forearm</i>
Global	BackTilt max	HeadSaggital mean	LBA max	LAF max
tempo	BackTilt mean	HeadSaggital dif.mean	LBA mean	LAF mean
	BackTilt min	HeadSaggital dif.SD	LBA min	LAF SD
Sound	BackTilt SD	HeadCoronal mean	LBA SD	LAF dif.max
level on	BackTilt dif.SD	HeadCoronal min	LBA dif.max	LAF dif.mean
impact	BackTilt dif.max	HeadCoronal dif.max	LBA dif.mean	LAF dif.min
	BackTilt dif.mean	HeadCoronal dif.mean	LBA dif.min	LAF dif.SD
Velocity		HeadCoronal dif.SD	LBA dif.SD	RAF max
	change		RBA mean	RAF mean
on impact			RBA min	RAF min
			RBA SD	RAF SD
			RBA dif.max	RAF dif.max
			RBA dif.mean	RAF dif.mean
			RBA dif.SD	RAF dif.SD

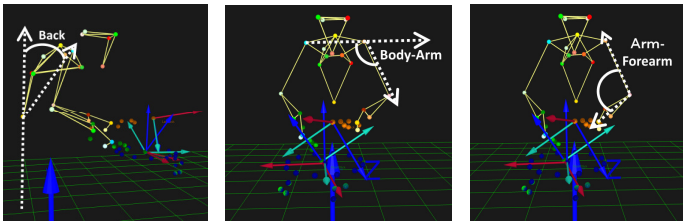


Figure 2. Body parameters: back angle, body-arm angle, and arm-forearm angle (left-right). (See full color version at [www.performance-science.org](http://www.performance-science.org).)

shows all obtained parameters, and Figure 2 explains obtained angles for (1) back, (2) body-arm angle, and (3) arm-forearm angle. Data were standardized for each player. Subsequently, tests for significant differences for each feature were conducted in order to confirm the validity of extracted features. All results reported below were above 5% level of significance.

### RESULTS

Several distinct features characterizing basic emotions could be identified. For “anger,” the upper body tilt showed large fluctuations, with spreading

arms, large deviations, and also with large bending between upper arms and forearms. For “fear,” every movement was basically stable, and the sound level was low. For “happiness,” everything was similar to “angry,” (only the sound level was not as high as in “angry”); head movements were large and the back was not tilted. For “neutral,” it was similar to “fear” but more stable in every feature, and unlike “fear,” sound level was increased. For “sadness,” the upper body was tilted like in “anger,” but the angle of arms to his/her body was narrow, and the tempo was slow. For “tenderness,” the head was tilted in the sagittal direction, and head movement deviation was large as in “happiness” and “sadness.” Figure 3 summarizes the results for each emotion.

	SOUND		BODY MOVEMENT							
	Sound level on impact	Tempo	Backtilt		Head		Body-Arm		Arm-Forearm	
			average	SD	Sagittal	SD of Coronal	Average	SD	average	SD
Anger	High	High	Down	large	-	-	Wide	Large	Bend	Large
Fear	low	-	Up	-	-	Small	Narrow	Small	stretch out	Small
Happy	-	High	-	Large	-	Large	Wide	Large	Bend	Large
Non-emotion	-	-	Up	Small	-	Small	Narrow	Small	stretch out	-
Sadness	-	Low	Down	-	-	Large	Narrow	-	-	-
Tenderness	-	-	-	-	low	Large	-	-	-	-

Figure 3. Characteristics of emotional drumming.

Table 2. Recognition results.

	Number of parameters	Average of F-measure	Kappa statistic	Correct classified (%)
Body and sound	14	0.89	0.87	88.89
Body	14	0.78	0.73	77.78
Sound	3	0.86	0.83	85.56

Table 3. Confusion matrix for recognition of emotion.

	Classified as					
	Anger	Fear	Happy	Neutral	Sadness	Tenderness
Anger	13	0	1	1	0	0
Fear	0	14	0	1	0	0
Happy	2	0	11	1	0	1
Neutral	0	0	0	13	1	1
Sadness	0	0	0	0	15	0
Tenderness	0	0	1	0	0	14

To validate the parameters, we conducted a machine learning experiment, on which a naive Bayesian estimation was conducted by using the compressed parameters by Principle Component Analysis (PCA), where the employed cumulative contribution ratio was 95%. Finally, 14 PCs were employed on the test. Table 2 summarizes the result, showing that recognition rate was 77.8% (body), 85.6% (sound), and 88.9% (body and sound). Table 3 shows the confusion matrix of the recognition when using body and sound parameters.

## DISCUSSION

The recognition rate shows that by using both sound and motion parameters more accurate results are obtained as compared to only body or sound parameters. Hence, we conclude that not only sound but also gestural expression will contribute importantly to clearer emotional expression. The necessity to conduct perceptual experiments for the recorded and normalized (stretched) motion data will be discussed in the near future.

### Acknowledgments

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# Characterizing violin glides in cadential versus noncadential sequences in solo Bach

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This study examines the articulatory changes (glides) between the leading tone and tonic note of cadential versus noncadential semitone sequences in solo violin performance. It was predicted that, though these glides would have similar slopes, they would differ in duration and semitone intonation and that these latter properties could characterize the expression of cadential finality and the structural insignificance of noncadential sequences. Cadential ( $n=46$ ) and noncadential ( $n=58$ ) targets from 17 recordings by 13 professional violinists were analysed using narrow-band spectrograms. Glide durations comprised 16% of the overall duration of semitone sequence irrespective of structure function. However, cadential glides comprised 28% of the duration of the leading tone compared with 11% for noncadential glides. As predicted, the leading note tended to be sharp in both contexts, but the mean cadential interval was nonsignificantly larger by 18 cents, mainly because the tonic tended to be tuned more accurately in cadential sequences. Finally, the glide direction was linear and followed the natural vibrato trajectory in both contexts as expected. These data confirm that articulatory modifications play a prominent role in the performance of intended musical structure and suggest that such distinctions will influence structural expectancies.

*Keywords:* glide; violin; pitch; cadentiality; structure

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# The use of fine-wire EMG to investigate the kinematics of cello bowing: The results of a pilot study

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Margaret Barrett, and Bronwen Ackermann**

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The mechanics of music making is important both in preventing injuries and in guiding how music is performed and taught. Electromyography (EMG) measures muscle activity patterns and has been shown to be a useful resource in understanding the loads involved in instrumental playing; however, only a small number of projects have been undertaken, and little is understood on the muscle activity used during string bowing. This project used a combination of fine-wire and surface EMG to evaluate the muscular load placed on the shoulder of a professional orchestral cellist playing a set of bowing exercises. The results indicated that EMG was useful in measuring shoulder load and that fine-wire electrodes did not interfere with normal playing technique. Different bowing techniques produced statistically different levels of muscle contractions, with the supraspinatus muscle in particular maintaining significantly higher levels of contraction during all bowing patterns.

*Keywords:* string biomechanics; electromyography; shoulder injuries; cello players; muscular load

The mechanics of muscle activity patterns and movements used during musical performance is an area of research that has the potential to have profound influences not only on the management of playing-related injuries, but also on the way music is taught and performed. Electromyography (EMG) has been used extensively to understand muscle loads and contraction patterns in elite athletes; however, EMG has only been utilized to a limited degree as a research tool in music (Visentin and Shan 2011). This is surprising considering the high-levels of musculoskeletal pain seen among musicians and that neuromuscular integration and control reaches its peak in music performance

(Visentin and Shan 2011). Surface EMG (sEMG) involving string players has produced some important contributions (Ackermann *et al.* 2002, Visentin and Shan 2011); however, only minimal research has attempted to understand the muscle activity around the shoulder during bowing on a string instrument. This is a significant research gap considering the high rate of right shoulder pain reported by string players (Middlestadt and Fishbein 1989). This research paper investigates the application of surface and fine-wire EMG (fwEMG) for research into the mechanics of cello bowing.

Electromyography is considered one of the most important tools in estimating the mechanical load on the human body in working life and measures the neuromuscular response to task requirements. The use of EMG to measure muscle loads during musical performance and other activities faces a number of challenges and controversy regarding the accuracy of sEMG versus fwEMG continues (Visentin and Shan 2011). Researchers argue that, while fwEMG produces more accurate results, it may interfere with the normal playing ability of the research subject (Visentin and Shan 2011). This research project aims to present a pilot study on shoulder muscle activity patterns during cello bowing using a combination of sEMG and fwEMG techniques.

String players experience high-levels of musculoskeletal pain which regularly includes dysfunction in the left and right shoulders (Middlestadt and Fishbein 1989). For cello players right shoulder pain is the one of the most common injury sites with 20% of student and 42% of professional cellists reporting pain in the right shoulder (Rickert *et al.* 2012). Motion-capture research has suggested that this may be related to high-levels of right shoulder abduction and flexion measured during cello playing (Turner-Stokes and Reid 1999). Such positions of abduction and flexion are likely to place high loads on the muscles of the rotator cuff, especially the supraspinatus muscle, which is required to co-contract against the superior (upward) force of the deltoids.

The aims of this project were to (1) investigate whether fwEMG could be used as a research tool during cello playing without significantly interfering with movements and sound production quality, and (2) to measure the muscular activity patterns in the right shoulder of a cellist during cello playing.

## METHOD

### Participants

The participant for this study was a professional orchestral cellist (first author) with no current pain in the shoulder and normal shoulder function.

## Procedure

Initially the professional cellist produced a set of reductive bowing exercises that tested a range of possible bowing techniques used during cello playing. These tested the influence of variables including dynamic, string level, string changes, part of the bow, and number of bow changes per second on shoulder muscle contractions. Before electrodes were applied and during the data capture process an external expert cellist (a Professor at a major Australian tertiary school of music) observed the subject performing all musical exercises in order to determine whether fine-wire electrodes influenced normal playing ability. During the testing procedure data were acquired on a PC with a 16 bit analog to digital converter (1401, Cambridge Electronics Design, Cambridge, UK). The data were normalized, tabled, and graphed as a percentage of MVC. Data was further analyzed using two-factor repeated-measures ANOVAs. When significant ( $p < 0.05$ ) ANOVA results were found, a follow-up Tukey HSD post-hoc test was used to further investigate the differences. For details of electrode placement protocol and signal processing see Rickert *et al.* (in press).

## RESULTS

The expert cellist observer noted no noticeable difference between the performance of the bowing exercises before the electrodes were inserted and the performance during the testing procedure.

Based on average EMG across the entire testing process, a significant difference in muscle activation was found between muscles ( $F_{9,117}=148$ ,  $p < 0.001$ ) with the supraspinatus maintaining levels of contraction more than twice that of all other muscles ( $p < 0.01$ ; see Table 1).

The percentage of time each muscle spent above or below Björkstén and Jonsson's (1977) muscle fatigue threshold of 14% of MVC is summarized in Table 2.

For the supraspinatus muscle, differences in individual bowing patterns produced statistically different levels of contraction with dynamic ( $F_{8,1040}=17$ ,  $p < 0.001$ ), string level ( $F_{8,1320}=1411$ ,  $p < 0.001$ ), and string changes ( $F_{8,1496}=12$ ,  $p < 0.001$ ) producing significant interaction effects (Figure 1).

Table 1. Mean ( $\pm$ SD) EMG level (% MVC) for each muscle across all exercises.

<i>ss</i>	<i>is</i>	<i>Sub</i>	<i>ut</i>	<i>lt</i>	<i>sa</i>	<i>md</i>	<i>pec</i>	<i>ch</i>	<i>pec</i>	<i>sh</i>
20.6(3.8)	6.4(0.8)	2.6(1.4)	9.2(1.6)	3.7(32.2)	5.6(2.3)	6.4(2.8)	2.9(0.9)	4.4(0.9)		

Table 2. Percentage of time spent above or below an established fatigue threshold.

%MVC	ss	is	Sub	ut	lt	sa	md	pec_ch	pec_sh
<14%	13%	99%	99%	95%	98%	98%	93%	100%	100%
>14%	87%	1%	1%	5%	2%	2%	7%	0%	0%

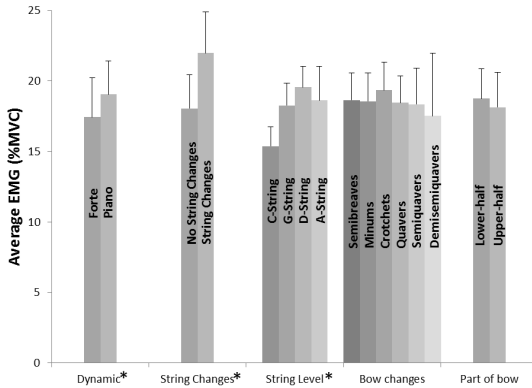


Figure 1. The influence of different bowing techniques on supraspinatus contractions. X-axis=bowing techniques, y-axis=muscular response (%MVC), \* denotes  $p < 0.05$ .

Figure 2 demonstrates right shoulder muscle recruitment while playing demisemiquavers on the A-string.

### DISCUSSION

This study provides an introductory investigation into the use of fwEMG as a research tool during bowing on string instruments. Contrary to arguments in the literature (Visentin and Shan 2011), fwEMG was not observed to interfere with normal musical performance during the testing procedure. The results also present preliminary information about the relative loads and contraction patterns of the right shoulder during cello bowing. Of particular interest is the finding that the supraspinatus maintains relatively high levels of contraction during all bowing techniques. The sustained supraspinatus loading seen during this study, based on the work of (Björkstén and Jonsson 1977) may lead to fatigue and a disruption of normal shoulder kinematics. This could in part explain the right shoulder pain profiles and physical testing results seen in Rickert *et al.* (2012). This research has important implications for musi-

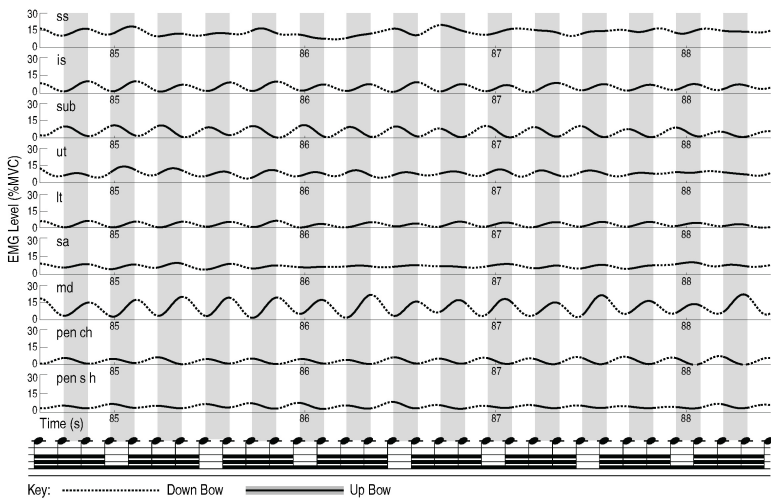


Figure 2. Muscle contraction patterns while playing demisemiquavers on the A-string.

cians and music educators in terms of structuring practice and rehearsal sessions to minimize the risk of muscular overuse.

The examination of right shoulder muscle contraction patterns during cello playing shows that muscle recruitment matches expected biomechanical function. For example, at the beginning of a down-bow peak contractions are seen in the middle deltoid muscle which would be consistent with the contraction force required to begin the elevation of the arm required during a down-bow. The supraspinatus and infraspinatus muscles contract with the middle deltoid offering stabilization against the superior (upward) force of the deltoid muscle and may contribute to external rotation at the shoulder during commencement of the down-bow. For the up-bow movement, peak contractions are seen in the pectoralis major, upper trapezius, and subscapularis muscles. The pectoralis major contraction would be consistent with the beginning of the up-bow movement which requires the abduction of the arm. The upper trapezius contractions align with the increased scapular abduction required during the position the arm assumes at the tip of the bow. The subscapularis contractions are likely to result from the increased internal rotation required to articulate the beginning of an up-bow at the tip of the bow.

This research project has established that EMG using both surface and indwelling electrodes can be a useful research tool in understanding the muscle activity patterns of the shoulder during bowing on a string instrument. Pre-

liminary data on the influence of cello bowing on muscular load in the right shoulder of a cellist have been presented. This pilot study protocol provides a working methodology for future research in string biomechanics.

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**Thematic session:  
Perception of pitch**





# Intervals as distances, not ratios: Evidence from tuning and intonation

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Many music theorists and psychologists assume a direct link between musical intervals and number ratios. But Pythagorean ratios ( $M_3=61:84$ ) involve implausibly large numbers, and just-tuned music ( $M_3=4:5$ ) only works if scale steps shift from one sonority to the next. We know of no empirical evidence that the brain perceives musical intervals as frequency ratios. Modern empirical studies show that performance intonation depends on octave stretch, the solo-accompaniment relationship, emotion, temporal context, tempo, and vibrato. Just intonation is occasionally approached in the special case of slow tempo and no vibrato, but the reason is to minimize roughness and beating—not to approach ratios. Theoretically, intonation is related to consonance and dissonance, which depends on roughness, harmonicity, familiarity, and local/global context. By composing and performing music in 19-tone equal temperament (19 ET), the second author is investigating how long it takes singers to learn to divide a P4 (505 cents) into eight roughly equal steps of 63 cents, or an M2 (189 cents) into three; and whether the resultant intonation is closer to 19 ET or 12 ET. Given that the average size of an interval depends on both acoustics (nature) and culture (nurture), it may be possible to establish a sustainable 19 ET performance community.

*Keywords:* singing; ensemble; rehearsal; microtonality; intervals

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# Does practice affect timbre-induced pitch shift?

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Fifteen pianists and sixteen string players had to decide whether the pitch of two tones heard in successive tone-pairs was the same or different. The level of the fundamental components of the spectrum of the sounds was either increased or decreased in order to acquire stimuli with bright and with dull timbral variants. The fundamental frequency of the tones was also manipulated. The  $F_0$ -s of the tones of the pair could fall either into a pitch region around  $D\#_3$ ,  $D_4$ , or  $C\#_5$ . The comparable stimuli could follow each other either immediately or after a 3.5 s interval of silence. The responses of the participants in different test conditions were analyzed and discussed in the framework of Signal Detection Theory. All factors of the experiment had statistically significant influences on the sensitivity ( $d'$ ) of the participants and on the bias ( $c$ ) of their replies. On the basis of the acquired results, we may conclude that although the timbre induced pitch shift is a universal phenomenon, the level of its manifestation may depend on the practice of the musician and on the type of musical task.

*Keywords:* timbre; pitch shift; pitch deviation; pitch perception; intonation

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**Thematic session:  
Performance health and wellbeing I**



# Vibrato retraining of a cellist suffering from musician's dystonia: A collaborative approach

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Dystonia affects musicians in a variety of ways; in pianists fingers can curl or extend uncontrollably, fingers can curl on a violinist's fingerboard, wind players can experience difficulties with forked fingering, and the cramping of lips in brass players can affect the embouchure. Less common is the effect of musician's dystonia on the vibrato of string players. This case study describes a professional cellist whose difficulty in controlling the speed and amplitude of vibrato was affecting her sound and threatening her orchestral career. A systematic retraining protocol based on principles of instrumental technique and optimum biomechanics was introduced and her condition improved significantly so that she was able to continue playing professionally.

*Keywords:* musician; dystonia; cellist; biomechanics; retraining

Musician's dystonia is a devastating condition that can result in the loss of an instrumental career. Rehabilitation is complex, and in spite of ongoing research a return to former playing ability is rare. Critchley has reported that violinists may experience what violinist Carl Flesch referred to as an "atrophy of the vibrato" (Critchley 1977), but there are no reports of focal dystonia affecting vibrato in a cellist. We have previously reported improvements in focal dystonia in pianists through a systematic retraining methodology at the instrument (de Lisle *et al.* 2006, de Lisle *et al.* 2010). The aim of this research was to see if a similar retraining protocol could alleviate the symptoms of focal dystonia in a cellist with the condition.

## METHOD

### Participants

The subject was a 42 year old professional orchestral cellist with a medically confirmed diagnosis of musician's dystonia who had been playing for 33 years. There was no family history of movement disorder. She had difficulty controlling the speed of the vibrato, which was often erratic and inconsistent. Apart from cello playing, other motor movement patterns were unaffected. Although she was continuing professional orchestral playing, the irregularity of her vibrato was threatening her long term playing career.

### Materials

The children's vibrato book *Viva Vibrato!* by Fischbach and Frost, published in 1997, was used in the study.

### Procedure

Prior to retraining, the subject recorded a series of chromatic notes in first, fourth, and thumb position on the A, D, and C strings. She also recorded a series of seven notes on the A string using a small box of sweets tied on the dorsum of the left hand with a rubber band. Retraining then began with eight hour-long sessions within two weeks, and after a five-week break a further ten sessions were completed within three weeks. The examples were then re-recorded. As the retrainer was a pianist, assistance was received from a respected cello pedagogue for five of these sessions. Four years after the initial retaining procedure the subject returned to be re-evaluated. The quality of the vibrato in the recorded examples (sound only) was assessed on a 4-point scale (see Table 1) by a professional string quartet, blinded as to whether the notes were recorded pre-, post-, or 4 years post-retraining.

Table 1. Vibrato Quality Evaluation (VQE).

<i>Vibrato quality evaluation</i>	<i>Score</i>
The vibrato was not consistent in amplitude or regularity	1
The vibrato was sometimes consistent in amplitude or regularity	2
The vibrato was mostly consistent in amplitude or regularity	3
The vibrato was always consistent in amplitude or regularity	4



During the retraining period the subject took leave from her orchestral position in order to concentrate on retraining. The initial goal of retraining was to eliminate unnecessary tension in the shoulder and to optimize biomechanics. It was noted that the vibrato technique used by the subject involved a large amount of rotation involving significant shoulder abduction in the scapula plane combined with pronation/supination at the elbow. Retraining focused on replacing these movements with a simple flexion extension of the elbow with the forearm in a neutral position with respect to pronation/supination, with minimal movement of the scapulothoracic articulation or glenohumeral joint.

To avoid interference from past learning, initial retraining involved teaching vibrato to the right hand, reversing the position of the cello to sit over the right shoulder. No attempt was made to use the bow at first, but the procedure concentrated on developing a regular movement with the right hand and then transferring this learning to the left hand and arm.

Relaxation of the hand was established by various tapping exercises on the fingerboard in a variety of rhythms. At first this was done between the strings, as any string depression could cause tension. Gradually it was possible for the fingers to make contact with the string without cramping and various tapping and sliding techniques were developed, beginning with a large movement and then refining the movement as had been found beneficial in our studies with pianists (de Lisle *et al.* 2006, de Lisle *et al.* 2010). Transferring enough weight to depress the string was at first practiced by dropping the finger to push the string down with a single impulse, and then releasing the pressure and allowing the hand to rebound several times. The number of impulses was then increased until an even vibrato was established. Playing with the bow was only introduced when the vibrato movement was perfected, progressively checking breathing, tension in the arm, shoulder, the flexibility of the finger, and the weight on the string. Without this systematic checklist, the speed of vibrato could suddenly increase at the end of the bow.

## RESULTS

Scores were analyzed using generalized linear methods using *Proc GLM* in SAS v9.1 (SAS Institute, Cary, North Carolina) with the VQE score used as a continuous outcome and time (pre-, post-, and 4 years post-), scorer, note, and position modeled as categorical variables. Statistical significance was defined at the 5% level.

The examples recorded with the box of sweets on the back of the hand showed that there was a statistically significant improvement ( $p < 0.01$ ) from

pre-intervention to post-intervention with the mean VQE score increasing from 1.14 (SD=0.52) to 2.82 (SD=0.86). Re-testing at 4 years post-intervention showed that this improvement had been maintained with a mean score of 2.75 (SD=0.89,  $p<0.01$ ). There were no significant effects of scorer or the note being played. The chromatic long-note examples in three different positions on three different strings which were recorded pre- and 4 years post-retraining again showed that there was a statistically significant ( $p<0.01$ ) improvement from pre to 4 years post-intervention with mean scores increasing from 1.41 (SD=0.61) to 3.31 (SD=0.64; see Figure 1). Again there was no significant effect related to scorers or position on the cello.

## DISCUSSION

Unlike other reported cases of musician's dystonia in string players, this subject displayed no visible cramping in the hand, although depressing the string would often cause the vibrato oscillation to be erratic and uncontrolled. Since regularity of vibrato is a key requirement for accomplished string playing (Rolland 1974), rehabilitation was essential if the subject were to continue playing professionally. As our previous studies have shown (de Lisle *et al.* 2006, de Lisle *et al.* 2010) retraining essentially involves reducing the technique to its most basic components, perfecting every movement slowly before attempting repertoire playing. It was important to first establish controlled arm freedom without the cello, using gross muscle movements and sometimes using the other arm as a mock cello. As the dystonic reaction seemed to come primarily from the shoulder, retraining involved changing the subject's approach to vibrato playing to focus on elbow flexion, with minimum rotation

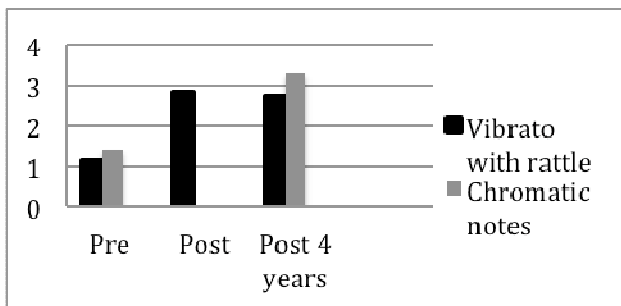


Figure 1. Improvement in vibrato quality (VQE score on the vertical axis).

from the shoulder and minimal pronation/supination. Extraneous wrist flexion and extension was reduced, so that the vibrato movement was generated from the elbow using a coordinated movement. When progressing to the string, the vibrato movement was obliquely downwards, without pronation/supination at the elbow. Only once the essential elements of an even vibrato were established did the subject begin to use the bow.

The sensory component that had been noted in the previous studies with pianists was also evident in the cellist. Merely touching the string would cause lack of control in the vibrato, and so at first the vibrato movement was learned by tapping and sliding up and down the fingerboard between the strings without settling the finger in one place on the string. When progressing to vibrating in one place on the string, the finger had to be given permission to transfer some arm weight to the string; in a similar way as with the pianists the dystonic finger had to learn to take the weight of the arm (de Lisle *et al.* 2006, de Lisle *et al.* 2010). Further complications were evident when the thumb was allowed to touch the fingerboard, where it was important to avoid any unnecessary pressure.

In a similar way that lateral transfer of learning had assisted the retraining of the pianists (de Lisle *et al.* 2006, de Lisle *et al.* 2010), vibrato was learned with the right arm first while holding the cello over the right shoulder. This enabled the subject to learn the movements as if she was a complete beginner, and her awareness of the contrast in movement freedom between the two arms proved to be an important learning tool.

The initial retraining sessions were close together, which ensured sustained motivation and helped to reinforce changes in movement patterns. Like the other successful subjects in our previous studies, she ceased all other playing during the intense retraining period and focused on establishing new movement patterns slowly and systematically. Because she took leave from her orchestral playing in order to undertake the retraining, the technical modifications implemented were internalized and she was able to continue to apply these principles once she returned to the orchestra. Therefore, when she was reassessed four years after the initial retraining period, her condition had remained constant; she was more satisfied with her own playing, and she was continuing to maintain her status as a professional cellist. By applying the principles of learning previously shown to be successful with pianists and perfecting each element of technique, it was possible to substantially improve the condition of musician's dystonia in another instrument: the cello.

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# Pointing to performance ability: Examining hypermobility and proprioception in musicians

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People have varying levels of hypermobility and proprioception that are held to be interrelated. This study sought to investigate hypermobility and proprioception in vocational-level musicians, comparing different instrument groups and examining variables that might account for these differences. Demographic information, handedness, musical background and training, injury history, joint hypermobility, and proprioception were collected from 28 music performance students. The participants had a mean hypermobility score of 2.14 ( $SD=2.45$ ) with the men exhibiting less hypermobility than the women. While not significant, all instrument groups demonstrated clear differences in proprioception between the left and right hands. For the strings, harps, and pianists, these findings appear indicative of the mechanics of sound production. No significant findings emerged when examining the impact of hypermobility, training, or previous injury on proprioception. The findings support the use of the Leeds Hand Proprioceptometer as a valid means of assessing musicians' finger proprioception and suggest that, in highly trained musicians, the instrument played does influence proprioception.

*Keywords:* proprioception; hypermobility; musicians; health; training

People have varying levels of hypermobility which can manifest itself in varying ways and in different parts of the body. For musicians, hypermobility has been found to have positive and negative effects (Grahame 1993, Larsson *et al.* 1993). Hypermobility in the fingers can increase hand span, flexibility, and speed for pianists, string players, and guitarists. However, hypermobility can contribute to pain in supporting muscles (e.g. the back and knees) and result in weaker joints, requiring greater force to ensure stability and leading to

potential finger and hand pain. Hypermobility has also been found co-occurring in people with impaired proprioception (Mallik *et al.* 1994).

As with hypermobility, people also have varying levels of proprioception. Proprioceptive memory has been found to influence musicians' pitch production, specifically within those possessing absolute pitch (di Carlo 2008). It is also likely that proprioception plays a role in shifting for string players. Proprioception appears to have a close relationship with injury occurrence and rehabilitation. Proprioceptive retraining has been employed as a method of addressing focal dystonia in musicians (Rosenkranz *et al.* 2009), while recent lower limb injuries have been found to negatively impact postural stability in dancers (Clark and Redding 2012).

Research remains conflicted on the role of training and expertise on task-specific and general proprioceptive abilities (e.g. Aydin *et al.* 2002, Schmitt *et al.* 2005). The use of inappropriate measures of proprioception has been proposed to contribute to varying findings and single proprioception tests may not adequately explain, or be generalizable to, the full system involved in proprioceptive ability (Riemann *et al.* 2002).

Given the state of research, this study sought to investigate hypermobility and proprioception in vocational-level musicians, comparing instrument groups and examining variables that might account for these differences.

## METHOD

### Participants

Six male and 22 female undergraduate and postgraduate music performance students were recruited at Trinity Laban Conservatoire of Music and Dance (mean age=24.67 years, SD=4.35). Of these, there were 11 strings, 2 harps, 3 pianists, 1 woodwind, and 11 vocalists.

### Materials

Demographic information, handedness, musical background and training, and injury history was collected using a self-report survey. Participants were assessed for hypermobility according to the Beighton scoring system for joint hypermobility (Beighton *et al.* 1973) and finger proprioception using the Leeds Hand Proprioceptometer (Wycherley *et al.* 2005).

### Procedure

Ethical clearance for this study was obtained from the Trinity Laban Research Ethics Committee and each participant provided informed consent prior to

testing. The participants first completed the self-report survey. For previous injuries, the participants were requested to record the area, type, and date of the injury sustained. They were then tested for joint hypermobility using the 9-point Beighton scoring system to assess hypermobility in both thumbs, little fingers, elbows, knees, and the lower back (Beighton *et al.* 1973). Each of these nine assessments received a score of either 0 (indicating no joint hypermobility) or 1 (indicating the presence of hypermobility), resulting in a total score ranging from 0 to 9. Lastly, finger proprioception was assessed using the Leeds Hand Proprioceptometer to measure joint position sense in the metacarpophalangeal joint of the index finger of either hand (Wycherley *et al.* 2005). Participants performed position matches twice with each hand: once in which they could see their finger movements and once in which they could not (the latter trials formed the test of proprioception). The degrees of difference between the participant's finger and each target position were recorded with an averaged "score" created for each trial per hand; a lower "score" indicated greater proprioception.

## RESULTS

The participants had a mean hypermobility score of 2.14 (SD=2.45). The men (M=1.17, SD=0.98) exhibited less hypermobility than the women (M=2.41, SD=2.67); this difference was not significant ( $F_{1,23,07}=3.19$ ,  $p=0.087$ ). The participants achieved a mean proprioception score of 5.96 (SD=2.27) with their dominant hand and 5.51 (SD=2.51) with their non-dominant hand. A paired-samples t-test revealed that this difference was not significant ( $t=0.78$ ,  $df=27$ ,  $p=0.440$ ).

In order to control for any potential influence due to handedness the three participants who reported being left handed were removed from further analyses. While the number of participants prevented between-instrument group comparisons, within-group left versus right hand comparisons were possible (see Table 1). Clear differences were observable between the left and right hand Proprioceptometer results for all instrument groups; however, none of these differences attained significance ( $p>0.05$ ).

Exploring for relationships between hypermobility and proprioception, no significant correlations emerged between the total hypermobility scores and the left and right hand proprioception scores ( $p=0.825$  and  $p=0.617$ , respectively). A one-way ANOVA was run to examine the impact of hypermobility within the little fingers upon proprioception. Those scored as having hypermobility in their left little finger ( $n=9$ ,  $M=4.99$ ,  $SD=2.37$ ) and right little finger ( $n=6$ ,  $M=4.74$ ,  $SD=1.64$ ) demonstrated greater proprioception than

Table 1. Mean scores (and standard deviations) for joint hypermobility and the Leeds Hand Proprioceptometer according to the difference instrument groups.

Group	Number	Hypermobility score	Proprioception left hand	Proprioception right hand
Strings	10	2.91 (2.77)	4.60 (1.86)	6.13 (2.16)
Harp	2	2.50 (3.54)	8.10 (1.98)	5.35 (.021)
Piano	3	4.33 (2.08)	5.60 (3.57)	3.72 (1.75)
Woodwind	1	3.00 (0.00)	3.50 (0.00)	5.00 (0.00)
Voice	9	0.64 (1.29)	5.52 (2.32)	6.83 (2.73)

those without hypermobility (left hand: 5.45, SD=2.34; right hand: 6.38, SD=2.43). Neither of these differences were significant (left hand:  $F_{1,16,50}=0.22$ ,  $p=0.643$ ; right hand:  $F_{1,12,62}=3.54$ ,  $p=0.083$ ).

Six participants reported having sustained a left upper extremity injury and five reported having sustained a right upper extremity injury within the 12 months prior to testing. No significant effects emerged between recent injuries and hypermobility or proprioception ( $p>0.05$ ). Further, no significant effects upon hypermobility or proprioception emerged when considering the age at which the participants commenced formal lessons on their instrument or voice or the number of hours practiced per week ( $p>0.05$ ).

## DISCUSSION

All instrument groups demonstrated clear differences (although significant) in proprioception between the left and right hands. Research conducted as part of the development and validation of the Leeds Hand Proprioceptometer noted significant differences between dominant and non-dominant hands with the dominant hand consistently performing better (Wycherley *et al.* 2005). In the present study, this was the case for harp and piano players but not for string and woodwind players and vocalists for whom the non-dominant hand exhibited better proprioception.

For the strings, harps, and pianists these findings appear indicative of the mechanics of sound production: string players perform the more intricate task of fingering with their left hand, harpists watch their left hand but not their right, and pianists typically play more complex lines with their right hand. Years spent playing their instrument may have resulted in an instrument-specific effect on proprioception that superseded the dominant hand preference found by Wycherley *et al.* (2005). Supporting this theory, a com-



parison of teenaged gymnasts and controls concluded that gymnastic training significantly influenced ankle joint position sense and balance (Aydin *et al.* 2002). While not all studies have reached similar conclusions (e.g. Schmitt *et al.* 2005), the present findings appear to lend support to the possibility of a task-specific practice effect on proprioception. The left versus right hand differences from the woodwind and vocalists are less easy to explain, however, and require further investigation.

No significant findings emerged when examining the impact of hypermobility on proprioception. This is in contrast to research that has found the two co-occurring and concluded that one might influence the other (Mallik *et al.* 1994). In dance, previous injuries have been found to impair proprioception (Clark and Redding 2012); however, the present results did not concur with these earlier findings. A recent study examining general joint hypermobility (GJH), joint hypermobility syndrome (JHS), and injury occurrence in a dance student population found significant correlations between injury and JHS but not injury and GJH (Ruemper and Watkins 2012). The authors recommended employing the Brighton criteria (Grahame *et al.* 2000) in order to better assess the presence of hypermobility.

These findings suggest that musicians have low levels of hypermobility and that, in highly trained musicians, the instrument played does influence proprioception. The findings support the use of the Leeds Hand Proprioceptometer as a valid means of assessing musicians' finger proprioception. In future research seeking to examine the impact of practice behaviors and previous injuries upon proprioception, the collection of more detailed information from a greater number of participants might better elucidate potential relationships. Understanding the extent to which such links function for musicians has implications for the training of musicians and musicians' health.

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# Performance measures in pianists: A method of enhancing communication with clinicians

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Pianists with clinical symptoms in the upper limbs can be a challenge for the medical practitioner. Meticulous history taking and clinical examination along with relevant investigations are essential in the diagnostic process. It is important, however, to also assess the technical elements of piano playing and correlate these to the clinical features. We used digital recording (MIDI), video filming, and surface electromyography to look at the biomechanical elements of playing. The system that provided this multimodal assessment was ProformaVision<sup>®</sup>. We recruited 10 pianists with various clinical presentations and assessed them with ProformaVision<sup>®</sup> while they performed basic technical tasks on the keyboard. We interpreted the visual recordings and graphs using measures for each modality and expressed these symbolically and numerically on a chart that enabled us to see the pianist's technical elements at a glance. Our participants were not enough to give us statistical results and this research remains in progress. These preliminary charts, however, give us the opportunity to envisage creating a method of communication between musician and clinician and promise to become a useful tool in the monitoring of rehabilitation and recovery from injury.

*Keywords:* communication; rehabilitation; biofeedback; technique; pianists

Various authors have written and discussed the importance of the physiologic hand position at the piano. "Performance-related injury might stem from a misunderstanding of human physiology and the physiologic aspects of playing a musical instrument" (Parr 1988, p. 100). There have been studies on the curved hand and the neutral wrist position, the correct muscle recruitment

and the preservation of the arches (Tubiana *et al.* 1989, Harding *et al.* 1989, Amadio and Russotti 1990, Meinke 1995, Watson 2009).

Amadio and Russotti (1990) also stated that “one of the most difficult barriers for many physicians is the understanding of professional terminology and perspectives” (p. 405). The same concept was enhanced in 1995 by Newmark and Weinstein who extended the importance of standardizing language between specialists when treating musicians.

Musical instrument digital interface (MIDI) data can be used to analyze technique and document and quantify impairments (Salmon and Newmark 1989). Kjelland (2000) used electromyography for research, observation, diagnosis, comparison of techniques, and biofeedback. Wristen (2000) used video analysis to look at movements that can potentially be harmful. It was Riley *et al.* (2005) who used the triple modality of MIDI, surface EMG, and video combined and they concluded that this method, using the new system ProformaVision®, provided extensive information concerning performance physiology and helped identify and correct technical issues.

ProformaVision® was also used for this current study. We aimed to (1) identify physiologic measures that can be scientifically used to evaluate piano performance and (2) design a comprehensive chart that can potentially bridge communication between clinicians and musicians and assist clinicians in their understanding of technique elements.

## METHOD

### Participants

We recruited 10 pianists between 22-55 years (6 female and 4 male), mean age 43.7 years with variable symptomatology and level of performance.

### Materials

We used the MIDI, surface EMG, and video multimodal system of ProformaVision® which analyzes all three modalities simultaneously. This system includes hardware and software including a PC and monitor, DynaVision dynamic surface electromyography, and a SoloVision computer interface. For the MIDI keyboard we used a Yamaha Portable Grand DGX-640. Two Logitech C910 web cameras recorded arm and hand movements.

### Procedure

Surface EMG electrodes were applied over the examined muscle groups of the forearm extensors/flexors and the upper trapezius. On the monitor we viewed

and assessed the MIDI representation, the video of both hands on the keyboard, and the rectified EMG pattern of muscle activity.

The participants performed 8 tests for each hand that represent basic elements of piano technique (baseline rest/contraction, scales, arpeggios, chords, octaves, and thirds). We recorded 5 measures for each modality. For MIDI we recorded Articulation, Force, Tempo, Temporal Equality, and Pattern. For the surface EMG we recorded Maximum Contraction Extensors, Minimum Contraction Extensors, Maximum Contraction Trapezius/Flexors, Minimum Contraction Trapezius/Flexors, and Tension/Release Cycle. For the video we recorded the Elbow Angle, the Wrist Angle, the Metacarpophalangeal Joint Position, the Interphalangeal Joint Position, and any Dystonic Movement. An M.E.V. (MIDI, EMG, Video) chart was designed to record all measures. This chart comprehensively profiles the pianist's performance. We added a descriptive M.E.V. report to facilitate further communication with the clinician.

## RESULTS

Figures 1 and 2 present a sample (2 out of 10) of our M.E.V. charts and M.E.V. reports.

## DISCUSSION

Performing Arts Clinics provide a specialized service with understanding of the peculiarities of the instrumentalist's technical applications. Closer assessment of basic instrument technique should become an integral part of the consultation and, in conjunction with subjective and objective examinations and clinical investigations, it can give the clinician a more complete profile of their musician-patient.

The methods of MIDI representation, EMG recording, and video filming independently or in combination have been reported in studies for the purpose of assessing musician's technique (Merriman *et al.* 1986, Berque and Gray 2002, Jabusch *et al.* 2004, Riley *et al.* 2005, Lai *et al.* 2008). The consensus seems to be that there is need for more progress and more research to validate their use and accuracy. As these methods can be musician-friendly and non-invasive if surface EMG is used, they could become the ancillary methods of assessment in the clinical setting. We used the ProformaVision® multimodal system for our study aiming to see whether accumulating data from all three modalities can give the clinician enough information to understand their patient's technical profile in order to correlate this to clinical



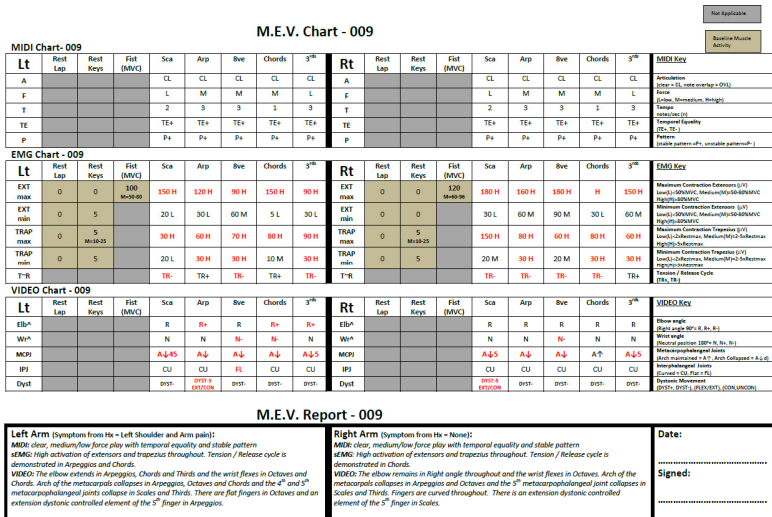


Figure 2. This chart corresponds to a pianist with left shoulder and arm pain, with left hand on the left and right hand on the right. In the left arm we recorded normal MIDI, high activation of extensors and trapezius throughout (EMG), and transverse arch collapse in arpeggios, octaves, and chords and collapse of the 4th and 5th metacarpophalangeal joints in scales and thirds (video). An unexpected controlled dystonic element of the 5th finger in arpeggios was also noted and recorded. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

We are not able to show any trends or statistical correlations at this stage as more volunteers are needed in order to validate these measures. Our results are a paradigm of how these assessments and charts can potentially bridge the clinician-pianist distance of communication rather than a reflection of true normal and abnormal values.

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Thematic session:  
Techniques for memorizing performance



# Retrieval cues as a teaching tool in one-to-one instrumental lessons: A pilot study

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In cognitive psychology, retrieval cues are considered stimuli that assist information recovery in long-term memory. In educational contexts, they have been investigated as a teaching and learning tool as a means to promote meaningful learning. However, discussion on the use of these specific cues as a tool in instrumental teaching literature has been scarce. Therefore, it is not yet possible to understand the potential impact of this exploration on instrumental lessons. The aim of the present study was to both verify and identify the use of retrieval cues by the teacher in one-to-one violin lessons. This empirical pilot study consisted of video observation of twelve one-to-one violin lessons. The participants (N=6; female) were two teachers (aged 28 and 32 years) and four violin students (aged between 11 and 13 years). A set of retrieval cues was identified using qualitative analysis. A quantitative approach has allowed us to verify that most of the retrieval cues were used during verbal communication; specifically, when the teachers focused on aspects related to technical and/or motor skills. The results of this study highlight the importance and the need to organize a way to explore the use of retrieval cues as a teaching tool.

*Keywords:* retrieval cues; performance skills; instrumental teaching and learning; multimodal communication; teaching tools

Learning an instrument is a process that can be difficult and strenuous due to the physical, mental, and emotional effort needed (McPherson and Zimmerman 2002). It involves the acquisition and development of specific skills, which typically are conveyed by a teacher through verbal instruction (Sloboda 2000). The quality of teachers' instructions has been appointed in studies as one factor that distinguishes expert teachers from their less-experienced

counterparts (Colpritt 2000, Duke and Henninger 2002). The reality of instrumental lessons is that teachers need to use technical vocabulary in order to explain and demonstrate a skill. The problem is that, frequently, technical vocabulary contains many words applied to common concepts, sometimes totally unrelated to the technical concepts (Novak 2010). If the instruction is too complex, the students may become confused and have difficulty remembering the details (Petrakis and Konukman 2001). Therefore, one of the teacher's challenges, while teaching an instrument in the earlier stages of learning, is to approach complex content (that involves a specific vocabulary) using effective and clear communication, which later can be recalled.

Based on this assumption, a possible hypothesis is that specific cues (retrieval cues) can be explored as a way to improve the communication between teacher and student in the lessons and, consequently, enhance the student's information memorization. This premise is based on the concept of retrieval cues in cognitive and educational psychology contexts, which are recognized as stimuli that assist with information retrieval from long-term memory, i.e. pictures, objects, gestures, or words (Baddeley 1999, Gleitman *et al.* 2010). In music, retrieval cues have been identified in a performance context as landmarks that help performers in musical memorization, i.e. performance cues (Chaffin *et al.* 2010). Likewise, the concept of retrieval cues has been used in sport education contexts as a teaching tool, i.e. teaching cues (Petrakis and Konukman 2001) or learning cues (Rink 1993). The use of these teaching/learning cues was identified in teacher-student communication, functioning to assist athletes in improving their learning in aspects such as attention, comprehension, and information retention.

However, the literature on the use of this teaching tool regarding instrumental teaching and learning is scarce. Therefore, one could ask how the use of retrieval cues could be explored in one-to-one instrumental lessons both as a teaching and learning tool. In this paper we report a pilot study, which forms part of a large study that investigates the potentialities of retrieval cues as a teaching and learning tool in one-to-one instrumental lessons. The main purpose of the study was to both verify and identify the use of retrieval cues in one-to-one violin lessons.

## METHOD

### Participants

This study involved six female participants from a Portuguese music conservatoire: two violin teachers (aged 28 and 32 years, each with a BMus degree and 6 and 10 years of teaching experience respectively) and two students

from each teacher (n=4, aged between 11 and 13 years, all attended levels II, III, and IV of the Portuguese music grading system).

### **Materials**

Twelve one-to-one violin lessons (around 45 minutes per lesson) were video recorded, three per student. Segments where the violin student was playing the same piece of music in the lessons were selected (approximately 22 minutes per segment). The total time of the lessons analyzed for the four students was 267 minutes. Semi-structured interviews were also used to complement the observations.

### **Procedure**

The three sequential lessons for each student were videotaped in the spring term of 2012. The researchers were not present during the recording and the teacher was responsible for handling the video camera. The camera was positioned in a place that captured both student and teacher. At the end of the last lesson, the first author conducted a short interview with each participant as a complement of the video data, in order to characterize the participants. Digital recordings of selected segments were analyzed with the aid of the software *WebQDA* (Web Qualitative Data Analysis). The analysis process was divided into four steps: (1) selection, to choose the segments of the same piece of music from each student; (2) transcription, inspired by the transcription charts of the multimodal communication (Rostvall and West 2003); (3) codification, where all information summarized was coded through performance skills (Davidson 2002); and (4) interpretation, with the triangulation of performance skills, multimodal communication, and summarized information.

## **RESULTS**

A set of retrieval cues were identified by means of qualitative analysis, taking into account the information summarized with five main characteristics derived from Rink (1993): (1) guides the focus during the performance, (2) gives a clear picture of the skill, (3) is accurate, (4) is essential to the task presented, and (5) is appropriate to the age and stage of student. Table 1 shows some examples found in the lessons.

The quantitative approach demonstrated that most retrieval cues were used during verbal communication, more specifically when the teachers focused on aspects as technical and/or motor skills. Furthermore, some retrieval cues were also utilized when teaching expressive skills, which emerged

from nonverbal communication. Figure 1 represents the number of occurrences of retrieval cues in verbal and nonverbal communication during the teaching of performance skills.

### DISCUSSION

This pilot study brings to light a phenomenon that, although not new in the teacher-learner communication field, can be looked at anew through the focus of retrieval cues. The outcomes illustrate that retrieval cues are present in both teachers' verbal and nonverbal instructions. On the other hand, in the interviews it was clear that teachers and learners are not conscious that certain specific words or gestures that they use may help to recall the information stored, and to improve communication and the learning experience itself.

Table 1. Some examples of retrieval cues in one-to-one violin lessons

<i>Verbal communications</i>	<i>Nonverbal communications</i>
Lift your elbow	Teacher corrects the elbow height
Look at your bow	Grimacing because of pitch
Press your left hand	
Lift the violin	
Look at the first finger	
Captain hook	
Like a slide	
The steps	

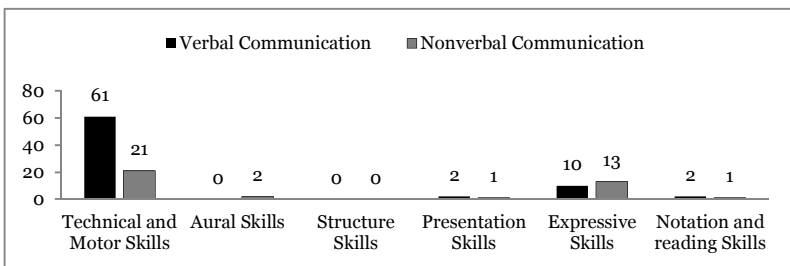


Figure 1. The use of retrieval cues.

In summary, the positive results and advanced exploration of retrieval cues in physical education, as well as the results from the pilot study, can provide evidence that: (1) in one-to-one violin lessons, retrieval cues can be identified as summarized information and (2) these retrieval cues have the function to alleviate the information overload and therefore optimize the memorization of information. However, the present results are limited by the small sample size of participants, namely the teachers. The challenges for future research will be: (1) to continue in identifying new examples of retrieval cues from different teachers, (2) to discover how teachers and students can explore them, and (3) to verify the impact and potentialities of this exploration.

The present pilot study illustrated both the importance and the need to organize a way to explore the use of retrieval cues as a teaching tool and thus contribute to more positive and enjoyable teaching and learning.

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# Recording thoughts as an aid to memorization: A case study

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We describe how an 18 year-old piano student (Grade 7, ABRSM) learned to memorize. The student, who had previously ignored suggestions that she play from memory, decided to learn to memorize, selecting Schumann's "Der Dichter Spricht" for this purpose. Rather than explicitly teaching the student to memorize, the teacher taught her to record her thoughts by marking them on copies of the score, a technique inspired by studies of how experienced soloists memorize. Over a seven-week period, the student recorded her thoughts while practicing (5 times) and while performing from memory for the teacher (3 times) and video-recorded three weeks of practice and three performances. Her thoughts were relatively stable over time and occurred at locations where playing started during practice. The student was able to perform from memory after four weeks and to reconstruct the piece from memory after a four-month break. The speed and durability of her memorization inspired the student to perform in public and use the same technique for new pieces. Recording thoughts appeared to aid memorization.

*Keywords:* memory; practice; performance; learning; performance cues

Students generally practice by rote; this results in rote memory (*associative chaining*), which is not very robust. When a failure does occur, the performer has to go back to the beginning of the chain. Experienced performers avoid such embarrassment by creating a safety net that provides them with *content addressable* access to their memory, allowing them to re-start at different points in the music (Chaffin *et al.* 2009). They do this by training themselves, during practice, to attend to *performance cues* (PCs). PCs are musical features that serve as mental landmarks during performance, allowing the

musician to monitor progress through the piece to ensure that the performance unfolds as planned.

The development of PCs has been documented in longitudinal case studies in which experienced soloists recorded their practice as they prepared new works for public performance. They then reported the features of the music they had attended to during practice and in performance by marking them on the score (Chaffin 2011). PCs were thoughts during performance that had previously occurred during practice (Ginsborg and Chaffin 2012, Ginsborg *et al.* 2013). PCs affected starts and stops during practice and written recall of the score months after the performance (Chaffin 2011).

As the musician in one of these studies, the first author was impressed by the benefits of the procedure to her own playing (Chaffin *et al.* 2010). Reporting practice decisions and PCs made her more aware of her musical intentions and strategies. She found that her practice and memorization became more efficient, for other pieces, as well as the piece under study. She wondered whether the same procedure might help one of her students. The student had never deliberately memorized before. Although the student had sometimes memorized incidentally, while learning a piece, after a few weeks, the memory would be gone. Now, the student wanted to memorize more permanently and securely. PC-theory suggested that she needed a retrieval organization to provide content addressable access to her rote memory.

## METHOD

### Participants

Maria was an 18 year-old piano student (Grade 7, ABRSM) of the first author. The teacher (the first author) trained in classical cello and piano, performs regularly as a cello soloist, and has taught private students on both instruments for more than three decades.

### Materials

The student had worked on “Der Dichter Spricht” (The Poet Speaks) from R. Schumann’s *Kinderszenen* a year earlier, but had set it aside as too difficult. She now selected it for memorization.

### Procedure

Over a period of six weeks, Maria had seven lessons, practicing the piece at home in between. She first performed the piece for the teacher from memory in lesson 4 and continued to do so in each lesson until lesson 7, at which point

she concluded that the piece was memorized and ended her work on the piece. During this time the student made five reports of her thoughts during practice and three reports of her thoughts during performances, which occurred during lessons. The teacher showed the student how to mark copies of the score with arrows to indicate features that were the focus of her attention. Together they classified each feature as involving expression, interpretation, basic technique, or musical structure. The teacher marked Maria's phrasing on another copy of the score at the end of the study.

Maria video-recorded three weeks of practice and three performances, starting after lesson 3. She also recorded herself, 11 weeks after last playing the piece, when she reconstructed it from memory during a lesson. She worked through the piece from memory, starting and stopping, until she recovered her earlier fluency.

We transcribed the reports by tallying the location (in beats) and type of thought in each report and the recordings by tallying the locations of starts and stops. For analysis we reduced the 114 beats of the score to 73 locations where we judged that a thought might plausibly be reported, eliminating beats on which notes were simply held. The lower value provided a more conservative test of the hypothesis that thoughts were randomly distributed. We used a mixed effect model to evaluate the relationship of starts in practice to the reports. Predictors were dummy-coded to represent the location of thoughts about basic, interpretive, and expressive features of the music in each report and of starts of phrases in the teacher's report. Predictors for each week's practice were drawn from the reports for the performance that ended the week. We treated thoughts and phrases as fixed effects. Phrases were also included as a random effect, nested within the longer piece.

## RESULTS

Maria and her teacher were both surprised at the speed with which Maria memorized the piece and her success in reconstructing it from memory almost four months later. Her teacher also noted that she played more musically than usual. To determine whether reporting her thoughts had contributed to this success, we looked for evidence that the thoughts were stable over time and had been prepared during practice.

Many of Maria's thoughts were stable. Thoughts were not distributed randomly but occurred at a limited number of locations (beats) within the piece. Figure 1 shows that while many locations elicited no thoughts, other locations elicited thoughts multiple times. To quantify this, we compared the number of thoughts that occurred in one report versus multiple reports for

each of the different types of thoughts (Figure 2). Most thoughts about basic and interpretive issues occurred in multiple reports, indicating substantial stability over time. In contrast, thoughts about structure and expression mostly appeared just once, reflecting lower stability or later appearance.

Thoughts during performance were related to the the practice that preceded it. Table 1 shows that starts during practice occurred at locations where Maria subsequently thought about expression during performance. The trend towards a similar effect for basic thoughts was not significant. Thoughts about interpretation, in contrast, were negatively related to starts, indicating that Maria systematically avoided starting at these locations,

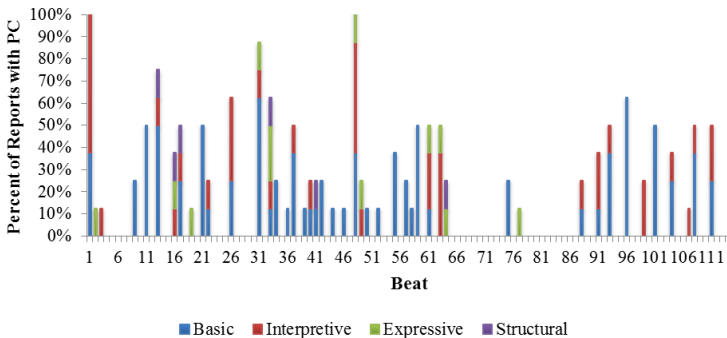


Figure 1. The percentage of reports in which thoughts were reported at each beat of the piece, showing the classification of the type of thought.

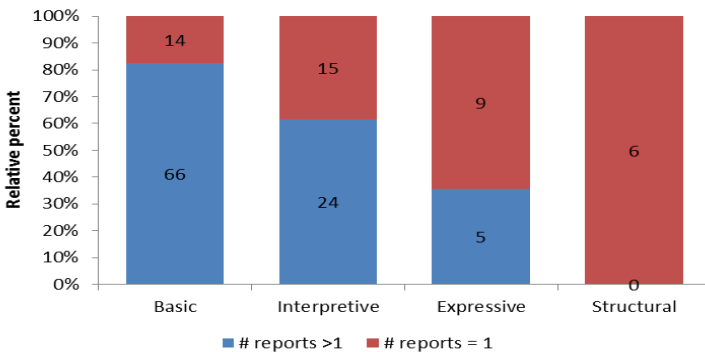


Figure 2. Relative percent of thoughts occurring in one versus more than one report. (See full color versions at [www.performancescience.org](http://www.performancescience.org).)

Table 1. Summary of mixed model of relation of thoughts during subsequent performance to starts during prior practice.

<i>Fixed effects</i>	<i>Estimate</i>	<i>SE</i>
Intercept	-2.04***	0.37
Expressive thoughts	1.82**	0.56
Interpretative thoughts	-1.05*	0.51
Basic thoughts	0.78†	0.41
Session	-0.76***	0.16
Phrase starts	0.33	1.13
<i>Random effects</i>	<i>SD</i>	
Events	2.0	
AIC	226.8	
BIC	250.4	
Deviance	-106.4	

Note. † $p < 0.10$ , \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

providing them with “practice in context”, an appropriate practice strategy for interpretation (Chaffin *et al.* 2002, p. 187). There were also more starts in early practice sessions, reflecting their greater length.

## DISCUSSION

Maria’s thoughts during performance appear to have been PCs. They were not simply random thoughts about whatever happened to catch her attention on that occasion. They were prepared during practice and stable over time. Thoughts about expression occurred at places where playing started during the previous week’s practice. Thoughts about interpretation occurred at places where Maria avoided starting. In either case, thought and action were linked, increasing the likelihood that the same thoughts would occur during performance. Although thoughts about basic technique were not reliably related to starts, they were stable, appearing in multiple reports, as were thoughts about interpretation.

Unlike the professional musicians in previous PC studies, Maria paid little attention to phrasing or musical structure. Her few thoughts on this topic appeared in a single report and were unrelated to starts during practice. The teacher resisted her impulse to direct Maria’s attention to phrasing in order to avoid shaping the outcome. As a result, we are able to see that thinking about structural features just once was not enough to produce an effect on practice.

Thinking repeatedly about interpretive and expressive features, on the other hand, did affect practice. It seems likely that combining thought-reports with suggestions to attend to musical structure would be even more effective.

### **Acknowledgments**

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# Mapping the strategies employed by piano students during memorized performance

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The present study investigated the strategies employed by undergraduate piano students (N=9) during memorized performances under two conditions: (1) the spontaneous use of the player's own resources and (2) after Chaffin *et al.*'s performance cues (PC) protocol. Data collection proceeded in two phases: the recording of the performance of repertoire the student studied during the investigated academic semester and a semi-structured interview. The students' own resources for memorized performance could be classified into seven categories; the most commonly used strategies were structural and expressive. Under the second study condition, the students were capable of managing the PC protocol. In the investigated sample, the employed PCs were found to be related to the style of the piece, which may indicate that explicit memory (content-addressable cues) seems to be associated with the deliberate expression of a given piece's stylistic structure. Furthermore, tempo seems to modulate the number of PCs necessary to guarantee a successful memorized performance, i.e. the faster the tempo was, the fewer PCs were employed.

*Keywords:* learning; performing; memorizing; piano; practice

Recent literature in performance science proposes that performance cues (PCs) are landmarks that professional musicians employ during memorized public performances (Chaffin *et al.* 2009). Performance cues suggest a deep and systematized knowledge that organizes the score into categories of basic, structural, expressive, and interpretative landmarks to be used as needed during performances. In previous research (Gerling and Santos 2011) that investigated the ways that students prepared musical works learned without tuition, the students did not memorize their pieces. Our conclusions showed that students were capable of expressing melodic contour and global coherence at the expense of timing, articulation, character, and/or tempo. We be-

lieve that the type of protocol proposed by Chaffin *et al.* may provide a framework for structured memorization in which less-developed parameters can be reintegrated into a meaningful performance. In addition, we propose that performance cues may act as a supplementary tool for both memorization and promotion of the coordination and command of musical intentions. One of these aspects of musical intention is the deepening of interpretative awareness. Nevertheless, we hypothesize that, before proposing the PC model, it is advisable to map the strategies that students employ spontaneously to assist with memorization. In the present exploratory study, we map the spontaneous strategies that students employed while learning and performing memorized pieces.

## METHOD

### Participants

Nine undergraduate piano students (seven males, two females; mean age=21.5 years,  $SD=2.8$ , range=18-27 years) from a Brazilian federal (public) university participated. Each participant selected one piece that he or she had previously studied and memorized.

### Materials

In Phase 1, the students played works by Mozart, Beethoven, Chopin, Respighi, Schönberg, Villa-Lobos, and Guarnieri. In Phase 2, the students played the exposition from piano sonatas by Haydn (Hob. 37), Mozart (KV 332 and 333), and Beethoven (Op. 2, No. 3; Op. 81; Op. 110) and excerpts from Chopin's *Ballade No. 3* (Op. 47) and *Scherzo No. 2* (Op. 31) and Debussy's *Minstrels* (Préludes, Book I, No. 12).

### Procedure

Data collection proceeded in two phases. In Phase 1, each participant selected one piece that he or she had previously studied and memorized. Data were collected using semi-structured interviews followed by observations of the participants' recorded performances. The data were then transcribed and coded into categories via an interactive process. For Phase 2, the students were introduced to the PC protocol (Chaffin and Imreh 2002). The data were collected and processed as in Phase 1, focusing on the students' own assessments of their performances. The students were interviewed after both the Phase 1 and Phase 2 performances. Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS).



*Table 1.* Frequency of performance strategies the students used to guide their memorized performances.

<i>Student</i>	<i>Performance strategies</i>						
	<i>Mental</i>	<i>Topography</i>	<i>Aural</i>	<i>Structural</i>	<i>Technical</i>	<i>Kinesthetic</i>	<i>Expressive</i>
U7	-	X	X	X	-	-	-
U4a	X	-	-	X	-	X	X
U6	-	X	X	X	-	-	X
U2a	-	-	-	X	-	X	-
U8	-	-	-	X	-	-	X
U4b	-	-	X	X	-	-	X
U4c	-	X	-	-	-	X	-
U2b	-	X	X	X	-	X	X
U4d	-	-	X	-	X	-	X

*Note.* “U” represents an undergraduate (college-level) student. The number following the letter represents academic rank. The lowercase letter (a, b, c) represents individual subjects.

## RESULTS

In Phase I, during which the students did not receive instructions and were encouraged to rely on their own resources, seven strategy categories emerged: (1) mental (visualization of the score), (2) topography (focus on the hand on the keyboard), (3) kinesthetic hints (awareness of the direction of hand movement), (4) aural (sound direction), (5) structural (harmonic and sections), (6) technical (leaps and scales), and (7) expressive (metaphor).

Table 1 shows that the students employed a variety of performance strategies, though they tended to use structural and expressive strategies more frequently than other types. Visualization of the hands on the keyboard (topography) also emerged as a powerful strategy, although it was associated with aural or kinesthetic strategies.

In Phase 2, during which the students were instructed to apply PCs according to the Chaffin protocol, all four categories (basic, structural, interpretative, and expressive) were employed. Figure 1 illustrates several patterns that emerged among the investigated cases.

Figure 1 shows that the students’ descriptions of the PCs are closely tied to their learning processes, e.g. U4a reported the relevance of a structural cue (m. 15) followed by a basic cue (m. 16) indicating that she needed to pay attention to the chord on the left hand. Although student U2b mentioned the importance of technical issues, his use of structural PCs seemed to be less

systematized, as he needed to think about the end of one section (m. 22) and the beginning of a new one (m. 23).

In the investigated sample we observed a rough balance between the four performance cues: 19.5% basic cues, 23.5% structural, 32.6% interpretative, and 24.4% expressive.

## DISCUSSION

Considering the characteristics of the score, such as stylistic period and required speed (tempo markings), and the nature and the frequency of the chosen PCs, some relationships come into view. For example, Figure 2 depicts the relationship between tempo and the total number of performance cues.

According to Figure 2, the faster the tempo was, the fewer PCs were employed. In addition, the analysis revealed an inverse correlation between tempo and interpretative PCs ( $r=-0.751$ ,  $p<0.05$ ). Furthermore, a cluster analysis provided some indication of the nature of the stylistic characteristics (historical period) and their effect on the PCs used during a memorized performance, as shown in Figure 3.

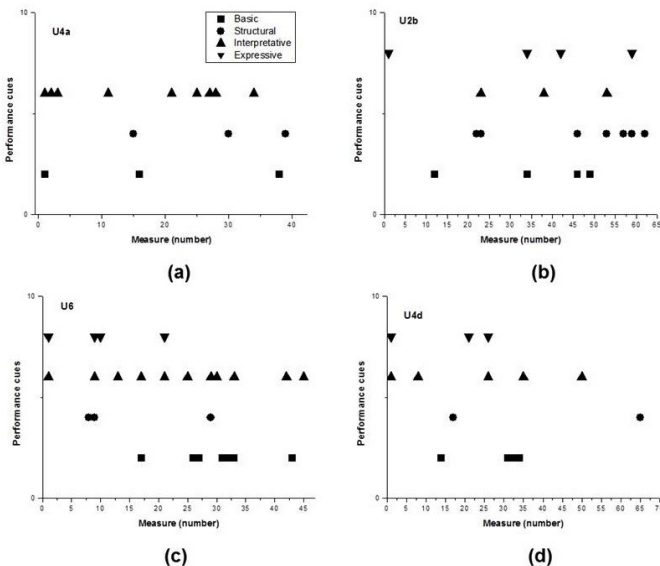


Figure 1. Examples of PCs employed by undergraduate students: (a) U4a, Haydn's *Sonata Hob. 37*; (b) U2b, Mozart's *Sonata KV 333*; (c) U6, Chopin's *Ballade No. 3, Op. 47*; and (d) U4d, Beethoven's *Sonata Op. 81*.

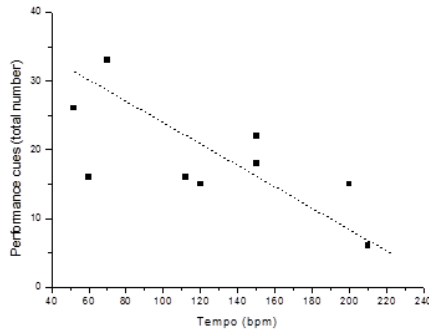


Figure 2. Relationship between tempo and the total number of performance cues employed by the investigated students.

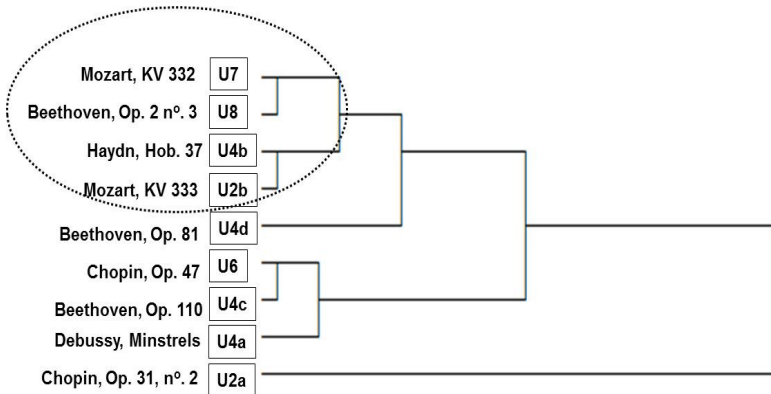


Figure 3. Dendrogram showing the proximity of the students and their performed piano pieces.

Figure 3 shows that the students who played pieces by Mozart, Haydn, and early Beethoven (Op. 2, No. 3) were similar, most likely because of their use of expressive (students U7 and U8) and basic (students U4b and U2b) cues. Students U6 and U4c also reflect this pairing tendency in the way they used expressive and interpretive PCs. Considering that the two students did not have a common instructor, their results could be related to their repertoires, a late Beethoven sonata and Chopin's *Ballade*, which are both centered

on *Ab* major. Student U4d (Beethoven's *Sonata Op. 81*) applied PCs in a way that resembled the first and the second groups; he resembled both in his reliance on basic, interpretative, and expressive cues. In contrast, Student U2a distinguished himself by his parsimonious use of PCs in Chopin's *Scherzo No. 2, Op. 31, in Bb minor*. He claimed to rely on PCs only after he had reached m. 64. Up to this measure, he seemed to rely on associative chaining memory.

The present study shows that students were capable of applying the PCs proposed by Chaffin *et al.* In the investigated sample, the employed PCs were related to the style of the piece, which may indicate that the use of explicit memory (content-addressable memory) seems to be associated with the deliberate expression of a given piece's stylistic structure. Furthermore, tempo seems to correlate with the number of PCs necessary to guarantee a successful memorized performance, i.e. the faster the tempo was, the fewer PCs were employed.

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Symposium:  
Timing and dynamics in  
Mande ensemble drumming:  
Metric well-formedness and  
perception-action coupling



# Mande ensemble drumming: An introduction to *Ngòn*

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This paper introduces an ethnically and regionally specific style of dance-drumming from central Mali. Subject matters include the performance context, instruments, and the musical roles of ensemble members: the central metrical accompaniment, the repertoire-determinative “hook,” and the improvising and regulative lead drum. With an example of a particular piece of repertoire (*Ngòn*), we will detail the basic drumming patterns used in each part. Finally, we will discuss the metrical implications of the ensemble’s polyrhythm.

*Keywords:* drumming; rhythm; Mali; Mande; Bamana

The Bamana (also Bambara) are the largest among a cluster of historically, linguistically, and culturally related ethnic groups from Mali and neighboring countries, called Mande or Manding (Mandingue, in French). Traditional Mande drum ensemble music involves interaction with song and dance, and sometimes masquerade. Occasions range from participatory social gatherings, such as wedding celebrations, to representative public performances. In each case, the percussion frames the social event. Its sheer presence separates celebration from everyday life. Its musical form regulates the syntax of the artistic interaction. Pieces typically show a two-part structure, with a cool and slow first section focusing mainly on song and a hot and fast second section where the dance is at the center of attention. The drumming incessantly marks the metric beat and cycle, to which performers and audiences entrain and on which they rely for synchronization. Thus, the instrumental music is a foundational prerequisite for the social function of the artistic interaction to add to the sense of community (Polak 2007), which has been argued as “the essential aspect of African music” (Chernoff 1979, p. 33).

This paper presents traditional Bamana drumming so as to establish ethnographical and analytical contexts for a performance timing study of the same style (London and Polak 2013). This is necessary due to the fact that Bamana drumming, as Bamana music in general, has not been subject to any musicological study until today.

## MAIN CONTRIBUTION

### Field research and audio-visual documentation

In February 2012, the first author did three weeks of field research in Kirango, a former village now part of the small town of Markala, some 30 km north of the regional capital Segou in central Mali. The location is known throughout the nation for its proficient tradition of masquerade sponsored by local youth associations, which is well researched and documented (see Arnoldi 1995, Otter 1998, Otter and Keita 2002). Author RP is fluent in the Bamana language and has been carrying out participatory research on jembe drumming and other styles of percussion ensemble music in Mali for 20 years. Under the auspices of Moussa Diakité, president of Kirango's youth association, he had daily encounters with two semi-professional expert drummers, Sidiki Diarra and Boukader Coulibaly. RP took private lessons each morning, while afternoons were used for informal conversations, observing rehearsals of the municipal ballet troupe, or recording commissioned studio performances. Only live ensemble playing was recorded; approaches unfamiliar to the musicians, such as splitting the orchestra in separate rooms, were discarded. The sound was recorded with the help of unidirectional clip-on microphones (AKG C419) on a portable digital four-track machine (Edirol R4). Crosstalk between the instruments on the separate tracks turned out reasonably low. Such multi-track recordings preserve note onsets detectable in the separate tracks, which is excellent for timing analysis. In two sessions, exclusively drum-based orchestras were documented in isolation; another two also involved singers and dancers.

### The repertoire

*Ngon Fariman*, “the mean chimpanzee,” is a standard piece in the repertoire of Segou Bamana drumming. It relates to an entertaining mask as well as to associated repertoires of song and non-masked dance. The masquerade portrays a nasty, sexually harassing character. On a day of celebration, *Ngôn* “goes around Kirango to pay important people a visit and announce the beginning of the masquerade” (Otter 1998, liner notes). When it comes to public



performance, *Ngòn* is the first mask to appear (see 01:07-01:24 at <http://tinyurl.com/denOtter>).

### **Instruments**

Bamana drum orchestras in the region of Segou feature three instruments. The *cunba* is a huge wooden kettle drum. Played with bare hands, its cow skin membrane bears a roaring bass. The Kirango youth association's 25 kg specimen is about 50 cm high and more than 60 cm in diameter. Its membrane is fastened with metal clamps, straps, and screws. The cylindrical *ngangan* has two goatskin membranes of 25-30 cm in diameter sewn on to its light wooden body. Leather strap lacings connect the drumheads. Beating the batter head with a light stick produces a trenchant sound of medium pitch; the other head is just for resonance. The *bòn* is a cylindrical, sometimes slightly conical, wooden drum. It has one goatskin membrane of about 30 cm in diameter sewn on and tightly fastened with lacings. Drummers produce a sharp, high-pitched sound with a very thin and slightly flexible rod stick in the right hand and a deeper and more resonant sound with the bare left hand.

### **Ensemble parts, roles, and patterns**

A typical Segou Bamana drum ensemble consists of two *bòn*, one *cunba*, and one *ngangan*. The rhythmic texture of the music is composed of three functional parts. The first *bòn* improvises the regulative lead part, while the second one serves as accompaniment. The *cunba's* and *ngangan's* patterns combine to create an antiphonal hook theme.

#### *Accompaniment*

The second *bòn's* motive is a short and simple ostinato: three strokes with two timbres span a period of one beat. The rhythm is long-short-short (LSS); the melody is low-high-high (see Figure 1). Locals call this motive *kèngèbu*, with *kèn* and *gè* onomatopoeically representing the high short notes, and *bu* standing for the low long note. The motive covers each piece of the repertoire, the term *kèngèbu* thus also designates accompaniment as such. The syllabification indicates that performers perceive the grouping as anacrusic, starting with the first of the two short notes on the off-beats, which, as a rule, they also use as point of entry.

The time-unit-box notation used in Figure 1 has been adapted to the metrical system of Mande drumming. The vertical lines mark the metric half-cycle (double line), beat (single line), and subdivision (light grey). The dotted

versus continuous lines indicate latent vs. manifest subdivision. The box width distinguishes two categories of subdivision elements (shorts and longs).

*Hook*

The basic *cunba* motive consists of two strokes: one on beat 1, another one right before beat 2. This motive is consistently repeated in each four-beat cycle and regularly varied in each second four-beat cycle by further two strokes, on beat 4 and its upbeat. These strokes in beat 4 function as an extended anacrusis to the following downbeat. Thus emerges a thematic phrase spanning eight beats (see Figure 1). Habitual variations fill the first half-cycle, yet carefully leave the four strokes in beats 4 and 5 and the long rest in the second half-cycle untouched.

The basic *ngangan* theme consists of a two-stroke motive (beat-upbeat) in the *cunba*'s first half-cycle and a three stroke motive (beat-upbeat-beat) in the second. It thus confirms the *cunba*'s eight-beat cycle. Each *ngangan* motive, including eventual variations, is perceived as a response to a foregoing *cunba* motive. This antiphony constitutes a catchy compound hook theme, which provides a figural timing reference to performers and audiences and identifies the piece of repertoire (see Video 1).

1			2			3			4		
bu	kèn	gè	bu	kèn	gè	bu	kèn	gè	bu	kèn	gè
						X	X				
O		O						O	O	O	
5			6			7			8		
bu	kèn	gè	bu	kèn	gè	bu	kèn	gè	bu	kèn	gè
						X	X		X		
O		O									O

Figure 1. Basic eight-beat ensemble thematic cycle for *Ngòn*. Rows from top to bottom: (1) metric cycle, (2) *kèngèbu* accompaniment, (3) *ngangan* (X=stick stroke, high-pitch), and (4) *cunba* (O=hand stroke, deep bass; optional anacrusis marked in grey).

•			•			•			•		
bu	kèn	gè	bu	kèn	gè	bu	kèn	gè	bu	kèn	gè
SH		SH	SH			SH	SH		SH		

Figure 2. Basic *bòn* lead part phrase for *Ngòn*. From top to bottom row: (1) metric beat, (2) second *bòn* accompaniment, and (3) first *bòn* lead phrase. (SH=flammed double-stroke with stick and hand.)

### *Lead part*

The lead part is the most complex musical and most prominent social part in the ensemble. It is rich in motives, phrases, and themes. The lead drummer musically activates, supports, and elaborates contributions to the multimedia event—dance, in particular. He focuses those elements and conveys them to the audience. In so doing, he also regulates the tempo, rhythmic density, form, and other core aspects of the musical performance. The most basic structure of *bòn* lead drumming for *Ngòn* is the alternation between off-beat accents in the first half and responsorial beat/upbeat accents in the second half of a four-beat half-cycle (see Figure 2 and Video 2, for instance at 0:28-0:33 or 1:07-1:12; see variations in 1:21-1:27 or 1:39-1:53).

## THE METRICAL IMPLICATIONS OF NGÒN PERFORMANCE

*Ngòn* drumming, and the compound hook theme in particular, implies an eight-beat metric cycle composed of two four-beat half-cycles. Much of the corresponding song and dance supports that perception. The basic movement pattern of the ordinary (non-masked) dancers, for instance, consists of a four-beat motive, which is carried out alternately to the dancer's right and left sides and thus constitutes an eight-beat cycle (see Video 3).

The periodicity of the *kèngèbu* accompaniment motive spans a period of one metric beat. Its anacrustic forward motion, with its last element falling onbeat, conveys a strong sense of pulse at the metric beat level. At the same time, its density and simple structure involves a stable presence of the beat subdivision. The accompaniment part thus gives a salient “feel” to the ensemble polyrhythm's texture. This feel is asymmetric, or “swung:” the onbeat element is markedly longer than the two offbeat elements, yet the long is by far not twice as long as the shorts. The distinction of longs and shorts in the LSS pattern further contributes to the perceptual salience of the beat (see Temperley 2004, p. 324, on the onbeat long in the LS jazz swing feel). That is, the *kèngèbu* LSS rhythm is qualitatively different from what would be the case if it was based on either a nominally isochronous ternary (1:1:1) or a nominally isochronous quaternary (2:1:1) subdivision. Its timing rather evokes an uneven (non-isochronous) fast pulse at the subdivision level which allows for *both* ternary and quaternary listenings. Despite this, the *kèngèbu* LSS pattern still creates a sense of regularity, holding together the parallel and subsequent elements of a complex rhythmic flow.

We thus have a meter which is non-isochronous and multideterminant on its foundational layer (the subdivision) yet does not at all result in metrical ambiguity or instability. This is a challenge to the many theories of rhythm

and meter which assume a nominally isochronous fastest pulse as density referent, or the metric floor.

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### Video samples

(All recorded in Kirango, Mali, February 2012, by author R. Polak.)

Video 1: Lansina Diakite Trio (2012). *Ngòn*. <http://vimeo.com/65625475>

Video 2: Drissa Diakite Quartet (2012). *Ngòn*. <http://vimeo.com/65629788>

Video 3: Adama Boare Quartet and Party (2012). *Ngòn*. <http://vimeo.com/65647406>

# Microtiming in *Ngòn*: Categorical production and perception of a non-isochronous meter

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Timings data from six performances of *Ngòn Fariman*, a Mande ensemble drumming piece characterized by a pattern of long-short-short beat subdivisions, are analyzed, providing evidence of discrete categories of beat subdivision (long versus short) as well as evidence of expressive variations within each category. The effects of the large-scale structural acceleration, characteristic of *Ngòn*, and the presence of performance-specific microtiming patterns indicative of distinctive “swing feels” are also assessed. The implications of *Ngòn*'s rhythms for the categorical perception of duration, beat induction, and theories of musical rhythm and meter are then discussed.

*Keywords:* non-isochronous rhythm; meter; expressive timing; categorical perception

Recent theories of rhythm and meter that encompass both western and non-western music (Arom 1991, London 2004, Temperly 2007, Toussaint 2013) have included both isochronous and non-isochronous beat patterns with the presumption that both are based on a substrate of rapid isochronous pulses. In the most common types of western classical and popular music these pulses form the duplets, triplets, and quadruplets that undergird the isochronous beat, whereas in other musics non-isochronous beats are understood as concatenations of a series of duplets or triplets (e.g. a series of three beats, long-short-short, is heard as 3+2+2). In these approaches non-isochrony is defined quantitatively. At the same time, data on timing musical performances (Gabrielsson 1982) have shown that these isochronous pulses are subject to expressive variations (i.e. rubato) in performance.

Mande drumming from Mali involves moderate to rapid beat subdivisions that are non-isochronous and which cannot be related to an isochronous substrate. Yet the timings in Mande drumming also involve a sense of rubato, or swing, and thus absent a quantitative definition for rhythmic categories (i.e. duplets vs. triplets). Thus the question arises as to how these timings are to be understood in their perception and production. Here we present evidence from six performances of the piece *Ngòn Fariman*, giving details of the timing structure of its accompaniment part. The performance data we have collected show (1) that the musicians are able to produce stable non-isochronous rhythms both within and across performances, (2) that these rhythms are evidence of distinct metrical categories on the level of beat subdivision, and (3) that these categories may also be nuanced, giving individual performers distinctive senses of swing. These results raise further questions regarding categorical perception of rhythmic durations and metrical elements, and how theories of musical meter should best accommodate pieces and performances like those found in *Ngòn*.

## METHOD

### Repertoire and participants

*Ngòn-fariman* (“The mean chimpanzee”) is a popular masked dance performance piece from the Segu region in central Mali. The percussion ensemble involves three or four drums/drummers: two *bòn*, a high-pitched single-headed cylindrical drum with light goat-skin membrane, played with one very light stick (strong hand) and one bare hand; one *cunba*, a huge and heavy (approx. 25 kg) kettle bass drum with cow-skin membrane, beaten with both bare hands; and one *ngangan*, a very high-pitched (goat-skin) double-headed cylindrical drum played with one stick. The first *bòn* is the lead drum, while the second *bòn* maintains the basic accompaniment pattern that is the focus of our analysis here. Performances 1, 2, and 3 were done by the Drissa Diakite Ensemble, with A. Traole playing the accompaniment part; performances 4 and 5 were by the Lansina Diakite Ensemble, with B. Coulibaly (performance 4) and S. Diarra (performance 5) on the accompaniment part; performance 6 was a student ensemble led by Adama Boare, with B. Diakite on accompaniment.

### Materials and procedure

The accompaniment pattern in *Ngòn* consists of a constantly repeated short-short-long rhythm that is readily heard as anacrustic, with the two short high

notes as upbeats to the long low note. This rhythm is known as “kèngèbu,” as the kèn and gè onomatopoeically represent the high short notes, and bu stands for the low long tone. Author RP made field audio and video recordings of these performances with each drum separately miked. Vegas Pro 11 (Sony) was used for video and audio editing, and Soundforge Pro 10 (Sony) and Wavelab 6 (Steinberg) were used for additional audio editing and onset detection. Timings were checked and markers for each onset inserted by hand. Marker time points (running milliseconds) were then converted to text files and then imported into Excel for data cleanup and organization, and then into PASW Statistics (18.0) for analysis. As the performances of *Ngòn* involved a large scale accelerando (average start=73 bpm, average finish=139 bpm, min=60 bpm, max=151 bpm), raw subdivision timings could not be used. Timings were therefore recalculated as percentages of the “local” beat duration (i.e. normalized for tempo).

## RESULTS

Beats in *Ngòn* are organized in a four-beat cycle. Within this cycle the grand average of all normalized beat durations for all performances was 0.248 (beat 1), 0.250 (beat 2), 0.250 (beat 3), and 0.252 (beat 4; SD=0.004). Thus, while there was some typical measure-final lengthening (and perhaps an artifact of the long-term accelerando), the beat-to-beat IOIs were remarkably stable and consistent. Within each beat the long-short-short figure (aligned to the beat as “bu-kèn-gè”) had an average timing ratio of across all performances of 40.83-30.66-28.53. Timing details for each performance are given in Table 1. T-tests comparing all subdivision elements within each performance were highly significant ( $p < 0.001$ ), showing consistent expressive timing differences between the two short elements. Results of a one-way ANOVA comparing differences among each element across all six performances were also highly significant (“bu”  $F_{5,2310}=199.36$ ,  $p < 0.001$ ; “kèn”  $F_{5,2310}=8.43$ ,  $p < 0.001$ ; “gè”  $F_{5,2310}=98.55$ ,  $p < 0.001$ ), showing distinctive expressive timings or “swing feels” for each performance. While these results are not surprising, given the size of the data set, the smaller F values for the “kèn” element are of interest. A Bonferroni post-hoc comparison across all six performances showed that while the contrasts between 14 of the 15 of the “bu” and “gè” pairwise comparisons were significant, for “kèn” only 6 of 15 pairs reached significance. Thus the first element of the kèngèbu figure seems to be most constrained in terms of expressive variation, and may serve as a timing anchor for the other elements.

Table 1. Mean timing ratios for each element of the kèngèbu figure in all six performances of *Ngòn*, with standard deviations and standard errors for each.

<i>Beat</i>	<i>Version</i>	<i>Mean</i>	<i>SD</i>	<i>SE</i>
Long:"bu"	1	41.42	1.51	0.09
	2	41.31	1.63	0.07
	3	41.85	1.78	0.09
	4	40.29	1.42	0.07
	5	38.93	1.51	0.08
	6	40.95	2.92	0.15
	Total	40.83	2.09	0.04
Short1:"kèn"	1	30.71	1.59	0.09
	2	30.39	1.44	0.07
	3	30.75	1.76	0.09
	4	30.97	1.18	0.06
	5	30.87	1.98	0.11
	6	30.33	2.49	0.13
	Total	30.66	1.79	0.04
Short2:"gè"	1	27.87	1.50	0.09
	2	28.30	1.74	0.08
	3	27.40	1.67	0.08
	4	28.74	1.30	0.07
	5	30.20	1.59	0.08
	6	28.72	2.98	0.16
	Total	28.52	2.07	0.04

Time series analysis in each performance also showed a tendency for the ratios of the two short elements in the kèngèbu pattern to converge over the course of the performance as the tempo accelerated (see Figure 1). This suggests that there may be an absolute limit on the duration of the shortest element in a rhythmic pattern, analogous to similar findings in jazz drumming (Collier and Collier 1994) and in tapping studies (Repp 2006).

## DISCUSSION

The six performances of *Ngòn* involved stable and replicable performances of a pattern of non-isochronous beat subdivisions. They are a real world analog to the experimental findings of Povel (1981) and Repp, London, and Keller (2012, 2013), who found that that the production of non-isochronous rhythms need not be yoked to simple integer ratios which would imply an



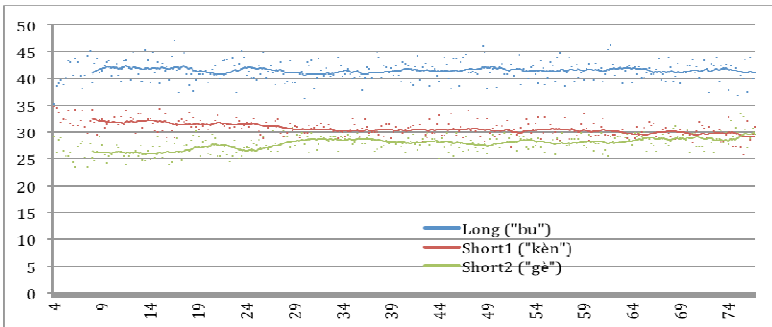


Figure 1. Change Timing ratio over the course of performance No. 1: Y-axis=normalized timings expressed as percentages of the total beat; X-axis=metric cycle. Top line=Long ("bu"); middle line=Short1 ("kèn"); bottom line=Short2 ("gè"). (See full color version at [www.performancescience.org](http://www.performancescience.org).)

isochronous substrate, such as 2:1. The timing data (both in terms of the absolute values of the durations of the long versus short elements, as well as the tendency for convergence between the short elements) suggest that two distinct rhythmic categories are involved in the production of the kèngèbu pattern (Fraisse 1956, Clarke 1987, Desain and Honing 2003). Preliminary results from recent fieldwork (conducted by author RP) which tested the performers' ability to discriminate amongst these categories also support this claim. Finally, music with non-isochronous beat subdivisions poses challenges for theories of rhythm and meter which presume an isochronous "density referent" (Arom 1991) or N-cycle (London 2004). In *Ngòn*, non-isochrony on the lowest level is "contained" by isochrony at higher metrical levels. Kvifte (2007), in his analysis of Norwegian *Springar* rhythms, proposed an analogous "common slowest pulse" to contain non-isochrony on the beat level. Kvifte asks if it is possible to image a meter with no isochronous units (2007, p. 82). While we are not quite prepared to do this, we recognize that pieces like *Ngòn-fariman* demonstrate that well-formed metrical structures need not be recursively organized, and this lack of recursion has manifold implications for theories of musical meter as well as rhythm and timing behaviors more generally.

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**Thematic session:  
Performance health and wellbeing II**



# Interactive performance: Toward the use of vibrotactile technology by musicians with hearing impairments

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Many people with hearing impairments enjoy playing music, but we know little about how they make use of vibrotactile information from their instruments and how this might be extended to the context of interactive performance. In semi-structured interviews, musicians who have hearing impairments and play in ensembles from duos to orchestras revealed that they meet challenges such as staying in time and in tune with fellow performers not only by rigorous preparation but also through awareness of vibrotactile feedback. An observational study of flute-piano duo rehearsals involving participants with and without hearing impairments has highlighted the importance of gesture in verbal as well as non-verbal communication during rehearsal. Experiments using vibrotactile technology showed no difference in the sensitivity to vibrotactile information of those with and without hearing impairments. They also indicate that it is possible to discriminate higher from lower pitches when presented as vibration and that this ability can be improved with training. However, to develop vibrotactile technology to help facilitate and enhance interactive music-making for musicians with hearing impairments, we still need to know more about potential constraints, including pitch, dynamic range, sensitivity of the skin on different parts of the body, and the ability to learn pitch-vibration associations.

*Keywords:* deaf; ensembles; music-making; strategies; vibration

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# The effects of hearing impairment on interactive performance: Two observational experiments

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Anecdotal evidence suggests that a hearing impairment increases reliance on visual cues in music performance. To investigate further, two studies were designed to explore how (1) auditory feedback and (2) natural deafness affect interactive rehearsal and performance. Study 1 aimed to establish a link between reduced auditory feedback and increased visual attending as evidenced by looking and movement behavior between violinists in duos. Study 2 aimed to explore verbal and non-verbal communication processes in rehearsal and performance as evidenced by looking behavior, rehearsal talk, and speech-gestures used by performers in flute-piano duos. The attenuation of auditory information using ear-plugs had no effect on violinists' movement or looking behavior. The possibility of eye contact, however, produced increases in both movement and looking behavior. In Study 2, profoundly deaf musicians spent significantly more rehearsal time talking, looking towards their co-performer, and gestured more during speech. Hearing musicians adapted their behaviors within rehearsals for their co-performers' benefit by looking and gesturing more. In conclusion, only profound, congenital deafness significantly affected rehearsal behaviors; the adjustments made by normally hearing musicians suggest that compensatory strategies can be adopted quickly. Small changes to the level or quality of auditory feedback did not hamper group music performance.

*Keywords:* deafness; interactive performance; visual feedback; gesture; communication

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# How to identify and manage stress VPI: Recommendations for wind instrumental teachers and students

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Stress velopharyngeal insufficiency (stress VPI) is frustrating and potentially career threatening to a wind instrumentalist. The prevalence among student musicians is as high as 39%. Most students seek advice primarily from their instrumental teacher, who is responsible for their technique development, and few students seek professional medical advice. Despite the high prevalence rate, anecdotal evidence suggests that many students and teachers are unaware of the symptoms of stress VPI and factors that may lead to this condition. A lack of knowledge may lead to insufficient advice from most woodwind and brass teachers, and many students may then experience prolonged recovery times due to their failure to respond to early warning signs. This paper aims to outline the symptoms and causes of stress VPI and attempts to recommend commonly used management methods.

*Keywords:* stress velopharyngeal insufficiency; woodwind; brass; diagnosis; management

The performance-related disorder *Stress Velopharyngeal Insufficiency* (stress VPI) occurs in musicians when the soft palate fails to close the oral cavity to separate it from the nasal cavity, which results in air leaking out through the nose while attempting to blow air out through the mouth. Previous published papers have reported prevalence rates between 17 and 34% (Malick *et al.* 2007, Schwab and Schultze-Florey 2004, Ingrams *et al.* 2000). Stress VPI is more likely to occur to players of wind and brass instruments that require a high intraoral pressure to generate a note, such as oboe, bassoon, clarinet, trumpet, or French horn (Malick *et al.* 2007). The amount of

pressure required to play a wind or brass instrument has been quoted as thirty times greater than the amount needed for speech (Schwab and Schultze-Florey 2004, Malick *et al.* 2007). It has been observed that stress VPI commonly occurs in young adults aspiring for professional careers, due to the physiologically demanding practice required to achieve excellence at an elite and competitive level (Schwab and Schultze-Florey 2004).

In a small online Delphi survey of speech-language pathologists and otolaryngologists, only four out of fourteen respondents reported they had seen five or more wind instrumentalists with stress VPI (Evans *et al.* in press). Malick and co-workers (2007) reported that out of 160 plastic surgeons and otolaryngologists 45% had knowledge of stress VPI but only 27% had seen cases with the disorder in their clinics. In our recent survey (Evans *et al.* 2011) 39% of students reported experiencing symptoms of stress VPI during their studies. Out of 30 musicians with self-reported symptoms of stress VPI only three sought medical advice from a health practitioner while the majority (21) reported seeking advice primarily from their instrumental teachers. Consequently for many young instrumentalists stress VPI can be left untreated resulting in delayed recovery, which may also adversely affect their course of studies. Teachers may perceive symptoms occurring to their students but remain unaware of possible risk factors—or know how to advise their students—which may potentially exacerbate the problem. These reports imply that a lack of knowledge and understanding of stress VPI causes and its management exists for students and music teachers.

Literature on stress VPI in wind players is limited to only a small number of case reports. The most recent article included a literature review and two case reports of successful surgical treatment for stress VPI in clarinet players (Visser and van der Biezen 2012). Some pedagogical texts have briefly mentioned the phenomenon and advocate exhalation through the nose while playing as a practice strategy, but contain limited information on relieving symptoms if the problem is more debilitating (Sprenkle and Ledet 1961, Stein 1958). In only one pedagogical text was research evidence provided of successful treatment for severe stress VPI cases (Hickman 2006). Other practical advice aimed at instrumental musicians has been published in music journals (Wolff 1995, Gibson 2008).

Some published injury prevention guidelines for musicians (Llobet and Odam 2007, Klickstein 2009) include tips that are easily transferrable when symptoms of stress VPI occur. These include increasing practice time gradually, incorporating an adequate warm-up and cool-down as well as sufficient rest breaks, minimizing tension by employing good posture and breathing habits, stress management, and general health maintenance. All these

measures are suggested to be beneficial to overall well-being. As with other more severe health conditions, when symptoms of stress VPI persist the student may need further evaluation from a trained health professional.

The main aim of this research is to present the known causes and management options available for students with stress VPI. This work described here will contribute to raising awareness of the disorder among wind instrumentalist students and teachers, as well as among health practitioners that consult with these musicians.

### **MAIN CONTRIBUTION**

Symptoms of stress VPI include audible air emission from the nasal cavity and the inability to maintain soft palate closure, affecting the player's ability to practice or perform on their instrument for an extended length of time.

#### **What to listen for?**

If nasal air leak is appearing while the student is playing their instrument it will sound like a "hiss" or a "snorting" rustle. This is the sound of air escaping from the oral cavity via the nasal cavity and exiting out through the nose.

#### **When is nasal air leak likely to occur?**

Case reports and discussions with other musicians reveal that stress VPI commonly occurs to students of 17 to 20 years of age or during a period of advanced instrumental study. The onset of symptoms is possibly due to a sudden increase of physiologically demanding practice, such as preparing for auditions or recital examinations. Students further report that symptoms usually appear when fatigued or during times of stress.

#### **What can you do?**

Firstly it is important to exclude any incorrect habits in instrumental technique through an assessment by either the student's teacher or another instrumental specialist. If general playing set-up (including posture, breath support, and embouchure) is considered appropriate and the problem persists then further investigation may be needed to ascertain possible anatomical causes of the disorder. In particular, the student may need to consult their usual general practitioner to obtain a referral to see an otolaryngologist (ear, nose, and throat specialist) for detailed assessment. The assessment of velopharyngeal closure is either done through video nasendoscopy (or fluoroscopy) and can determine the most appropriate type of medical intervention

(Brigger *et al.* 2010). This examination would normally involve either the student playing their instrument while the ENT inserts a flexible video camera into the nose to view the nasal and oral cavities (nasendoscopy) or an x-ray of the velopharyngeal mechanism (fluoroscopy). From this examination the specialist can ascertain the anatomical position where nasal air leak is occurring. This may be important when determining appropriate management.

### **Treatment and management**

Previous case reports have reported the use of both non-surgical and surgical interventions to improve symptoms of stress VPI. It has been suggested that speech-language pathology intervention (or speech therapy) and other conservative methods be attempted for at least six months and if symptoms persist it is advisable to consult a specialist for surgical treatment options (Gibson 2008). Speech therapy may consist of palatal exercises (such as blowing, swallowing, and sucking) designed to increase the awareness of soft palate closure. Although speech therapy may be useful for patients with other speech disorders, some research suggests that muscle exercises may not be effective in improving velopharyngeal closure (Shprintzen *et al.* 1975). Another suggested vocal technique to increase the student's awareness of the oropharynx is playing with an "inner smile" whereby the oropharynx is broadened and the soft palate is elevated by attempting to smile without moving the outer corners of the mouth (Gibson 2008). The functional mechanics necessary for instrument playing however, are different from the velopharyngeal movements used for speech or singing, and further research in the efficacy of speech therapy is needed.

If surgical intervention is appropriate, there are three procedures commonly used to correct structural VPI that have been successfully used in treating cases of musicians with stress VPI. The least invasive is injection augmentation where injectable material is administered to the posterior pharyngeal wall. Surgical procedures are pharyngeal flap (inferior or superior based), and sphincter pharyngoplasty.

### **When is too much practice too much?**

Despite the old maxim "practice makes perfect" there are arguments to suggest that over-practicing may cause more harm than good. Misconceptions still exist such that when problems appear in a student's playing they are accused of "not practicing enough." Well-meaning teachers and colleagues may even erroneously suggest to the instrumentalist experiencing symptoms of

stress VPI that there is a “weakness” (either physiologic or psychological) that they have to overcome. The student consequently increases their practice load, unaware of potential harm they may be causing to themselves.

### **Recommendations**

Previous guidelines have recommended a short period of rest (or reduced playing) be taken. However, current research suggests that muscle fatigue or overuse is not the only factor leading to stress VPI. While a period of rest may relieve symptoms temporarily it is advised to seek immediate help if symptoms persist. If a structural deficiency exists an evaluation is needed by a health professional to determine individual-specific treatment options. Some cases may benefit from employing specific exercises done away from the instrument and by using a structured practice plan upon returning to playing activities. A guided rehabilitation program can be designed with advice from a health professional in collaboration with both music teacher and student. This may involve teachers and students dividing their practice sessions into shorter sessions, including rest breaks, and gradually increasing the level of physically demanding repertoire and including an adequate warm-up and a cool-down before and after practice.

### **IMPLICATIONS**

Advanced student instrumentalists may have already spent many years of deliberate practice at their instrument, and stress VPI may produce unwanted setbacks to their career development. Both students and teachers need to be aware of the symptoms of stress VPI and know what options are available for diagnosis and management. Further research currently being undertaken, investigating the velopharyngeal mechanism when playing a woodwind instrument will provide more evidence on the anatomical causes of stress VPI. Due to the small number of case reports published it is difficult to assess the most appropriate treatment method. Therefore if a student who suspects stress VPI in their playing or has persisting symptoms, it is advisable they seek assessment by a trained health professional in order to determine appropriate rehabilitation and/or treatment suited to the individual.

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**Thematic session:  
Evaluating music performance**





# Thoughts in concert: A multi-method approach to investigate the effect of performers' focus of attention

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Does it matter what a performer feels or thinks about while performing? To investigate the effect of performers' focus of attention on their performances we asked eight violinists to play the same musical phrase in response to three different instructions. The first instruction was to focus on the technical aspects of playing. The second instruction was to give an expressive performance. Following a sadness-inducing mood induction task, the third instruction was to play while focusing on felt emotions. High quality audio and three-dimensional motion-capture recordings were made of all performances. Subsequently, thirty individuals rated how much they liked each performance, how skilled they thought each performer was, and to what extent each performance was expressive of sadness. Computational analysis of the audio and motion-capture recordings revealed differences between performance conditions. Statistical analysis of the perception data revealed that individuals preferred the Expressive performances to the Technical and Emotional ones. In addition, the Expressive performances were rated as played by the most skilled performers. The Emotional performances were rated as being most expressive of sadness. The findings suggest that a performer's focus of attention has an effect on the audio features, movement features, and perception of their performances.

*Keywords:* performing musicians; technique; expressivity; emotions; multi-method approach

Performing musicians face the question of how to best achieve an expressive performance. Should they feel the musical emotions when expressing them (e.g. Persson 2001)? Or should they focus rather on technique or expressivity

when trying to bring a musical message across (e.g. Sloboda and Lehman 2001, Chaffin *et al.* 2002)?

In the field of sports psychology, the effect of performers' focus of attention on motor skills has received quite some attention (e.g. Wulf 2013). Research in this field has consistently demonstrated that an external focus (i.e. on the movement effect) enhances motor performance and learning relative to an internal focus (i.e. on body movements). In line with this research, Duke *et al.* (2011) examined the effect of different foci of attention on the consistency of piano playing. Their results supported the notion that an external focus (e.g. on the sound of the piano) resulted in more consistent playing than an internal focus (e.g. on the fingers).

Of course, music performance is not just about playing a phrase as quickly and evenly as possible. In music performance the aim is rather to bring a musical message across and allow the audience to experience music related emotions (e.g. Lindström *et al.* 2003, Woody 2000). The aim of the present study was to investigate whether a different focus of attention of the performer affects the audio features, movement features, and audience's perception of the performance.

## METHOD

### Participants

Participants who provided the musical stimuli were eight violinists (4 professionals and 4 amateurs, all female, mean age=24.3 years, SD=1.8). Participants who provided the perception data were thirty students (18 females, mean age=28.07 years, SD=5.64).

### Materials and procedure

The violinists were asked to play a 14-bar phrase in G minor (Harty 1911) three times in response to three different performance instructions. The first instruction was to focus on the technical aspects of their playing (i.e. the Technical performances). The second instruction was to give an expressive performance (i.e. the Expressive performances). Following a sadness-inducing mood induction task, the third instruction was to play while focusing on their felt emotions (i.e. the Emotional performances). After each playing condition, the participants were interviewed about their thoughts and feelings. Before the first and after the final performance, participants completed the Positive and Negative Affect Scale (PANAS) state questionnaire (Watson *et al.*

1988) to assess their mood. Data collection lasted approximately 90 minutes per participant.

High quality audio (using ProTools8, Avid) and three-dimensional motion-capture recordings (using a Qualisys ProReflex eight-camera optical motion-capture system) were made of all 72 performances.

Twelve of the performances were used as stimuli in the perception study (4 performers x 3 performance conditions x 3 presentation modes). The performances were presented in three blocks on a big screen in an auditorium, each block containing the same 12 performances but in a different presentation mode (i.e. vision only, audio only, and vision and audio). The order of the performances was randomized within each presentation mode.

Participants were asked to rate their agreement with the statements (1) “I like this performance,” (2) “the performer is skilled,” and (3) “this performance is expressive of sadness” on a seven-point bipolar scale (*completely disagree* to *completely agree*). Data collection was preceded by an example performance to make sure all participants understood the rating procedure. After having rated all performances, participants were asked to write down any comments they had about the study and their experiences. Data collection lasted approximately 45 minutes.

### **Feature extraction**

Using the MATLAB Music Information Retrieval (MIR) Toolbox (Lartillot and Toiviainen 2007), several audio features representative of playing tempo, dynamics, articulation, timbre, and vibrato were extracted for each performance.

Using the MATLAB Motion Capture (MoCap) Toolbox (Toiviainen and Burger 2010), the amount, speed, acceleration, and smoothness of movement were estimated from the 3-dimensional position data of 33 reflective markers attached to the body and instrument of each participant.

### **Analyses**

To compare the Technical, Expressive, and Emotional performances, repeated-measures ANOVAs were performed. The repeated-measures ANOVAs of the audio and motion-capture data are based on 69 performances (8 violinists x 3 performance conditions x 3 performances; 3 performances were excluded due to missing data). The repeated-measures ANOVAs of the perception data are based on the ratings of 30 participants of 36 performances (4 violinists x 3 performance conditions x 3 presentation modes).

## RESULTS

### Audio data

Computational analyses of the audio recordings revealed statistically significant differences in playing tempo ( $F_{1.57,33.01}=15.76$ ,  $p<0.001$ ), dynamics ( $F_{1.35,29.69}=11.32$ ,  $p=0.001$ ), articulatory features such as the attack slope ( $F_{1.42,29.85}=9.72$ ,  $p<0.01$ ), timbral features such as mean roughness ( $F_{1.45,31.85}=6.51$ ,  $p<0.05$ ), and the extent ( $F_{2,42}=9.06$ ,  $p<0.01$ ) and rate ( $F_{3,43,72.05}=3.85$ ,  $p<0.05$ ) of vibrato between the three performance conditions. The Expressive performances, for instance, were characterized by the fastest playing tempo, the loudest sound, the brightest and roughest timbre, direct note attacks, and a wide and fast vibrato, as compared to the Technical and Emotional performances.

### Motion-capture data

Computational analyses of the motion-capture recordings revealed statistically significant differences between performance conditions in terms of body posture ( $F_{1,536,32.260}=4.837$ ,  $p<0.05$ ), amount ( $F_{1,490,31.282}=21.943$ ,  $p<0.001$ ), speed ( $F_{1,532,32.162}=22.398$ ,  $p<0.001$ ), acceleration ( $F_{1,446,30.364}=17.358$ ,  $p<0.001$ ), and smoothness of movement ( $F_{2,42}=12.276$ ,  $p<0.001$ ) of the performers. In the Expressive performances, for instance, performers were standing most upright, and moved most, fastest, with the highest acceleration, and lowest smoothness as compared to the Technical and Emotional performances.

### Perception data

Statistical analysis of the perception data revealed that, overall (i.e., regardless of presentation mode or expertise of the performers), individuals preferred the Expressive performances to the Technical and Emotional ones ( $F_{2,58}=13.43$ ,  $p<0.001$ ). In addition, the Expressive performances were rated as played by the most skilled performers ( $F_{2,58}=25.75$ ,  $p<0.001$ ). The Emotional performances, however, were rated as being most expressive of sadness ( $F_{2,58}=10.09$ ,  $p<0.001$ ).

## DISCUSSION

The results of the present study suggest that a performer's focus of attention affects the audio features, movement features, and perception of the performances by an audience.

The Technical performances were played in a moderate tempo, with moderate note attacks, moderate dynamics, moderate spectral centroid and roughness values, and a vibrato characterized by a moderate width and low rate. In the Technical performances, participants moved least, with medium speed, medium acceleration, and medium smoothness. The Technical performances received the lowest ratings in terms of preference and perceived emotional expression, and average ratings in terms of perceived skill of the performer.

The Expressive performances were characterized by the fastest tempo, the loudest sound, the most bright and rough timbre, direct note attacks, and a wide and fast vibrato. In the Expressive performances, participants moved most, fastest, with most acceleration, and lowest levels of smoothness. The Expressive performances received the highest ratings in terms of preference and perceived skill of the performer, and average ratings in terms of perceived emotional expression.

The Emotional performances were characterized by the slowest tempo, the softest sound, the least bright and rough timbre, the least direct note attacks, and a moderately fast and wide vibrato. In the Emotional performances, participants moved with a moderate amount of movement, minimal speed, minimal acceleration, and highest levels of smoothness. The Emotional performances were rated average in terms of preference, lowest in terms of perceived skill of the performer, and highest in terms of perceived emotional expression.

The auditory and movement characteristics of the performances indicated that a focus on technique or felt emotions resulted in more introverted playing (e.g. less loud and with less movement), whereas a focus on expressivity resulted in more extraverted playing. The perception data indicated that individuals preferred the Expressive performances and believed they were played by the most skilled performers. The perception data also indicated that individuals perceived the Emotional performances as being most expressive of sadness. Does this mean that a more external focus (i.e. “give an expressive performance”) results in a “better” performance, and that a more internal focus (i.e., “focus on felt emotions”) results in an “emotionally expressive” performance?

These and other questions remain open. However, the multi-method approach applied in the present study indicates that a performer’s focus of attention affects the characteristics and perception of the performance. The findings as such are valuable for music education and performance: it does seem to matter what a performer feels or thinks about while performing.

## Acknowledgments

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# Between producers and consumers: Critics' role in guiding listeners' choices

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This study investigated how professional critics' judgments of recorded performances relate to other listeners' preferences. Music students (n=10) and music professionals (n=7) were asked to rate their liking of five interpretations of the opening of Beethoven's Piano Sonata Op. 111. Listeners' likings were compared with judgments given in reviews published in the *Gramophone*. Correlation between critics' judgments and music professionals' preferences was moderate, while no correlation was found between critics' evaluation and music students' likings. The results suggest that preferences for given interpretations of a piece vary between listeners and may be influenced by the listeners' prior experience of detailed listening and study of repertoire and its renditions.

*Keywords:* performance preferences; music criticism; musical expertise; listeners' choices; Beethoven

Professional critics' reviews of recorded performances are published regularly in newspapers and specialized music magazines. Arguably, the aim of these reviews is to guide consumers' choices when it comes to deciding which recording to buy (Frith 2009, Pollard 1998). Yet no research so far has investigated the actual role that music reviews play in listeners' choices or their efficacy in guiding listeners toward purchases of recordings that promise long-term satisfaction.

In the classical music market, listeners are exposed to an ever-increasing number of interpretations of canon repertoire from which they can choose to listen. Previous research by the authors found that in the magazine *Gramophone* alone 845 recordings of Beethoven's Piano Sonatas, produced by 217 different pianists, were reviewed between 1923 and 2010. This amount of

material seems impressively large. Findings in decision-making research suggest that this increase in options (quantity of different versions of an item to choose from) may paradoxically lead to paralysis of choice and dissatisfaction (Schwartz 2008): in this scenario the critics' guidance—working as a filter of choice—seems to be particularly significant.

However, critics are seasoned listeners, with an extraordinarily rich experience in listening to music and in comparing high-level professional performances. When it comes to canon repertoire, critics have most likely listened to and evaluated plenty of different interpretations of the same piece. It could be reasonably expected that this level of familiarity with the piece, and with various interpretations of it, may color their attitudes and preferences toward certain performances in such a way that what may be considered a good performance by critics may not be considered thus by a listener who has a different level of musical expertise and listening history. Exploring this hypothesis was the aim of this study.

## METHOD

### **Phase 1: Establishing the valence of critics' judgments**

#### *Participants*

A total of 28 music undergraduates at the University of Leuven took part in the first phase of the study in the context of a seminar on music criticism that was part of their study programme.

#### *Materials*

From the material published in the *Gramophone*, five reviews of recordings of Beethoven's Piano Sonatas Op. 111 were chosen. From the reviews, sentences were extracted that discussed the Maestoso section at the beginning of the sonata. These review excerpts (length=86-169 words) were used as stimuli.

#### *Procedure*

Students were asked to read all five review excerpts and to evaluate each on a 7-point scale answering the question: "What is the critic's opinion of this performance?" from -3 (Not at all worth listening to) to +3 (Absolutely to be listened to!).



## **Phase 2: Critics' versus listeners' likings**

### *Participants*

For Phase 2, 17 musicians were recruited: 10 students with a major in music performance and 7 "experts" who studied music at professional level and are currently involved in different music-related jobs that require large amounts of regular musical exposure (performing, teaching, researching).

### *Materials*

The Maestoso parts of the recordings corresponding to the five reviews evaluated in Phase 1 were used. Recordings were cut at the beginning of the *Allegro con brio ed appassionato* (at the end of bar 25) using Audacity 1.2.6, a 1 s fade out was added at the end.

### *Procedure*

Participants listened to the five recordings and rated them on three 7-point scales: (1) their liking of the performance (1=not at all, 7=very much), (2) the expressiveness of the performance (1=not expressive at all, 7=very expressive), and (c) how well the performer managed to keep the tension throughout the passage (1=not well at all, 7=very well).

## **RESULTS**

### **Phase 1: Establishing the valence of critics' judgments**

Agreement among participants on the valence of the single reviews was strong; Kendall's coefficient of concordance ( $W$ ) was 0.65 ( $p < 0.001$ ). Friedman's test showed that participants were able to discriminate between the different valences of reviews ( $\chi^2_4 = 67.19$ ,  $p < 0.001$ ). Post-hoc Wilcoxon tests were significant for three levels of valence: Good for Taub, Barenboim, and Michelangeli; not so good for Pogorelich; very bad for Ugorski (see Table 1).

### **Phase 2: Critics' versus Listeners' likings**

Results for the liking ratings are shown in Table 1. A multivariate analysis showed a significant main effect of level of expertise on the liking of one or the other interpretation: Wilk's  $\lambda = 0.10$ ,  $F_{5,11} = 22.40$ ,  $p < 0.001$ . Individual t-tests were significant for one of the five recordings (Ugorski). To test the level of agreement between listeners and critics, Spearman's rank-order correlation coefficient was computed between each participant liking ratings and the

*Table 1.* The valence of critics' judgements (rated -3 to +3), students' and experts' liking ratings for the five recordings (rated 1 to 7), and t-tests between students' and experts' ratings.

	<i>Barenboim</i>	<i>Taub</i>	<i>Michelangeli</i>	<i>Pogorelich</i>	<i>Ugorski</i>
<i>Critics</i>					
Mean	2.44	2.39	2.25	1.25	-2.22
SD	0.74	0.63	1.11	1.08	0.92
<i>Students</i>					
Mean	4.60	4.20	4.00	4.10	5.60
SD	1.78	1.40	2.26	2.18	1.35
<i>Experts</i>					
Mean	5.29	4.86	4.86	5.71	2.57
SD	1.38	1.46	1.46	1.60	0.98
t	-0.85	-0.94	-0.95	-1.66	5.06
p	0.41	0.36	0.36	0.12	<0.01

valence of critics' reviews (correlations were converted to z scores for the analyses, and means reported here were transformed back into correlation coefficients). The mean correlation was significantly higher for expert listeners' likings ( $r_s=0.47$ ) than for students' likings ( $r_s=-0.16$ ) ( $t_{14,10}=-2.73$ ,  $p<0.05$ ). The correlation between expert listeners and critics was moderate to strong, and significantly different from zero ( $t_6=3.87$ ,  $p<0.01$ ), while that between students and critics was not ( $t_9=-0.81$ ,  $p=0.44$ ).

The largest difference between students' and experts' ratings was in the evaluation of Ugorski's performance (cf. t-tests in Table 1). This performance was harshly criticised by the *Gramophone* reviewer David J. Fanning for the "ultra-spacious" tempo employed by the pianist that in the reviewers' opinion makes the music "fall apart." This effect is made worse by Ugorski's expressive playing that, according to the critic, does not reflect a "compelling interpretive vision," but rather results in "studied eccentricity" (February 1993, p. 62). This critic's judgement echoes in expert listeners' ratings. Figure 1 shows ratings of liking, expression, and tension for both experts and students. Ugorski's excessive use of expressive inflections seems reflected in experts' expression ratings. In line with the reviewer, this use of expression does not add to the overall liking of the performance. Students, on the other hand, seemed to appreciate Ugorski's slow tempo and use of expression, so much so that this recording was their favourite among the five.

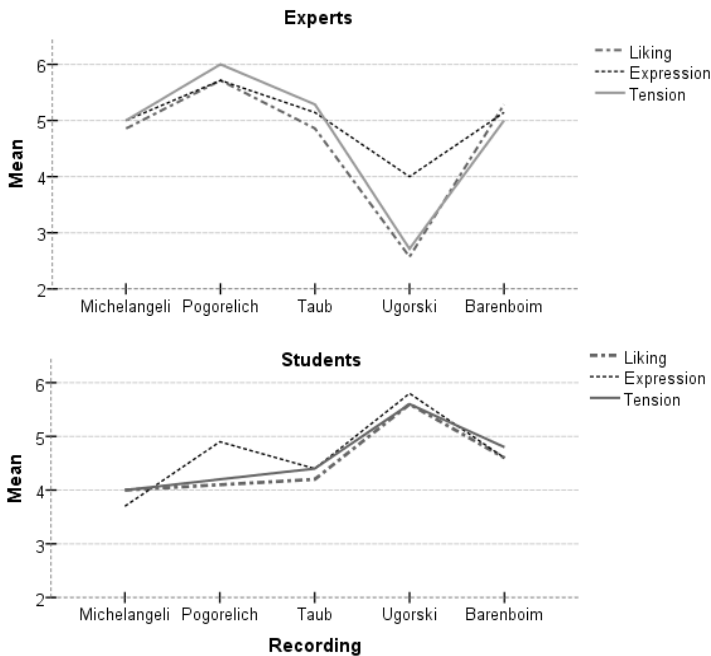


Figure 1. Experts' and students' ratings of liking, expression, and tension.

## DISCUSSION

This study opens an exploration of the relationship between critics' judgments of performances and wider audience's preferences and, in a wider perspective, of the role of critical practice in the classical music market. Likings of one or the other interpretation were significantly different for the two groups of listeners; in particular, preferences expressed by more experienced listeners correlated more highly with critics' judgments, even though the level of correlation remained moderate. These results seem to support the hypothesis that critics' preferences for a given performance may be sharable only by similarly informed listeners; however, this needs to be substantiated by repeating the test with more participants and different sets of recordings. The difference between experts' and students' ratings depended mainly on students' liking of Ugorski's performance. Participants were given no information regarding the nature of the recordings; however, the quality of both the recording and performance may have led participants to think that they

were listening to commercially available professional recordings. This in turn might have reduced students' self-confidence in giving low ratings. On the other hand, this interpretation fails to explain why students rated Ugorski's recording as their favorite. An alternative explanation could be linked to the different level of familiarity with the piece and its renditions (cf. Levinson 1987). It could be that the slower tempo employed by Ugorski allows non-familiar listeners better to grasp the structure of the work, while it is perceived as dull and unexciting for listeners who know the piece well. It could also be that, with increased familiarity and knowledge of the piece, listeners develop a more precise idea of how the work should be performed, thus becoming less ready to appreciate interpretations that move away from this idea. In any case, to better understand these results follow-up studies should focus particularly on performances that are negatively reviewed by critics. Finally, if the hypothesis that critics' preferences for given performances are shared only by similarly informed listeners should be further supported, the next step would be to investigate to what extent critics' preferred performances can in fact offer the best possible aesthetic experience also to listeners who do not like them at first.

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# Pianists' perceptions on performance criteria: Results of a factor analysis

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This paper focuses on constructed elements of piano performance from the viewpoints of the performers themselves. Performers were asked to classify fourteen key features of piano performance as either more technical or interpretative in nature, and also to indicate the relative importance of each feature in their own piano performance. Sixty-four professional standard pianists participated. The data were analyzed by undertaking an exploratory factor analysis and, as a result, five factors were extracted: representative of overall quality, expressive variation, technical precision, rhythmic integrity, and stylistic appropriateness. In terms of relative prioritization of creating a piano performance, some elements were strongly correlated, such as dynamics and touch. It could be said that piano performance criteria embraced hierarchical dimensions in performance that were evidenced across the participant group.

*Keywords:* piano performance; criteria; priority; technique; interpretation

In previous studies in the field of performance research, performance criteria have been classified in diverse ways and there is no common agreement evidenced as to what counts as the most important aspects of performance (e.g. Jones 1986, Juslin 2003, Nichols 1991, Russell 2010, Stanley *et al.* 2002, Zdzinski and Barnes 2002). For example, the diversity of criteria and factors in performance evaluation are evident in research into the comments of judges (Wrigley 2005). Several elements of performance classification used by one researcher are likely to be redundant to another.

However, it is evident from the literature that performance embraces both technical and interpretative aspects, although sub-criteria are still needed for each of these macro headings (Chaffin and Imreh 2001, 2002, Wapnick and Rosenquist 1991). As might be expected, there is a reported relationship be-

tween the written score and performance because notation needs interpretation by artists to become performed music and this is closely related to perceived performance expression. In most of the research studies, either interpretation is comprehended in terms of musical components or musical effect (e.g. Abeles 1973, Bergee 2003, Jones 1986, Russell 2010, Zdzinski and Barnes 2002). Also, it has been reported that technical components or elements are also included in judgements of performance quality (e.g. Bergee 2003, Jones 1986, Saunders and Holahan 1997). Considerable technique is required in order to express performers' intentions, interpretations, and emotions (McPherson and Thompson 1998). Therefore, technique and interpretation are hypothesized in two interrelated core components in the process of preparing for music performance (Reid 2002). However, there is little agreement among music performance researchers as to which the most important aspects of performance are and how musical elements might be categorized into interpretative or technical components.

This study focused on the perspectives of expert performers and investigated how these performers perceived performance criteria in terms of interpretative and technical elements. The study also explored how the performers prioritized performance elements when developing the quality of their own performances. Finally, the study investigated how performance elements might be grouped into larger performance components.

## METHOD

### Participants

The participants in this study were sixty-four pianists ( $M=29.0$ ,  $SD=7.4$ ) who lived in Japan and the UK. They were either currently students at a university (UG/PG), or graduates of piano and professional-standard pianists. The mean age for beginning piano lessons was 5.8 years old ( $SD=3.0$ ).

### Materials

A mapping sheet was designed to show the intersection of two continua at right angles, i.e. the vertical alignment indicated high priority/low priority and the horizontal alignment indicated a more technical/more interpretative conception. Fourteen performance elements delivered from a synthesis of related literature (e.g. Morijiri 2010, Thompson *et al.* 1998, Wrigley 2005) were to be arranged by placing labels on the sheet by each participant according to their performance experience. The elements were: overall flow, musical expression, phrasing, rhythm, melodic accuracy, tempo, technique,

interpretation of music, dynamics, rubato, pedalling, tone quality, touch, and style.

### **Procedure**

The participants were asked to make a performance element “map” of the important criteria in the development of their own piano performances by arranging the fourteen performance elements somewhere on the intersecting continua. The “maps” were created by each individual on the basis of which element was perceived to be more technical or interpretative, as well as its relative priority (from high to low) in developing their own performances. The physical distance from the mid-points of vertical and horizontal alignments to each element was measured. These measures were converted into a range of numbers: -10 (minimum) to +10 (maximum) and entered into a spread sheet. To explore any relationship amongst the spreadsheet elements, a factor analysis was undertaken using a Principal Axis Factor (PAF) with a Varimax rotation.

### **RESULTS**

Figure 1 shows the result of mean location on the map of how the participants allocated each of the fourteen elements. Participants’ prioritization of the performance elements showed individual differences, especially in the elements of melodic accuracy ( $SD=5.8$ ) and rubato ( $SD=5.3$ ).

An exploratory factor analysis, using a Principal Axis Factor (PAF) with a Varimax rotation, was undertaken in terms of interpretative and technical dimensions. An examination of the Kaiser-Meyer Olkin measure of sampling adequacy suggested that the sample was factorable ( $KMO=0.565$ ). The result of an exploratory factor analysis indicated that, in terms of technical or interpretative dimensions, the original fourteen elements could be classified into five main components: representative of overall quality, expressive variation, technical precision, rhythmic integrity, and stylistic appropriateness (see Table 1). A paired-samples t-test was conducted to evaluate any effects of gender and nationality. Also, a one-way between-groups analysis of variance (ANOVA) was conducted to explore the effects of the pianist’s experience and the level of qualification (UG/PG certificate/master’s degree/doctorate). Both tests revealed no statistically significant difference in describing the outcomes of these data.

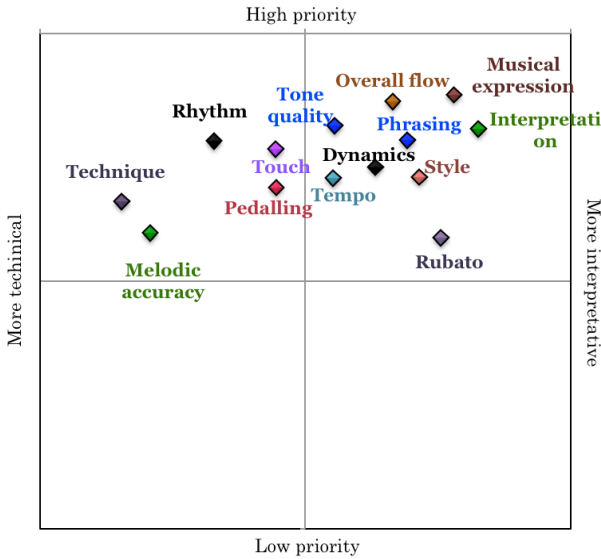


Figure 1. Mean ratings of the fourteen performance elements on two dimensions. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

Table 1. Classification of elements and the names of each factor.

<i>Representative excellence</i>	<i>Expressive variation</i>	<i>Technical precision</i>	<i>Ultimate understanding</i>	<i>Stylistic appropriateness</i>
Overall flow	Pedalling	Technique	Interpretation	Phrasing
Tone quality	Dynamics	Melodic accuracy	Rhythm	Style
Touch	Rubato		Tempo	

### DISCUSSION

Overall flow, interpretation, tone quality, and musical expression had the highest mean scores and were identified by the participants as the most important elements in evaluating their own piano performance. Moreover, the result of the factor analysis revealed that overall flow, interpretation, tone quality, and touch were classified into the same component, termed as “representative of overall quality.” Therefore, it can be argued that this component and its constituent elements seem to play an important role in estab-



lishing professional pianists' perceptions of performance quality. In contrast, aspects of melodic accuracy and rubato varied greatly in priority between individuals.

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**Thematic session:  
The science of dance III**



# Pain, pleasure, and performance: Embodied identity of young dancers and musicians

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This paper examines aspects of the social worlds of dance and music, embodiment, and identity of young ballet dancers and young classical musicians. Pierre Bourdieu's critique of the perpetuating social order and theoretical concepts of *habitus* and capital are applied as a way of understanding the social worlds, as well as to examine the performers' habitus. This work is part of a larger, longitudinal study of young performers that focuses on the experiences and identities of 12 young performers: 6 dancers (3 boys, 3 girls) and 6 musicians (3 boys, 3 girls) during their process of "becoming" a performer as they engage in non-residential specialist schooling. Mixed methods are used in the larger study. This paper reports qualitative findings from individual, semi-structured interviews. It is suggested that the performers' habitus is produced through dominant beliefs about the body where it is assumed that the young performers will accept emotional and physical pain, develop resilience, and engage with the body as a project. Alongside the pain there are also memorable felt bodily pleasures that have physical and psychological significance. Findings reveal relationships between the performer, the social worlds of dance and music, and identity.

*Keywords:* pain; pleasure; performance; habitus; identity

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# Controlling balance: Static and dynamic balance within dance populations

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All dance genres demand a high level of control in static and dynamic balance, but there is little published research on balance in the dance field. Previous research on dancers' balance abilities has relied on tests such as the Star Excursion Balance Test (SEBT), Y Balance Test, a modified SEBT (mSEBT), a modified Romberg test, and the Airplane test. This study has assessed the validity of existing balance tests for dancers with particular reference to the relevance of static versus dynamic balance. Eighty-five female dance undergraduates were recruited for balance tests using the Star Excursion Balance Test (SEBT), the Y Balance Test, the modified Romberg test, the Airplane test, the BioSway Balance System (Biodex, USA), and the dance-specific pirouette test. No correlation was found between the types of balance tests, and the variables helping to determine one test did not necessarily help to determine the other tests. Previously, the balance and stability tests have been employed during screening of dancers with low to moderate success in predicting injury. The present study challenges the validity of these tests in relation to dance relevant skills and points toward the need to develop dance-specific tests.

*Keywords:* balance tests; static balance; dynamic balance; dancers; performance

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Saturday  
31 August 2013



Symposium:  
The collaborative space:  
Directing performers' awareness  
via creative role-play



# The studio experience: Control and collaboration

**Amy Blier-Carruthers**

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Classical musicians have traditionally not been trained for the recording studio to the same extent as for the concert platform. This paper presents how we at the Royal College of Music aim to provide students with a conceptual understanding and practical experience of recording.

*Keywords:* recording; production; control; collaboration; role play

Classical musicians have traditionally not been trained for the recording studio to the same extent as for the concert platform. In this age of technological saturation this is a strange situation. They get little training in dramatic stage presence, but nowhere do they feel so exposed as in the recording studio. The musician's performance goes through the prism of the production team and recording process, but they have never been taught how to manage this experience successfully. Either because of the inherent qualities of the product and process themselves, or because of this lack of preparation during their training, many musicians approach the recording studio with fear and dislike. This is surprising enough when thought of in relation to professional musicians, but perhaps even more so when we realize that even the technologically-savvy conservatoire students of today describe recording using words such as: "perfection, permanent, clean, clinical, not natural, no audience, exposing flaws, daunting."

At the Royal College of Music (RCM) we run a postgraduate course called *Studio Experience*, in which we aim to give students practical experience of the recording studio, as well as opening up for debate ideas about what a recording is in comparison to a live performance, what the problems are, and what recording can help musicians to achieve. In this way we hope to make them more aware as performers. A central element of this course is that the students are given the experience of being a producer—of producing a recording session for their peers, and then of choosing the edits for their own

recording. This act of changing places with the producer gives them a rare chance to experience the challenges of recording from the other side of the control room glass. By going through this process we hope to give them experience of how they can keep control of the recording situation while also working collaboratively with their production team.

From Benjamin (1936) to Gould (cited in Page 1987) to Auslander (1999), musicians and listeners have been aware that live and recorded performance modes are different. My research (Blier-Carruthers 2010, 2013), however, reveals that many professional musicians today express a fear of the process and a dislike of the product of recording. Day (2000), Katz (2004), and Philip (2004) describe many examples of early recorded performers approaching recording with trepidation and anxiety, but it is striking that even after over a century of commercial classical recordings, many of the same issues are still in evidence today—a sense of loss of control, distrust of the technology, discomfort with the power wielded by the producer, and disillusionment with the editing process. There is a widely shared belief that a concert is about expression whereas a recording is about perfection (Blier-Carruthers 2010). Gould is one of the few classical musicians to have abandoned the concert platform and opted solely to perform in the recording studio (cited in Page 1987). He saw that it gave him creative control of the final version of the music, but he made sure to be involved at every stage of the process, a luxury not usually granted to classical musicians. Producer Stephen Johns has also spoken about the studio as a creative environment, saying that it is equally possible to be alive in the studio and dead in the concert hall—it depends on how you approach the situation and what you are trying to achieve (Johns 2011). Also relevant to this topic is the research conducted into this *Studio Experience* course by Aguilar (2011). I will describe our course as a model of how this kind of teaching can be done, as this kind of training for performers is rare, and suggest how it is useful to students. I will show that by changing hats, the performer's enhanced knowledge of the producer's role can enlighten and empower the performer and allow the studio to become a collaborative and creative space.

## MAIN CONTRIBUTION

### Course design

The course was created with the performer/producer element by Timothy Salter in 2000; he explains that “having their playing scrutinized under the ears of a sound engineer and producer within a three-hour session was in itself a new and intense experience for most students; themselves acting as a

producer was even more revelatory for them” (personal correspondence). Since 2011, I have taught the course with my colleagues: sound engineer Ben Connellan (Chandos and Hyperion labels, among others) and producer Stephen Johns (Artistic Director at the RCM, formerly Vice-President, Artists and Repertoire, at EMI Classics). We developed a series of lectures to add critical, aesthetic, and self-reflexive aspects to contextualize the studio sessions. Also participating are our final-year postgraduate students, with little or no experience of recording, but about to go into the world of freelancing and auditioning. The course itself is the experimental set-up, and provides the research material through lectures, mock-up session, and recording sessions. These provide evidence through the lecture content, field-notes I take of my observations, the session takes and editing scores, and the reflective commentaries which the students write.

### **Course delivery**

The students are taken through a programme of introduction to, practice in, and reflection on various elements of the recording process. There are lectures on aesthetics of recording (and points of tension and opportunities), being a producer and editor, and the recording process itself. We then stage a mock-up session to observe recording in action. The students then pair up to do two three-hour sessions where each takes the role of performer and producer, respectively. In the industry, the producer makes the edit plan, but we think it is important for the performer to gain experience in choosing his own edits. It is a painstaking and often painful process to have to listen to oneself in such detail, but extremely useful. One is confronted by one’s performance, “warts and all,” and has to decide where one stands on questions of long takes versus short takes, whether editing is cheating or a positive force, and how to achieve a good arch in the recorded performance. We then have a final lecture to discuss thoughts and outcomes. At each stage the students write a reflective commentary about their developing thoughts and opinions; we provide a template with questions to prompt their thinking.

### **Course aims and benefits**

The aims and benefits of the course can be shown through the following quotes by my colleagues:

Making your first recording can be a daunting prospect. *Studio Experience* gives students a view of the process which hopefully removes some of the negative preconceived ideas of recording and editing which many

musicians seem to hold. Although they may look upon recording as an unnatural and unmusical process the course aims to show that it can be the complete opposite. With the aid and encouragement of a team of supporters (producer, engineer, and editor) a musician can try out ideas which they may not have dared in the concert hall (Ben Connellan).

It is remarkable that musicians so often have a completely unrealistic view of how recordings are made, and even why they are made. *Studio Experience* endeavors to ask students to confront their prejudices about recordings, to become comfortable with techniques that will enable them to succeed in the studio environment, and to have the knowledge to take control in a studio environment that will allow them to perform at their peak—no less than they would expect to perform in public. All musicians who have grasped the combination of freedom, concentration, and self-examination that recording provides have, in my experience, found a deepening of their abilities to perform and communicate (Stephen Johns).

When we teach the course, there are several significant characteristics of a good recording session (for performer and producer). Their performance and preparation: a well prepared performer, who would be able to play their varied and interesting repertoire live, performs well with the other musicians involved, and the producer is knowledgeable and ready to lead the performer through the process. Their communication and collaboration: they are communicating well with each other, and sharing control. They have an ear for the sound and details of performance and are able to successfully discuss their thoughts about these. Their ability to adapt: the performer is able to listen to a playback and adjust to get his desired result. He is trying out the producer's musical or technical suggestions. The producer can also adapt her working style or manner. They engage with opportunities afforded by recording: both are listening for the overall musical impression of the performance and also the small details. Both are embracing the chance to work in both long and short takes, to go for the feeling of a full arch (or trajectory), as well as dropping in to work on smaller sections or very small patches when necessary. The feeling of positivity and forward movement, of something unique achieved: it has gone well when you all get the sense that you have worked until you have achieved an ideal version, at least for today/now, both musically and technically. Both feel that they have the takes they need to edit together a great recording and that this great outcome was only made possible by their team-work, combined input, and creative collaboration. In the



final edited recording we are looking for musical creativity, fluency, control, awareness, conception of sound, choice of takes and placing of edits, and an awareness of how the performance comes across through the recorded medium. We give detailed feedback on all the assessed elements so that they can improve their studio technique. However, this is not simply a “how-to” apprenticeship. I believe that by teaching the practices and ideologies of recording one can not only prepare students for their careers as recording artists but make them more conscious and enquiring musicians. I want them to purposely question if the current situation is satisfactory or if they can see new ways forward.

### IMPLICATIONS

Looking at the students’ concept of recording before and after taking this course will help to show the impact of the learning environment we have created. When asked, in the first lecture, “what is the first word that comes to mind when you think about recording?” they replied: “perfection; permanent; clean, tidy; exposing flaws; no audience; microphones; not natural, no visual [dimension], clinical, tiring.” The tutors then interjected, suggesting that they might want to think of some of the positive aspects; the students continued with “commercial opportunity; pressure not to [do] too many takes; trying to fix things; self-criticism; time limits; experimental; part of your history; exciting, imaginative, no audience; performer becomes audience, too; intimacy; hearing yourself differently; daunting, expectation of perfection.” We can see that the tone of their responses did not lift very much, even when given this encouragement. This cohort emerged from the learning process saying that for them recording was now: “experimenting, trying different ways of doing something; time going fast, faster than you expect; concentration of the producer, [attention to] detail; stress, good stress; preparation; relief, because you’ve already captured some good moments; pressure; detail; layers of detail; a lot more fun than expected; need forward planning and structure; good intensity, stressful and fun; not enough time; more creative than I was expecting; catalyst, crucible, transformational.”

This *Studio Experience* course is an experimental model of how performers can be prepared for their relationship with recording. This is especially interesting at a time when the recording industry as we know it (both capture and dissemination) is in a period of abrupt change. Only by engaging with the past and present of recording practices and aesthetics can we hope to forge a path for the future. By directing the students’ awareness to the different roles that exist in the recording process, we achieve several types of collaborative

space: the physical space of the studio with the performer and production team working collaboratively; the aesthetic space given to the students to consider the ontologies of live performance and recording and the implications for their performing lives; and the psychological space created in their heads, where in an internal collaborative dialogue they can now be both performer and producer when working in the studio.

### Acknowledgments

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# The actor at the piano

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Frederic Rzewski's *De Profundis* is a score which implies skills far beyond those normally associated with pianism. We have approached the realization and performance of this work through a hybrid methodology synthesizing theatrical and musical disciplines. Our objective is to allow the essence of the performance to co-habit Wilde's and Rzewski's voices, alongside those of Coomb's and Barker's. From the outputs of rehearsals, workshops, and accompanying discussions, we demonstrate the ways in which acting is implicit for all pianists, as well as identify methodologies and techniques that might be offered as a tool for training in stage presence for conservatoire musicians. The pianist, the most proverbially immovable of all instrumentalists, is in fact never still, constantly shifting or moving between many persona or characters, seen and unseen, all together. From the results we hope to demonstrate that the pianist, as an actor at the piano, assumes different roles, both implicitly and explicitly, regardless of the score.

*Keywords:* actor; pianist; performance; music theatre; Rzewski

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# Listener enactments in song without a singer

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This paper arises from the *SongArt* network of the Institute of Musical Research, London, which the first author founded with Kathryn Whitney. *SongArt* seeks to bring theories of the lyric into dialogue with current experiences of performing song, so as to explore the nature of “liveness” in performance. With the collaboration of Paul Barker, we have set up a series of further dialogues between actors and musicians, singers and pianists, to investigate the benefits of cross-disciplinary role play in the search for lyric presence in performance. This paper draws insights from workshops centered on the preparations of pianist Maria Setiadi to “sing” Liszt’s transcription of Beethoven’s *An die ferne Geliebte*. These have explored the relevance of actor training techniques with the breath to the pianist, encouraged by the nature of the changes Liszt made to Beethoven’s score. In the paper we seek to establish the significance of working with the breath, as a potent means of communicating the expanded span of Beethoven’s work to an audience. Through engaging with the breath, as a singer would, the pianist is able to project specific lyric moments within the epic and dramatic sweep of Beethoven’s cycle, including crucial moments at its beginning and end.

*Keywords:* singing; piano performance; theories of the lyric; breath

The metaphor of the pianist as singer is perhaps as old as the piano itself. Taking an example from pre-piano history, C. P. E. Bach’s improvising was often likened to poetry at the keyboard. The poet Gerstenberg even added a literal singing part to Bach’s *Fantasia in C Minor* to encourage the identification of breathed quasi-vocal phrases within the fantasia figuration. For the words of his singing part, Gerstenberg gave the performer a choice between Hamlet’s *To Be, Or Not To Be* and Socrates’s meditation on death, though he expanded Hamlet’s soliloquy to create a gentler central contrast—as though Hamlet had momentarily gained Horatio’s faith and was contemplating

heaven—and a definite ending as Romeo-like he grasps his own death. Gerstenberg hints that all of heaven and hell can be traced through the tonal and textural fluctuations of Bach's music, as the improviser seeks to expand the limits of his own and his listener's attention. To hold that attention the performer must turn singer-poet and project all contrasts as a single arch of experience, as a soliloquy, such as can draw the listener into the mind of the improviser. One can take Gerstenberg's poetic addition, as laid out by Friedrich Chrysander (1993), practically as well as aesthetically. The poetic words can be taken as an extra layer of performance instructions, direct hints to the keyboardist on how to breathe and pace a narrative, hints that might help a performer realize C. P. E. Bach's general instruction in his *Versuch über die wahre Art das Clavier zu spielen* (An essay on the true art of playing keyboard instruments) of 1753 that one should sing from the heart and not like a trained bird. This paper seeks to expand on the practical advantages for a current day pianist of turning singer-poet, using the example of Liszt's transcription for solo piano of Beethoven's song cycle *An die ferne Geliebte*. For when Liszt lays the words of Jeitteles's poems over the score of his transcription, he seems to be encouraging the pianist to embark on a similar course of practical imaginative enactment.

### MAIN CONTRIBUTION

In his *An die ferne Geliebte* for solo piano, Liszt does not transcribe Beethoven's cycle in his usual sense; he provides hardly any musical embellishments, simply a realization of what a pianist needs to do to play both the piano and the vocal part of Beethoven's original. A few changes to slurs or articulation marks, some shifts in register to bring out the vocal line, a few changes or additions to pedaling, these represent the immediate sum of Liszt's musical additions to Beethoven's appeal to a distant beloved. Any fuller transcription of Beethoven, in the sense of inhabiting and enacting the composer's communication, is left to the pianist-performer himself as he grapples with the implications of the words coming in his line of sight as he seeks to play the notes beneath.

The six songs in Beethoven's *An die ferne Geliebte* certainly stretch pianists' narrative capacity to the full. As experienced in live performance it is the pianist-performer who takes responsibility for managing the moments of transition from song to song and so for delivering the cycle's unbroken arch. In removing the singer altogether, Liszt might be said to be making explicit this test of the pianist-musician's power to direct the complete span of a poetic experience. It is the musician who has to complete the task set out in

Jeitteles's verses of singing to a distant beloved, the listener, in such a way as to bring her near.

At the completion of the cycle the poet declares "and you sing what I sang." A performance of Jeitteles's poems demands the communication of something having been achieved in song, not just the activity of singing. Yet what that song is, as heard and joined in with by the listener, remains open to interpretation. Goethe once likened the successful delivery of a song to a "flight," which he said must be created by the singer-performer from mixing together the epic, lyric, and dramatic ingredients prepared by the poet (Von Goethe 1912). "Flight" implies spontaneity, as well as a singleness of experience that can be grasped by the listener. But the mixing of ingredients also implies preparation, especially since three not two ingredients are involved. A choice between "either/or" can happen as though instantaneously, but a choice between "this, or this, or this" demands a standing back to consider what "this" might mean. Aristotle in his *Poetics* deals largely with a choice between two modes of poetic communication, the epic and dramatic. The dramatic as a mode of communication, according to Aristotle, implies a singleness of action and precision of denouement, whereas the epic allows "scope for considerable extension of length" (Halliwell 1987, p. 59) and for "multiple plot-structures" (p. 52). Aristotle praised Homer for being able to switch back and forth between the epic and the dramatic seemingly at will, confirming that these could be conceived fluidly as matters of address as a listener is directed moment by moment—to the linear pull of time as in the drama, or to the resonance of space, suggesting the epic's stretching towards infinity. In his *Basic Concepts of Poetics* Emil Staiger (1991) was adamant that the epic and dramatic should refer to ways of being rather than simply to genres as such. And the medium which allowed that interpenetration of those possibilities of being was, according to Staiger, the lyric where the performer finds himself in the closest intimacy with the listener. In this Staiger calls on the theory of Goethe's teacher, Herder, who believed Homer was not so much an epic communicator as a lyricist. According to Herder, in his *Kritische Wälder: Erstes Wäldchen* of 1769, what the listener hears enacted in Homer is not so much a narrative or a drama, with their expectations of a particular end, but the "I sing" of the poet himself, his breath, and the energy of his breaking into utterance (Herder 1992). According to Herder and Staiger, in the lyric the performative presence of the poet supersedes the object nature of the poem, to create "a remnant of paradise" (Staiger 1991, p. 47).

And yet lyric presence is still given an object nature by Goethe when he refers to a performer mixing ingredients of the lyric with the epic and dramatic to create a flight. Even Staiger (1991) allows that the lyric can be identi-

fied objectively with the repetition of small units, as “the poet listens once again to the chord he has struck” (p. 61). In *An die ferne Geliebte* Beethoven could be said to prepare specific lyric ingredients for the performer with the provocative moments of transition that punctuate the cycle. At these points the pause between songs is extended so that the question of “what next”—whether a contrast which suggests the action of a drama or a contrast which suggests the episodic accumulation of the epic—has to give way to a concentration on the moment itself. In the transition from the first to the second song, for example, the use of a fermata and then a silence as the piano waits on a repeated G and Eb, focuses the listener’s attention for a detailed change of color, like a subtle shift in mood, as the Eb then drops to D in the left hand of the piano. Staiger would say that mood is the particular provenance of the lyric, but the silence which allows the mood to be registered is perhaps the most significant ingredient of all. Liszt ensures the silence is absolute by indicating a lifting of the sustaining pedal before the second striking of the repeated G and Eb. And in this silence the pianist cannot avoid the question of how to take a breath. For though the first absolute silence leads forward into the shift from Eb to D, this is then followed by another fermata and absolute silence, which Liszt again marks with a lifting of the sustaining pedal. The demand to make a visible gestural sign of breathing is as pressing on the pianist as if he were a singer. The action of breathing itself is highlighted, rather than the breath simply acting as an upbeat to the next passage of melody. When the melody of the second song does begin to pick up, after the transition of two-and-a-half bars, the exaggerated pauses for breath continue. Three times in the first verse of the second song Liszt removes the voice’s steadier entries at the half bar so that the pianist is left exposed dealing with the off-beat rest at the start of each phrase. Liszt’s transcription subtly underlines how Beethoven’s second song builds out of fragments, fleeting fragmentation being another of Staiger’s objective signs of the lyric (Staiger 1991).

In Liszt’s reading of Beethoven’s cycle, the domain of the first transition with its pauses invades the following song, so disturbing the hierarchy between musical link and fabric. Or perhaps, more positively, Liszt draws attention to the action of breathing of the performer to encourage the pianist’s personal interaction with the material and the communication of “I sing” moments for the listener to join in with. The most radical reading (or misreading) offered by Liszt in this respect concerns the opening of the whole cycle, where he omits the piano chord on the downbeat of the first bar and asks the pianist to begin directly with the vocal melody on the second beat as if directly taking the role of the singer. Yet whereas the singer in Beethoven’s original can take energy from the impetus of the piano chord, announcing a



definite rhythmic frame for the opening, Liszt's pianist faces the vulnerability of breaking silence with the offbeat. In Liszt's reading, the need for a definite "I sing" utterance is highlighted from the start. In addition to the rest that precedes the first vocal phrase, he inserts an extra quaver rest at its close in bar three, so drawing attention to the size of the breath needed for this melodic opening. The melodic phrase for *Auf den Hügel sitz ich spähend* (On the hill I sit gazing) is held suspended, surrounded by silences, before the pianist begins the further linear and vertical unfolding of thirds that constitute the melodic, harmonic, and tonal fabric of the cycle as a whole.

Staiger says that with a lyric sensibility the initial sound of a syllable, creates a connection to the object of a word in space and then to the linear relationships of a sentence (Staiger 1991). But even before the sound itself, a taking of breath has gestural and temporal dimensions; it powers and delineates the shape that will govern the progress of the larger narrative, as the performer creates a balance between linear temporality (drama) and accumulation in space (epic). Looking at Jeitteles's poems, their narrative can be taken as the progress of a day, until the beloved sings back in the evening, or as expansions of the poet's gaze to clouds, brooks, breezes, birds—all of which move around the poet while he stays still caught in the moment. The strophic variations of each song can be experienced as time-driven, or as a series of spatial expansions. The progress from song to song can seem to be implying a precise denouement—as Aristotle identified with the drama—or as simultaneously leading round in circles in the manner of the epic's multiple structures. The return to the opening song midway through the sixth and final song is a case in point for it can either seem a dramatic surprise, or the opposite—an expected confirmation of the sense of "deja vue" that pervades the cycle as each song reiterates the same third-related motifs.

Taken in its event nature the cycle is ambiguous and open-ended, but approached performatively there are ingredients for a precise conclusion. In Beethoven's cycle, as in Liszt's, the final word is reserved for the pianist alone as he reiterates a two-bar fragment from the cycle's opening melody. Yet Liszt changes a detail of the slurring for the pianist; he elides the first beat of the penultimate bar into the long slurred sweep of the previous phrase, so that the final melodic fragment is clearly enunciated as requiring a fresh offbeat emphasis. Liszt indicates once more how the final phrase must be breathed from the second beat, so connecting it to the gesture with which the cycle began. The crescendo marking, kept from the original, suggests the triumph of a journey completed, but the emphasis on the moment of breathing with its connection to lyric energy indicates a final intimate appeal for the listener to join in.

## IMPLICATIONS

Practical investigations into what it means to sing at the keyboard can learn from poetic distinctions between epic, dramatic, and lyric modes of communication and can contribute to current explorations into the nature of “liveness” in song performance. The theories of Herder, Goethe, and Staiger establish the lyric as aspiring to a uniquely intimate relationship with the listener, prompting an engagement with details of gesture and breath that can be projected across the macro—as well as the micro—aspects of singing in performance. From the case-study of Liszt’s transcription of Beethoven’s *An die ferne Geliebte*, it can be shown that taking the role of singer, in practical as well as aesthetic terms, can give specific prompts to pianists as they seek to communicate an extended narrative span to their listeners.

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Thematic session:  
Piano performance I



# The pianist's acoustical and motional expressions in the live performance of Schumann's *Träumerei*

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According to previous studies, expert performers construct their acoustical (i.e. durational, dynamical) and visual (i.e. motional) expressions by highlighting the structurally important points. However, it is still unclear whether such expressions are influenced by the presence of the audience. In the present study, we examined the effects of context (i.e. *audience present* versus *audience absent*) on expert pianists' acoustical and motional expressions in their performances of Robert Schumann's *Träumerei*. In the experiment, 13 pianists performed six pieces including *Träumerei* in front of 11-23 audience members. Either before or after the live performance, each pianist performed the same pieces without any audience. According to the functional data analyses for the duration, the dynamic range, and the motional range, the trough and the peak points within each parameter were in phase with the boundaries between the sections regardless of the context. The analyses also showed that the pianists amplified the ranges of the expressions at the trough and the peak within each parameter in front of their audiences. These results suggest that sharing time and space with the audience amplifies the pianists' expressions in performing structurally salient points (e.g. phrase endings).

*Keywords:* live performance; piano performance; acoustical expressions; body movement; functional data analysis

The artistry of music performance is determined by the liberation from the rigidity and the regularity notated on the score (Seashore 1967). For piano performance, this involves the manipulation of timing and dynamics (e.g. Repp 1992, 1996). Performers' body movements also vary during their performances (e.g. Davidson and Correia 2002), which makes the performances

expressive. Performers manipulate these parameters according to the structure of the piece. For example, performers tend to slow down while making the sound softer at the end of the phrase (e.g. Repp 1996, Seashore 1967). The performer's postural movement is in phase with each of the boundaries between the sections (Shoda and Adachi 2012).

However, the experiments reported in the aforementioned studies have been conducted in laboratory settings (Repp 1992, 1996) or by a single pianist (Shoda and Adachi 2012). It is still open to question whether the acoustical and motional expressions are affected by the presence of an audience.

In the present study, we examined the effects of the context (i.e. *audience present* versus *audience absent*) on expert pianists' acoustical (i.e. durational, dynamical) and motional expressions in their performances of Robert Schumann's *Träumerei*. In the previous studies using this piece (e.g. Repp 1992, 1996), pianists made rich expressions based on the musical structure in laboratory settings. We predicted that the pianists would express the durational, dynamical, and motional contrasts more clearly with than without the audience.

## METHOD

### Participants

Thirteen pianists (4 men, 9 women, 24-40 years old,  $M=30.46$ ,  $SD=4.41$ ) with a music degree either at an undergraduate or a graduate level participated in this study. They were a concert pianist ( $n=1$ ), lecturers at a university or a vocational school ( $n=4$ ), piano teachers at private music institutions ( $n=7$ ), and a music therapist at a hospital ( $n=1$ ). They started to play the piano between ages 4 and 13 ( $M=5.28$ ,  $SD=2.43$ ).

### Materials

#### *Piece*

We selected six Western-classical pieces as the experimental materials, including *Träumerei* ("Dreaming") in F major (*Kinderszenen*, Op. 15 No. 7) by Robert Schumann. This piece is composed of three 8-bar sections (A, B, A'), with the obligatory repetition of the first section (see Figure 1).

#### *Apparatus*

Experiments took place in a small auditorium (with a maximum capacity of 114), equipped with a grand piano (GP-193, Boston). The piano was tuned

The image shows a musical score for the first 10 measures of Robert Schumann's *Träumerei*. The score is written for piano and is in 3/4 time. It is divided into two sections: Section A (measures 1-6) and Section B (measures 7-10). Section A is marked with a boxed 'A (A rep)' and a bracketed '[1]'. Section B is marked with a boxed 'B' and a bracketed '[6]'. Performance markings include 'ritard' and '(espr)'.

Figure 1. The first 10 measures of Robert Schumann's *Träumerei*. The boxed capital letters are section IDs. Each bracketed number indicates the number of measures.

professionally within one week before the experiment. The performances were recorded onto a multi-track recorder (R24, Zoom) using a microphone (NT4, Rode). Each pianist's body movements were recorded by two HDD video cameras (HF-M32, Canon, 59.94 fps). The pianist was dressed in black (or white); markers made of white (or black) drawing paper were attached on the head and the waist. The color contrast of each marker against the hair and the clothes enabled us to trace the pianist's body movement.

## Procedure

The pianists rehearsed each piece as many times as they wished before the experiments. Subsequently, the pianists performed six pieces in a random order specified by the first author in front of 11-23 undergraduate or graduate students who were not music majors (*audience present* context). Each pianist performed the same pieces in the same order either before ( $n=6$ ) or after ( $n=7$ ) the live performance without any audience (*audience absent* context). The performance portion of the experiment lasted 25.25-36.18 ( $M=29.1$ ,  $SD=2.83$ ) minutes (*audience present*) and 17.93-26.6 ( $M=20.79$ ,  $SD=2.09$ ) minutes (*audience absent*).

## Measurement

From the digital recordings of each performance, the first author measured the duration of each quarter note (i.e. beat) with Wavosaur ([www.wavosaur.com](http://www.wavosaur.com)). The A-weighted sound pressure level of each performance was measured by using a 1/3 octave band analysis (DSSF 3.5.1, Yoshimasa Denshi). A pianist's body movement was measured by tracing each marker on the head

and the waist with the rate of 60.00 fps on a Windows 7 computer using a 3-dimensional video analyzer (Frame DIAS IV for Windows, DKH). We calculated the pianist's postural angle  $\theta$  (rad) determined by the locations of head and waist of the pianist (Shoda and Adachi 2012; see Figure 2).

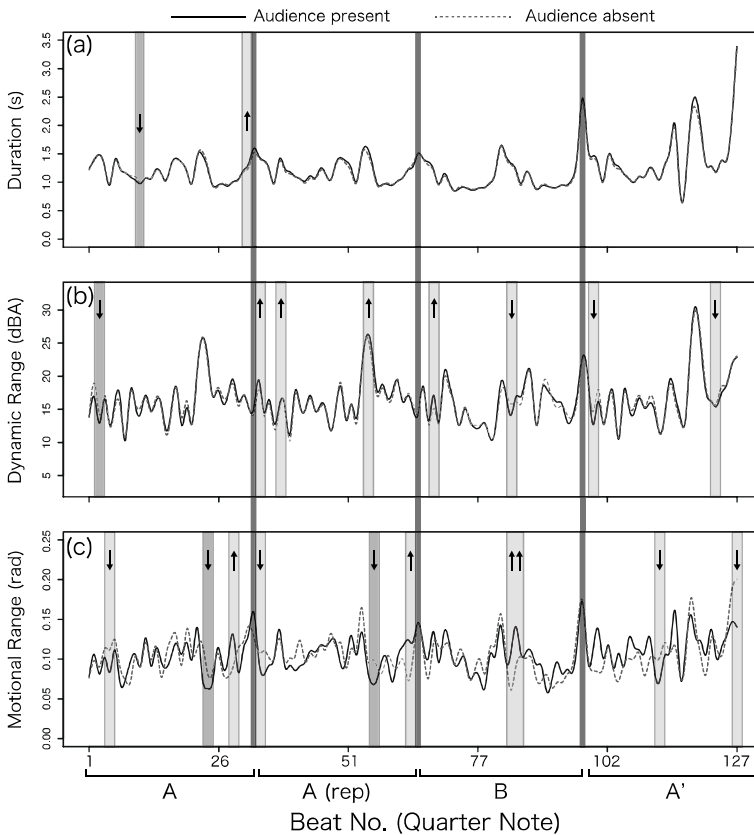


Figure 2. The averaged curve for (a) the duration, (b) the dynamic range, and (c) the motional range in the *audience present* (solid line) and the *audience absent* (dotted line) contexts. The highlighted portions in each graph indicate the results of functional paired t-tests: dark grey ( $t_{12} > 2.69$ ,  $p < 0.01$ ) and light grey ( $1.91 < t_{12} < 2.69$ ,  $0.01 < p < 0.05$ ). The upward arrows indicate that the values in the *audience present* condition were significantly greater than those in the *audience absent* condition, and vice versa. The capital letters on the bottom of graph (c) are section IDs.



In order for the sound pressure level (dBA) and the postural angle (rad) to be synchronized with the beat, we calculated “dynamic range” and “motional range,” respectively. Each of these values was computed by the difference of the maximal and the minimal values per beat.

### Statistical Analysis

The functional data analyses (Ramsay and Silverman 2005) were used to analyze the duration, the dynamic range, and the motional range in the present study. In detail, after smoothing each of the time-series data by the third order spline function, we conducted a functional paired t-test for each parameter to test our hypotheses.

## RESULTS

Figure 2 shows the smoothed curves for the duration, the dynamic range, and the motional range in each context. As can be seen in Figure 2, the peak or the trough points of each curve were in phase with the transitions between the sections regardless of the contexts. The pianists slowed down (Figure 2a) with greater body motions (Figure 2c) at these transitions. The pianists made the dynamic range narrower at the end of sections A and A', but they reversed the tendency at the end of section B. Thus, the expressions of the duration, the dynamic range, and the motional range were amplified altogether in returning to the main theme (i.e. section A').

According to the functional paired t-tests, significant effects of the contexts were found at 2, 8, and 10 points for the duration, the dynamic range, and the motional range, respectively (see Figure 2). For the duration, we found significant differences at a trough and a peak in section A where the main theme of the piece was presented for the first time. That is, the pianists made the contrasts between the lengthened and the rushed notes clearer in the *audience present* than in the *audience absent* context. Similarly, the pianists made greater contrasts in the dynamic and the motional ranges in the *audience present* than in the *audience absent* context. These results indicate that the pianists amplified their expressive ranges in front of their audiences.

## DISCUSSION

The main contributions of the present study are the following. First, the pianists' expressions are based on the structure of the piece, not only for the acoustical but also for the motional parameters, as evident in the synchronizations with the sectional boundaries. This finding is in line with Shoda and

Adachi (2012), in which a single pianist performed Sergei Rachmaninoff's pieces. Second, the pianists demonstrated clearer expressive contrasts in their acoustical and motional manipulations in the live performance. Perhaps the pianists are more motivated to amplify their expressions in order to achieve the main aim of musical performance, i.e. to communicate the structure of the piece to the audience (e.g. Davidson and Correia 2002).

The present study has suggested that the pianists make clearer contrasts in their durational, dynamical, and motional expressions in the live performance where the performer shares time and space with the audience. How these findings differ as a function of pianist or piece (e.g. style, tempo) awaits future study.

### **Acknowledgments**

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# Playing hands together: Exploring the use of asynchrony as an expressive device

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Pianists often use asynchrony with the purpose of making multiple voices more transparent or providing extra emphasis at particular locations. This study evaluates the perceptual effects of such asynchronies in performances of three pieces with varying textures: a Bach Fugue, a Brahms Intermezzo, and a Chopin Prelude. By varying onset times (+55 ms, 0, -55 ms) and key velocity values (0, +10 units) of the bass and melody voices of a pre-recorded professional performance on a Yamaha Disklavier, 11 different performances were synthesized. 21 participants were presented these performances in random order and asked three questions in consecutive sessions: How rich is the timbre? How transparent are the different voices? How expressive do you think this performance is and is it appropriate for the piece? Strong agreement is found for ratings of richness and transparency, but few significant differences appear between different levels of asynchrony and key velocity. ANOVAs revealed effects of asynchrony in Bach, and pianists differed from non-pianists in their ratings of transparency and expressiveness for Chopin and Brahms.

*Keywords:* asynchrony; melody lead; voice separation; perception; expressive performance

Asynchrony is an expressive device often used in musical performance to make multiple voices more aurally transparent or distinct. It can also be used to give salience to downbeats for metrical purposes or provide extra emphasis at salient locations in the score (Dodson 2011). Current empirical studies identify melody lead as the most frequently occurring in piano performance (Palmer 1989, Goebel *et al.* 2010), however, its existence is disputed as a velocity artifact rather than the result of such deliberate expressive intention that we can attribute to bass anticipations (Repp 1996, Goebel 2001). Asynchronies are perceivable from around 30-50 ms before the onset of other

voices in a chord, note intensity rather than asynchrony being the main factor in voice salience perception (Goebel and Parncutt 2003). With this in mind this study questions the purpose of using asynchrony in performances of pieces with different compositional textures by examining their perceptual effects in terms of timbre, transparency, and appropriateness of expressive devices, extending Goebel and Parncutt's (2003) method.

## METHOD

### Participants

21 participants were recruited via email from undergraduate and postgraduate classes at the Conservatory of Southern Switzerland and the Royal College of Music, London. Ages ranged from 18-34 years with an average of 25.2 years ( $SD=5.24$ ). Four participants were pianists.

### Materials

A professional pianist's performances of three musical excerpts (from Brahms' *Intermezzo Op.118 No.2*, Chopin's *Prelude in C minor Op.28 No.20*, and Bach's *C major Fugue BWV 870*) were recorded through a Yamaha Disklavier. These pieces were chosen to reflect different compositional textures from chordal to fully contrapuntal. Manipulating the recorded MIDI data, a "synchronized" version of each performance was created, removing all asynchronies between notes of each chord but retaining the overall expressive timing patterns. The distance in velocity units between each voice was also kept constant. From this "synchronized" version, eleven different versions of each piece were created with the following variations for bass and melody voices applied at selected salient locations in the score (see Figure 1): asynchrony (-55, 0, +55 ms) and intensity (0, +10 units). These salient locations were selected by the second author with advice from local pianists and examining the use of asynchrony in various famous recordings. The manipulated MIDI data was played back through the Disklavier and recorded aurally so to create acoustic performances in identical settings.

### Procedure

Repeating the procedure for each piece of music, the 11 performances were played in a random order to audience judges. The perception tests were run in individual sessions using presentation software, with participants listening via Roland RH5 headphones. Participants first listened to the "synchronized" performances and saw the original score excerpt onscreen to familiarize

themselves with the music. In three consecutive sessions, participants were asked to answer the following questions listening to the audio performances without the score. Each question required the participant to rate on a 7-point Likert scale: (1) how transparent do you feel the range of voices are in this performance? (2) How rich is the sound in this performance? (3) How expressive do you think this performance is and how appropriate is this for the piece? (1=not at all, 7=very; see Table 1 for answers to question 3)

Figure 1 shows three musical scores with red rectangular boxes highlighting specific locations. (a) Bach's Fugue in C major BWV 870 Bars 1-21: The score is in 4/4 time. Red boxes are placed around the first few notes of the right and left hands in several measures. (b) Brahms' Intermezzo in A major Op. 116 No. 2 Bars 1-8: The score is in 3/4 time. Red boxes are placed around the first few notes of the right and left hands in several measures. (c) Chopin's Prelude in C minor Op. 28 No. 20 Bars 5-8: The score is in 3/4 time. Red boxes are placed around the first few notes of the right and left hands in several measures.

Figure 1. Scores for extracts of (a) Bach's *Fugue* bars 1-21, (b) Brahms' *Intermezzo* bars 1-8, and (c) Chopin's *Prelude* bars 5-8. Rectangular boxes mark salient locations for which onset asynchrony and key velocity were changed. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

Table 1. Description of answers for the 7-point scale for question 3: how expressive do you think this performance is?

Scale answer	
1	I hear lots of expressive tools being used, but I don't think it is suitable for the piece.
2	I hear some expressive tools being used, but I don't think it is suitable for the piece.
3	I don't hear any expressive tools being used and I don't think it is suitable for the piece.
4	I don't hear any expressive tools being used and I feel neutral about its suitability.
5	I don't hear any expressive tools being used and it is very suitable for the piece.
6	I hear some expressive tools being used and it is very suitable for the piece.
7	I hear lots of expressive tools being used and it is very suitable for the piece.

## RESULTS

Kendall's *W* measure of concordance determined the strongest agreements between participants occurring for responses on richness or transparency of sound (for Bach and Brahms respectively, see Table 2). Figures 2 and 3 show mean results for perceived richness or transparency of sound respectively. Paired *t*-tests with Bonferroni corrections ( $\alpha$  level=0.05) between each possible combination of asynchrony level and velocity level resulted in only one significant difference in means between a bass anticipation at an amplified velocity (bass -55 ms, +10 velocity) and a melody lag at the same amplified velocity (melody +55 ms, +10 velocity) for transparency in the Bach fugue. Figure 4 shows the frequency of results for the question on expressiveness and appropriateness. Repeated-measures ANOVAs were conducted for each piece and each question separately, with a between-participant factor of instrument (pianists and non-pianists) and within-participant factors of voice (bass, melody, or none), asynchrony level, and velocity level. A two-way interaction effect was found in the transparency question for the Bach between asynchrony level and voice ( $F_{1,209}=4.39$ ,  $p<0.05$ ). A four-way interaction effect of all factors was found in the expressive question for the Chopin ( $F_{1,209}=4.68$ ,  $p<0.05$ ). Main effects were found for instrument in the transparency question for both Brahms and Chopin ( $F_{1,224}=23.89$ ,  $p<0.001$  and  $F_{1,224}=7.31$ ,  $p<0.01$  respectively) and for asynchrony level and voice in the expressive question for the Bach ( $F_{2,224}=3.54$ ,  $p<0.05$  and  $F_{2,224}=3.76$ ,  $p<0.05$  respectively).

## DISCUSSION

Differences in ratings and main effects of different asynchrony levels were seen particularly for the Bach Fugue, which may be a reflection on the generally accepted performance traditions of playing simultaneous notes in contrapuntal voices in perfect synchrony. The higher means of non-pianists versus

*Table 2.* Kendall's *W* measure of concordance for all three pieces and all three types of question. All measures are  $n=11$  and  $df=20$ , with significance  $p<0.001$  unless marked with an asterisk ( $p<0.05$ ).

<i>Question</i>	<i>Bach</i>	<i>Brahms</i>	<i>Chopin</i>
Rich	0.54	0.38	0.32
Transparent	0.28	0.54	0.41
Expressive	0.14*	0.18	0.20

pianists for transparency ratings in the Brahms and Chopin may also reflect a difference in preference for the use of asynchrony in their own instrument and lower ratings in general. From our results we may infer that participants' ideas of richness, transparency, and expressiveness change depending on the musical context.

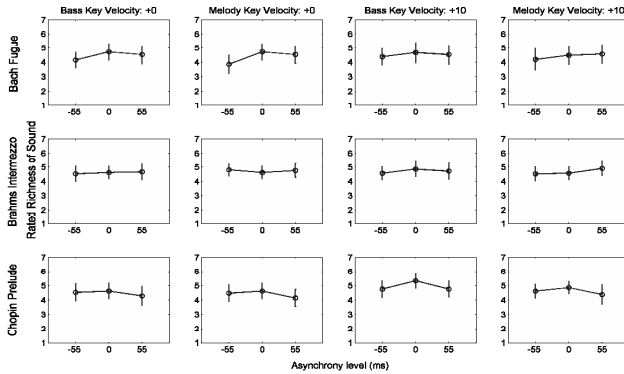


Figure 2. Mean ratings for perceived richness of sound over 21 participants for each level of asynchrony (-55 ms, 0 ms, +55 ms). Each column of figures presents results for modifications of the bass or melody voice, all at the two different levels of key velocity (0 or +10 units). Error bars denote 95% confidence intervals.

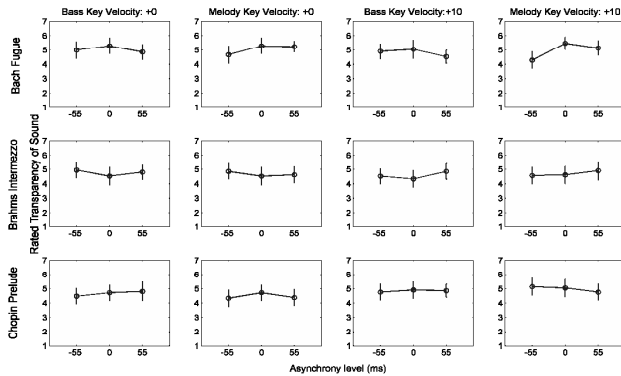


Figure 3. Mean ratings for perceived transparency of voices in the sound over 21 participants for each level of asynchrony (-55 ms, 0 ms, +55 ms). Each column of figures presents results for modifications of the bass or melody voice, all at the two different levels of key velocity (0 or +10 units). Error bars denote 95% confidence intervals.

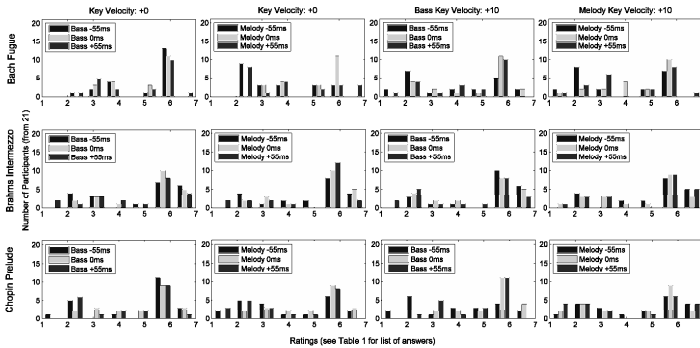


Figure 4. Histogram of responses for question on expression for Bach, Brahms, and Chopin pieces.

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# Piano playing and chronotype: Chronobiological influences on sensorimotor precision in pianists

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Chronotype-dependent circadian fluctuations of sensorimotor precision may be a challenge for musicians. We investigated pianists' sensorimotor precision in a relevant musical context in two different times of the day as well as its potential association with their chronotype. Twenty-one piano students were included in the study. Sleep habits were assessed applying the Munich Chrono Type Questionnaire. Mid-sleep time served as a marker for the individual chronotypes. Performance was tested in standardized scale playing twice on two different days: one test took place at 08:00, one at 20:00. Timing variability was assessed as (1) variability due to deviations that are present across trials (irregularity) and (2) variability between trials (instability) according to an established procedure. ANOVAs with performance parameters as dependent variables were calculated to assess potential interactions between pianist chronotype and recording time-point. With the instability of timing as a dependent variable, an interaction was seen between pianist chronotype and recording time-point ( $F_{1,19}=10.20$ ,  $p=0.004$ ,  $\eta^2=0.03$ ): the timing patterns of late chronotype pianists were more stable in the evening than in the morning, whereas early chronotype pianists did not show a difference between the two recording timepoints. We conclude that in different chronotypes, circadian performance differences may occur with respect to the timing instability.

*Keywords:* chronotype; sensorimotor skills; music performance; piano; scale playing

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**Thematic session:  
Modeling and analyzing improvisation**



# Chords not required: Incorporating horizontal and vertical aspects independently in a computer improvisation algorithm

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Most previous computer improvisation algorithms for tonal jazz create an output based primarily on the underlying chord progression. This approach may partly ignore melodic continuity often seen in transcriptions of traditional jazz artists. Here we suggest a different approach implemented as a computer algorithm that creates material solely based on probabilities related to past note choices. This approach aligns with theoretical work suggesting that stored motor patterns are the basis of improvised music. Our computer algorithm analyzes pitch and rhythm patterns from a given corpus and then creates improvisations using this information. We describe an example in which a corpus of 48 solos by jazz saxophonist Charlie Parker was used by our algorithm to create an improvisation of the same length. The artificial corpus contained pattern structures similar to that of the original corpus. In contrast, previous research by one of the authors showed that a chord-based computer algorithm generated an output with a pattern structure very different from that of the human improviser even though the same chord structure was used as input. Future work will add a vertical aspect to our model in which a given chord pattern influences note choices in addition to the current horizontal focus.

*Keywords:* improvisation; patterns; rules; computer modeling; jazz

Two prominent theories have been proposed to explain how improvised musical material is created. One theory posits that stored fragments of musical material is retrieved from memory and linked during improvisation (Pressing 1988). Pressing divided improvisations into collections of concatenated note

groupings. Each grouping is triggered by a creative intention in the form of a mental schema that contains a cognitive image of sound and corresponding motor realization. His theory implies that these mental schemas are retrieved from a stored library. Therefore, if his theory is accurate, improvisations by artist-level improvisers should contain repeated melodic and rhythmic figures as the improviser repeatedly accesses the same mental schema from this library.

A competing theory emphasizes the role of tonal rules and how these rules may guide the improvising performer without storing and reusing material (Johnson-Laird 2002). According to this view, improvisations may still contain repeated melodic figures but they appear by chance due to the guiding tonal rules or are temporarily stored to be used again only within the same improvisation. Johnson-Laird wrote a computer program that can create jazz bass lines from a given chord progression using rules in support of his theory. Similarly, the computer program Impro-Visor uses rules to create monophonic jazz improvisations based on a given chord progression (Gillick *et al.* 2010). One problem with this approach is its dependence on a given chordal framework.

A previous study by one of the authors explored the use of patterns in tonal jazz by analyzing a large corpus of improvisations by the jazz saxophonist Charlie Parker (Norgaard in press). The study showed extensive use of patterns lending support to Pressing's theory that improvisers develop a stored library of patterns serving as the basis for new improvisations. In that study, interval and rhythm patterns were investigated starting on each note position. Results showed that 82.6% of all notes in the corpus began a four-interval pattern and 57.6% began interval and rhythm patterns. Furthermore, patterns up to 49-intervals were identified. Importantly, many of the longer interval patterns were distributed over several improvisations recorded at different times. Specifically, of the 98 identified unique patterns of 15-intervals or longer, 61% occurred in different solos suggesting that these patterns were not temporarily stored during the current improvisation as suggested by Johnson-Laird (2002).

Improvisations containing a large number of repeated patterns may appear more structurally sound as listeners focus on the melodic line. Artist-level jazz improvisers weigh both melodic (horizontal) and chordal (vertical) considerations during improvisation (Berliner 1994, Norgaard 2011). Improvisers may follow the logic of the horizontal line to create material that may or may not fit the actual chords. In a previous qualitative study, one participant described a phrase as having "no map behind that part" referring to the lack of attention to the underlying harmonic "map" (Norgaard 2011, p. 120).

The current project further explores the possibility that improvisations are based on a library of patterns through the implementation of a computer algorithm for improvisation based on this principle. We compare the output from our algorithm both with the results from the Parker study but also with results of a competing computer algorithm. This algorithm uses a rule-based approach where the output is dictated by the underlying chord progression.

The majority of previous computer models of improvisation are based on strict relationships between the improvised line and the underlying chords (Gillick *et al.* 2010, Johnson-Laird 2002, Rolland and Ganascia 2000). In two of these models, grammars based directly on the underlying chord progression are used to create improvised material, thereby overemphasizing vertical elements in improvisational thinking (Johnson-Laird 2002, Keller and Morrison 2007). To counter this bias, the current computer model emphasizes the horizontal aspect exclusively. In future work, we plan to further develop our model to take a given chordal structure into consideration. Our final goal is to create software for improvisation in which both horizontal and vertical aspects interact in a manner that more accurately reflects the thinking of artist-level jazz improvisers.

### MAIN CONTRIBUTION

In the previous study, transcriptions of 48 improvisations by Charlie Parker were included in the corpus for analysis (Norgaard in press). The master MIDI file was imported into the Matlab computer environment using a modified version of the Midi Toolbox for Matlab (“Matlab” 2011, Smit n.d.). Then, for example, the use of five-note patterns was investigated by searching for four-interval patterns with an algorithm within Matlab that, starting with the first four intervals (e.g. +2, +2, +1, -1), looked for additional occurrences of this interval sequence in the corpus. The result represented the number of times the interval pattern +2, +2, +1, -1 occurred in the corpus and the number of times the pattern starting on this note position reappeared in the corpus. The program then went on to the interval pattern starting on the following note and looked for the number of occurrences of this pattern. Using this procedure, the number of patterns occurring on each note position was reported. A similar procedure using beat onset times was used to investigate rhythm patterns.

Building on this previous work we decided to find a way to concatenate pitch patterns to generate improvisations based on transitional probabilities within a given corpus. The first step was to create a model for the melody (intervals). In the algorithm, a change in pattern was determined by deleting

the first interval of the previous pattern and adding a new interval. For example, a 4-interval pattern, [2212], might be followed by [2121], with the result that the concatenated interval sequence would be [22121]. Indeed, in this case, the following pattern was contingent upon the last 3 intervals of the preceding pattern.

## Results

The initial version of the algorithm only incorporated pitches (see Figure 1). The examples provided are all improvisations based on the probabilities extracted from the Parker corpus mentioned above.

After evaluating the result of the melody algorithm for the concatenation of the patterns, we decided to continue in the same vein for the treatment of rhythm. To keep these techniques as similar as possible, rhythmic patterns were also decided to span 5 notes. A rhythmic pattern is a combination of four contiguous note durations and the time from each of these note onsets to the next. We tested this approach by superimposing separately-generated rhythm and pitch improvisations into the same improvisation. This melody/rhythm algorithm created improvisations in which both pitch and rhythm patterns were present but where no relationship existed between the two parameters (see Figure 2).

In the music created by a human improviser, typically there is a relationship between pitch and rhythm patterns. For example, Charlie Parker often plays arpeggiated chords using a triplet rhythm. Therefore the final implementation of our algorithm takes this relationship into account. In the latest working version of our algorithm, rhythm and interval patterns are played concurrently only when they coincide at some point in the imported corpus (see Figure 3).

## IMPLICATIONS

The strength of this approach is evident in that a given chord pattern is not necessary for the algorithm to create new material. It is well known that jazz musicians can improvise without a given chord structure by solely focusing on horizontal considerations. In other words, the underlying chord progression used in tonal jazz is only partly responsible for the creation of melodic material. We believe this is the first time computational modeling of musical tonal improvisation has independently applied vertical and horizontal aspects in the model. In future developments of our algorithm we aim to incorporate underlying chord structures in a way that will independently influence note choices.





Figure 1. Example of an improvisation created with the pitch-only algorithm.



Figure 2. Example of an improvisation created with the independent pitch and rhythm algorithm.



Figure 3. Example of an improvisation created with the most current algorithm in which pitches and rhythms are related.

Our model appears to support the viability of Pressing's (1988) theory in which stored fragments are reused during improvisation. It also aligns with existing motor learning research outlining how general motor programs are acquired and later reused (e.g. Shea and Wulf 2005). Language acquisition theories that emphasize statistical processes for pattern learning also may share features with the described computer model for musical improvisation (e.g. Saffran 2003). The current model may therefore illuminate domain general mechanisms related to pattern-based generative and learning processes.

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# Ambient auditory feedback promotes synchronized improvisation

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Performers describe unique moments of togetherness where it seems as if “the music played us.” We previously developed an experimental paradigm to study such moments using the mirror game, a practice from theater in which two actors improvise mirror-like motions together. Here, we study the effect of providing players with auditory feedback regarding their state of togetherness. Three pairs of experienced improvisers produced linear motions that were accurately traced. Players were instructed to create “interesting and synchronized” motion together. In feedback rounds, when moments of togetherness were detected, players were presented with an ambient “Omm” sound, growing richer with overtones as the synchronization time increases and gradually fading when players diverge. Players produced significantly longer togetherness periods, while the complexity of the motions was somewhat smaller, in feedback rounds. Auditory feedback can thus help players stay synchronized in the mirror game for longer durations, possibly at the expense of the richness of the motions. This effect might be similar to the process that encourages improvisers to continue their current movement sequence or musical line in response to audience applause. Our results have the potential to further the understanding of the dynamics of entering the state of togetherness in live performance.

*Keywords:* joint improvisation; synchronization; auditory feedback; mirroring; sonic interaction design

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# Rhythmic entrainment in communicative, dyadic improvisation

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In our everyday interactions with others, we rhythmically entrain with the movements of each other's bodies and voices, and this entrainment seems to share a quality with that of musical interaction. In order to understand this quality, we have taken the case of improvisation where both musical and linguistic interaction are considered as performance, and compare how we entrain when we jointly create music and stories together. Using a combination of qualitative and quantitative analysis of video and motion capture data, we have identified salient rhythmic moments (SRMs) that are heightened moments of rhythmic and empathic connection. A perceptual experiment has tested the effects of these SRMs on the perceived qualities of the performance.

*Keywords:* improvisation; movement; entrainment; communication; pragmatics

We automatically entrain gestures, expressions, and body movements with each other in social situations (Kendon 1970, Chartrand and Bargh 1999). Entrainment of body movements and body sway suggests that entrainment is a basic building block of interpersonal understanding and communication (Shockley *et al.* 2003, Shockley *et al.* 2009).

Music and dance as joint action foreground this rhythmic entrainment (Himberg and Thompson 2011). As with conversation, musical improvisation is based upon conventions and rules, and the dynamics of the interaction unfold in unpredictable ways as performers negotiate the shared musical time. As part of this process, there are moments of heightened rhythmic and empathic connection that we call *salient rhythmic moments* (SRM; Gill

2007). These mark pivotal points in the interaction. Here, we present preliminary results from a production task whereby participant dyads interacted with each other through verbal exchanges and improvisatory musical performances. A related perception task, in which observers reported the temporal locations of SRMs within the production task, is also detailed.

The data were collected using video recordings and motion capture. Motion capture provides an accurate, three-dimensional representation of movements, allowing patterns of interaction to be studied in detail (Thompson 2012). This complements the analysis of film footage, which has a rich complexity of information, thereby affording greater clarity for identifying SRMs. Our aims are to: (1) combine qualitative observational analysis and quantitative movement analysis methods to identify SRMs in dyadic musical improvisation, and explore their kinematic properties; (2) explore the roles of auditory and visual modalities in generating SRMs by comparing interaction in face-to-face and non-face-to-face conditions; and (3) investigate the effects of SRMs on perceived qualities of the performance.

## METHOD

### Participants

For the Interaction study, 9 pairs of participants were recruited from the Department of Music, University of Jyväskylä. With the exception of one pair, they consisted of friends. For the Perception study, 26 students were recruited from the University; 21 had prior dance training, 10 were semi-professional or professional musicians, and 7 had no musical training.

### Materials

In the Interaction study, participants were asked to freely co-create stories or improvise using shakers in two-minute segments. For “inspiration,” they were provided with a soundscape and a matching, slowly changing video of still pictures of natural places (e.g. forests, beaches) or urban places (e.g. street corners, restaurants). Optical motion capture, audio, and video recordings of the two minute performances were captured.

In the Perception study, participants viewed 12 video excerpts from the Interaction study, lasting 30 minutes. The excerpts were selected for the quantity of movement and observable interaction, contrasting the most and least movement. 30 second segments (within the 60- to 90-second period of each trial) were presented in random order within the Max software ([www.cycling74.com](http://www.cycling74.com)).

## **Procedure**

For the Interaction study participants changed into motion capture (mocap) suits with reflective markers on suits, hands, and feet. The experiment started with a practice session. Each pair performed eight trials, half facing and half non-facing. Participants were instructed to take turns in half of the trials, and in the others were asked to perform freely. The starts and ends of trials were signaled by a beep from the loudspeakers.

For the Perception study participants received a verbal definition of a Salient Rhythmic Moment and practiced using the Max interface. Excerpts were presented in a random order. Participants were permitted to re-watch an excerpt up to six additional times. They were instructed to click on a virtual button within the Max patch when they perceived a SRM. This recorded the temporal location of SRMs. After clicking, participants were asked to rate Cooperation, Synchronicity, and Ease of Interaction for each excerpt using a 1-7 Likert scale, and rate the level of difficulty of scoring.

## **RESULTS**

### **Interaction study**

The kinematic analysis of the SRMs is currently on-going. Windowed cross-correlation (WCC) was used to look at body entrainment at a general level. This analysis is good in unveiling the temporal evolution of entrainment, and possible lags between participants (Himberg and Thompson 2011).

For example, in Figure 1 the WCC of wrist movements in a free, facing, musical task shows the sensitivity of the WCC to changes in the pulse and lag between the participants. At the beginning of this interaction there was a sequence of tentative attempts (74 to 100 seconds) to engage, mostly initiated by the female participant, rather like a “game.” The WCC shows no clear pattern of entrainment. At around 100 seconds the female participant initiated a clear pulse (in the video she could be seen tapping her foot to this beat), and they locked in synchrony (100 to 112 seconds).

After this, the male participant continued the “game” from earlier on, deliberately missing his turns and shifting to a slower tempo. The WCC shows this as a changing lag (downwards pattern of high correlations) between 112 and 120 seconds. The trial ended with an accented hit, taken in turns.

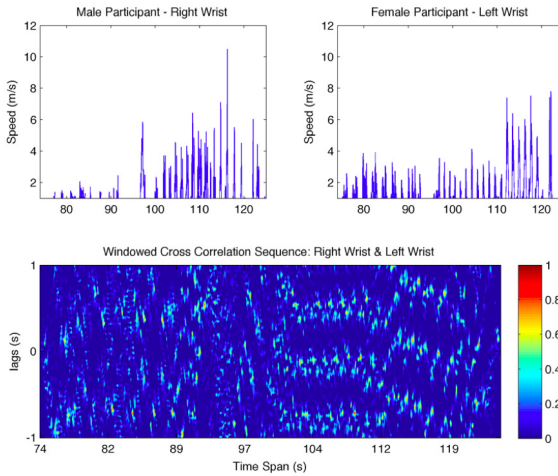


Figure 1. Windowed cross-correlation of hand movements in a music task. The top panels show velocities of wrist markers, and the bottom shows the WCC of these time-series. Parallel bands of high correlation reflect periodicity of rhythmic patterns. (See full color version at [www.performance-science.org](http://www.performance-science.org).)

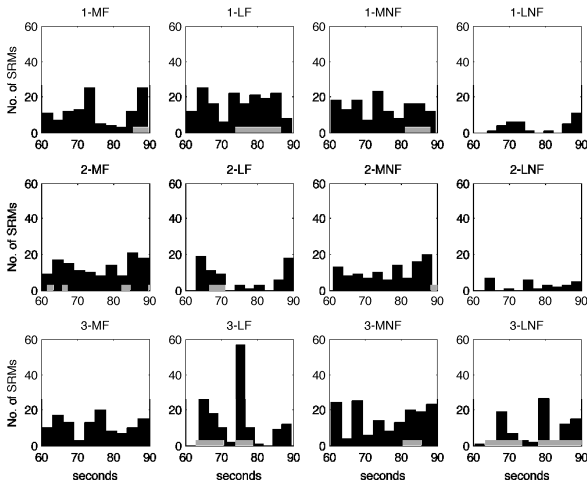


Figure 2. Analysis of SRMs reported. SRMs were perceived quite uniformly throughout each excerpt, with the exception of 3-LF, in which there was large agreement about one SRM. The LNF condition yielded the smallest number of perceived SRMs.



## Perception study

The recorded temporal locations of perceived SRMs made using the Max patch have been plotted in histograms in Figure 2. The rows represent the three performer dyads observed by participants and the columns are the four performance conditions: music facing (MF), language facing (LF), music non-facing (MNF), and language non-facing (LNF). Each bar represents a time span of two seconds. In the bottom row, the plot labeled 3-LF shows a general consensus among the 25 participants that there was an SRM at around the 70s mark. The other excerpts produced a good number of perceived SRMs, which are more scattered. The story-telling, non-facing condition warranted the smallest number of SRMs (right-most column).

Based on post-experiment questionnaires, 48% of participants reported that they found it easier to perceive SRMs in the music trials than in the language trials; however, there were clear findings for the language non-facing (LNF) results, and differences between music facing (MF) and language facing (LF).

The grey bars at the bottom of each plot indicate the periods of heightened corporeal interaction within participant dyads, as coded by one of the authors of this study—an expert in interaction analysis. The figure thus provides a comparison between expert and novice SRM rating. For instance, in plot 1-LF (pair 1, language facing), the location between 73 and 86 seconds shows that the participants overall observed an extended period of interaction, which was supported by the expert rating. Likewise, in plots 1-LNF and 2-LNF the expert observer coded no SRMs, which was reflected in the participants' comparatively few SRMs for these trials.

## DISCUSSION

Complementary qualitative and quantitative analyses were used to discover the dynamics and kinematics of interaction and mutual sense-making, evident in the occurrence of SRMs. WCC analysis revealed dynamics of interaction, sections of entrainment, and a shifting lag between performers. The expert analysis of SRMs and the novice participants' annotations showed good agreement. Originally, SRMs had been described after meticulous expert analysis, but our results suggest that they are perceivable for laypersons as well, supporting the theory that they serve an important communicative role in structuring and making sense of interactions, e.g. in gauging the level of mutual understanding.

The analysis is on-going. Taking advantage of the results of the quantitative analysis and the perceptual experiment, computational analysis of the

kinematics and movement coordination is on the way, with the aim of constructing a computational model of SRMs.

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**Thematic session:  
Creating collaborative performance**



# How good are groups at estimating time?

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Many factors affect people's time estimation abilities, such as estimating how long a particular task took to complete. Most time estimation research to date has investigated individuals, but many tasks for which timing could be relevant are performed by groups. This study investigated how individuals' prospective time estimates differ from those of groups. Eighty participants completed a word search task in groups of four. After the task, participants estimated how long the task took, how long they would have taken doing the task alone, and, finally, reached a group consensus on the time taken. Participants' individual estimates of how long their group took were significantly longer than the actual time, but the group consensus correlated extremely well with the actual time taken. This suggests that groups are more accurate at estimating task duration than individuals, at least for this task.

*Keywords:* duration; groups; time estimation; word search; prospective timing

Estimating how long a task or event lasted is relevant to many aspects of human behavior. However, our time estimation ability is far from perfect: psychological time is complex and does not have a one-to-one correspondence with actual time (Zakay 2012), as highlighted by such English phrases as "time flies when you're having fun" and "a watched pot never boils."

There are two main experimental paradigms for investigating how we estimate time, termed retrospective estimation and prospective estimation. Retrospective estimation occurs when the duration is only considered and estimated after the event, and relies heavily on memory processes (Block and Zakay 1997). It has been explained by the contextual-change model (Block and Reed 1978), which states that the more information there is in memory after the event (i.e. the more changes to the situational or task-related context), the longer the duration appears to have been. Prospective time estima-

tion occurs when we expect to estimate a duration in advance, or when we are aware of the passage of time, such as in a waiting situation. This relies heavily on attentional processes (Block and Zakay 1997). A leading theory to explain prospective time perception is the attentional gate theory (Zakay and Block 1996). This suggests that a pacemaker (internal clock) emits pulses at a steady rate, and that these are counted by an accumulator, which is accessed via an attentional gate. More attention to time opens the gate wider, so the accumulator counts more pulses and the time period seems longer.

Many factors have been shown to affect time estimation ability. For instance, a duration filled by events is retrospectively considered to have been longer than an empty interval of the same duration (Wearden *et al.* 2007) due to increased data in memory in the filled condition. Similarly, being stuck in a traffic jam on the way to the airport greatly focuses attention on time and counts as a prospective situation, so time appears to drag. Emotion has been shown to affect time perception, both in terms of the affect of the perceiver and the emotional nature of the stimuli. Those in a state of fear or high adrenaline perceive time as stretched out (e.g. Stetson *et al.* 2007), and negative valence emotional pictures and pictures of angry faces tend to lead to overestimation of time duration (Angrilli *et al.* 1997, Droit-Volet and Meck 2007). However, previous research has not investigated whether the presentation duration of negative emotional words would be similarly overestimated.

Finally, humans are social animals, and tend to work and socialize with one another in groups. As groups increase in size, group members often tend to decrease their individual effort (Karau and Williams 1993), but groups of three to five members have been shown to be the optimum size for solving certain complex problems (Laughlin *et al.* 2006). A question arises as to whether groups are any more accurate than individuals at time estimation, but to our knowledge this has not been investigated until now. The main aim was thus to compare the accuracy of group and individual time estimates of the duration of a word search task containing emotional words.

## METHOD

### Participants

The 80 participants ( $m=42$ ,  $f=38$ ) were students or local residents. Age ranged from 19 to 28 years ( $M=21.7$ ,  $SD=1.9$ ). Participants were split into groups of four (Laughlin *et al.* 2006), making 10 groups in each of the two emotional conditions. The group members were generally friends or acquaintances.

## Materials

Two word searches (20 letters by 20 letters) were designed using the teachers-direct website *Word-Search Maker*. Each word search contained 30 words, one containing positive words (e.g. joy, success) and the other containing negative words (e.g. anger, disgust). The words used did not differ in terms of either frequency (Leech *et al.* 2001;  $t_{58} = 0.763$ ,  $p > 0.62$ ) or word length ( $t_{58} = 1.141$ ,  $p = 0.26$ ) between the two lists.

## Procedure

After giving informed consent, the four participants in each group were asked to remove watches and electronic devices. They were each told that they would solve a word search containing 30 words and, after completing it, estimate how long it had taken, thus testing prospective timing. They were then given the word search with the list of target words and told to solve it as a group with no time limit. The time the group took to finish the task was unobtrusively measured by the experimenter. After completing the word search, the participants estimated how long they thought it took the group, how long they thought it would have taken them to complete it by themselves, and to what extent they had been thinking about time during the task (from “never” to “all the time”). Finally, the four group members were asked, through discussion, to arrive at a group consensus for the estimate of the task duration. All time durations were recorded in minutes and seconds.

## RESULTS

The three estimates, all obtained after the completion of the task, were the group estimate (how long the individual participant thought their group had taken), the individual estimate (how long the participant thought they would have taken if doing the task alone), and the group consensus estimate, reached after discussion. These estimates, together with the actual times taken for the participant groups, are shown in Table 1, which shows that the group consensus were remarkably accurate to within one second across the 20 groups. Moreover, these group consensus correlated strongly with the actual times for the groups ( $R^2 = 0.852$ ,  $p < 0.001$ ). The group estimates were rather longer than the actual times, suggesting that most participants overestimated. Perhaps not surprisingly, the individual estimates were considerably larger, as participants felt they would have taken longer to find the words by themselves.

*Table 1.* Means (and standard deviations) for estimated and actual durations for the word search task, by emotional condition, in seconds.

	<i>Positive words</i>	<i>Negative words</i>	<i>All groups</i>
Group estimate	741 (290.0)	752 (240.7)	746 (264.8)
Individual estimate	885 (473.3)	984 (429.9)	935 (452.0)
Group consensus	664 (331.0)	655 (203.8)	660 (273.1)
Actual time	652 (223.7)	667 (123.2)	659 (179.6)

A 4x2 mixed ANOVA was carried out on the timing data. IV1 was emotional valence and was found not to be significant. IV2 was timing measure (group, individual, consensus, actual time) and was highly significant ( $F_{1.63,126.87}=21.297$ ,  $p<0.001$ ). Post hoc Bonferroni pairwise comparisons showed that the actual time differed significantly from both the group estimate ( $p=0.010$ ) and the individual estimate ( $p<0.001$ ), which differed from each other ( $p=0.001$ ), but that the actual time did not differ from the group consensus. Even when absolute consensus errors (ignoring whether an underestimate or an overestimate) were considered ( $M=139s$ ,  $SD=62.3s$ ), they were still significantly lower ( $t_{79}=2.139$ ,  $p=0.036$ ) than the absolute errors for the group estimates ( $M=182s$ ,  $SD=174.7s$ ). Finally, the degree to which participants thought about time during the task correlated negatively with both the error between their estimate and the actual time ( $R^2=-0.313$ ,  $p=0.005$ ), and the absolute error (i.e. size of inaccuracy ignoring whether it was an underestimate or an overestimate;  $R^2=-0.276$ ,  $p=0.013$ ): thinking about time more reduced the size of the time estimation error.

## DISCUSSION

On average, participants thought that the task had taken significantly longer than it actually had, with 60% giving an overestimate. Previous research (e.g. Block and Zakay 1997) suggests that people generally underestimate durations, though less so for prospective estimates than for retrospective estimates. However, other research (e.g. Loftus *et al.* 1987) has demonstrated overestimation, particularly for emotional stimuli. The emotional nature of the target words might explain the overestimation found in the present study. There was, however, no effect of emotional valence, unlike other studies (Angrilli *et al.* 1997, Droit-Volet and Meck 2007). This may be due to methodological differences, as the words would not be expected to be effective in generating emotion in the participants. Furthermore, the present study



did not ask participants to estimate stimulus presentation durations of a few seconds, but to do a higher level task involving the complex processing of 30 stimuli and lasting several minutes.

In accordance with attentional theories of prospective time perception (Zakay and Block 1996), there was a clear relationship between attention to time and duration estimation accuracy. In general, the more the participants thought about time during the word search task, the more accurate were their estimates. Perhaps unsurprisingly, hypothetical individual estimates (“how long it would have taken me if I’d done the word search alone”) were significantly longer than the actual estimates given for the group. This suggests that participants realized that others helping would speed this particular task, as four pairs of eyes would be more likely to spot words than one. However, it was notable that 34% of participants still thought they would have been quicker on their own than their group actually was. The reasons for this are a subject for future investigation.

The most striking finding was that group consensus was exceptionally accurate. Bahrami and colleagues (2010) suggest that group decisions can be better than individual ones, though they were investigating perceptual judgments, not time estimation. Although the overall mean was accurate to within one second, when absolute errors were analyzed, the mean error for all groups was 139 seconds, suggesting that the overall consensus underestimates balanced the overestimates. However, these absolute consensus errors were still significantly smaller than the absolute group estimate errors, suggesting an advantage for group estimation.

The participants were mostly young university students, and thus not representative of the general population. Group members generally knew each other, and it would be interesting to investigate whether groups of strangers are similarly superior at time estimation, as well as those with a greater range of ages. Future research should also investigate other tasks, both emotional and non-emotional. These findings suggest that groups can estimate duration more accurately than individuals, but the reasons for this superiority have yet to be determined.

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# The collective choral voice: Artistic impact on young singers of newly composed music

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The context for the paper is the virtual absence in the singing literature of research into expert youth choirs and their engagement with newly composed repertoire. *Living Song* has provided a unique opportunity to address this need. It is a collaborative composition project with the RCM Junior Department (RCMJJD) and the English Folk Dance and Song Society (EFDSS) where new compositions, based on folk songs originally collected by Vaughan Williams and Holst, are created by student composers and performed by my RCMJD Chamber Choir. The project led me to consider generic principles that enhance the art of collective choral performance by young voices through their engagement in newly composed repertoire. Semi-structured interviews were undertaken during 2012 in which eminent choral conductors and composers working with youth choirs responded to questions regarding the ways they select or compose repertoire in order to promote the highest level of musical performance. The findings from this empirical study suggest a need for further research into the artistic outcomes of new composition and performance projects, both in terms of the music produced by the composers and in relation to the artistic impact on the young singers and their ability to perform collectively.

*Keywords:* expert youth choirs; newly composed repertoire; Living Song; artistic impact; collective performance ability

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# Collaboration in the choral context: The contribution of conductor and choir to collective confidence

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This qualitative study explored some of the factors influencing confidence levels amongst adult amateur choral singers. Three initial focus groups were completed, followed by sixteen individual interviews. The majority of interviewees had participated in a range of different types of choral singing, and each had performed with several different conductors. Emergent themes included: situational and environmental factors, such as rehearsal and concert venues, acoustics, choir formation, and spacing; the influence of other people, with special reference to conductors and fellow choral singers; and a number of significant issues related to choral direction, musical leadership, and group dynamics.

*Keywords:* confidence; choral; singers; choirs; conductors

Choral singing as a collaborative activity has not always received the attention it deserves, and confidence issues among amateur choral singers have not yet been widely researched. Existing work in the related area of music performance anxiety (MPA) has tended to concentrate on instrumentalists rather than on singers (Kenny *et al.* 2004). Where MPA among singers has been studied, soloists have usually been the main focus (Wilson 2002). The relatively rare studies of choral singing generally involve professional choruses (Kenny *et al.* 2004) or conservatoire students (Hamann and Sobaje 1983). Research into self-efficacy amongst singers and musicians has similarly tended to revolve around professional performers (McPherson and McCormick 2006), music students (Ritchie and Williamon 2011), and semi-professional choristers (Ryan and Andrews 2009). The adult amateur singers who form the bulk of the performing population in the wider community (Pitts 2005) have so far been largely neglected. Earlier research by the author (Bonshor 2002) has indicated that, for adult amateur singers, confidence issues

are a widespread concern which can impair enjoyment and limit participation in choral activities. This study therefore examined the effects of the collaboration between choir and conductor, and between choir members, on individual and collective confidence levels. The research aimed to (1) explore the lived experience of choral singers, (2) identify some of the main influences on their perceptions of their voices and performance ability, and (3) highlight some of the factors affecting their confidence as singers. The ultimate aim was to provide a set of useful recommendations for conductors with an interest in confidence-building.

## METHOD

### Participants

Participants (N=34) were drawn from a selection of adult amateur choral ensembles, including church choirs, choral societies, chamber choirs, and amateur operatic societies. Each interviewee was involved in a variety of choral singing types, and had experience working with several different conductors.

### Materials

The focus groups were provided with a series of open questions for group discussion. Semi-structured interviews for the individual sessions developed some of the emergent themes from the group interviews. Background information forms provided additional descriptive and contextual data concerning the participants.

### Procedure

Three preliminary focus group interviews, involving eighteen singers in total, were followed by sixteen individual interviews. The interviews each provided approximately two hours of recorded verbal data (over 40 hours in total). The transcriptions were analyzed using techniques based on interpretative phenomenological analysis (Smith *et al.* 2009). Post-interview member checks were carried out to confirm the accuracy of the researcher's interpretation.

## RESULTS

The superordinate themes emerging from the data included the collaborative role of the other singers as an adjunct to the leadership of the conductor.

Table 1. The choir as a team.

<i>Researcher's commentary</i>	<i>Singers' commentary</i>
The conductor does not criticize individuals. This enhances the sense of the choir as a team.	I think the way we do it is that no-one is singled out, so I think that has a definite impact on us feeling like we're a team.... 'Cause we <i>all</i> have to get there. And we all have to sing as a unit.... It's just like "No, we just need to keep going until we <i>all</i> get it right" (S10.30).
Feelings of cohesion, solidarity, and support for each other, as team members.	
Exercising patience while others learn.	

Table 2. Unofficial "team leaders."

<i>Researcher's commentary</i>	<i>Singers' commentary</i>
Reliance on informal "team leaders." This role may vary according to the repertoire.	It's very helpful to have a <i>rock</i> ...within the group that you can latch on to. Sometimes that rock changes, depending on the type of material it is, 'cause we're all individuals.... But it's good to have that rock. It gives you confidence (FG3.1.16).
Just knowing that the "team leader" is there can boost confidence.	
Influence of "team leaders" felt by their absence as well as their presence.	If we don't have an anchor there, and it's up and down a bit, I get quite disheartened with that (FG3.8.23).
Identification of "team leaders" partly based on impact of their absence.	In the male voice choir...if there are key people missing, they tend to get a bit lost, as we do in the second tenors [laughs], if we've got a few key people missing (S6.3).
Depending on reliable singers for entries and pitches.	Well, standing next to someone who you know is going to pitch the note right and come in at the right time is good for your confidence, 'cause you can sort of go along on their coat tails! But someone who just doesn't come in—I start to think "Was I wrong? Can they only hear me?" (S15.13).
Knowing that the "team leader" is reliable boosts confidence.	
Self-doubt without a strong lead.	

Subordinate themes included positive feedback from other singers and support and encouragement from peers, role models, and informal mentoring.

Many participants viewed the choir as a team, with team spirit and teamwork seen as important for the success of the choir and for collective confidence (see Table 1).

As an extension of the “teamwork” theme, all three focus groups and several individual interviewees spontaneously introduced the subject of unofficial “team leaders” who gave confidence to the singers around them (see Table 2).

Reciprocal trust between the singers and the conductor, and between the singers themselves, was seen as vital to the development of a supportive rehearsal environment. Positive feedback and constructive criticism from peers were particularly valued. Relationships with fellow singers were often seen in terms of mutual support and shared learning (see Table 3).

*Table 3.* Trust and collaboration.

<i>Researcher's commentary</i>	<i>Singers' commentary</i>
Importance of trust and respect.	I know his voice. I <i>trust</i> him. We like each other! ... And I nudge him and say “You made a balls there!” or something like that [laughs]. And he does to me as well, I may hasten to add. It's two-way traffic. That's what learning's about, isn't it? (S13.15-16).
Feedback from fellow singers.	
Honesty and good-humored banter.	
Learning from each other rather than solely from the conductor.	

*Table 4.* The choir as a team.

<i>Singers' commentary</i>
If we're somewhere like in the open air, it's really difficult to hear everybody unless we're really, really close together. [Indoors], it's a lot easier... Even with people talking and other noises going on, you know, you can hear each other. And that gives you confidence as well (S2.5).

The Students' Concert, the annual one, was the most appalling one, because of where we stood, and the acoustics. We just couldn't hear each other, and everybody was really disappointed that we hadn't done what we meant to do (S5.4).



Partly due to this collaborative approach, and the reliance on “team leaders”, acoustic conditions or physical positions which limited the ability to hear other singers were reported as having a negative impact on perceived self-efficacy (see Table 4).

## DISCUSSION

The results of this research demonstrate the importance of collaboration between choral singers, both as a factor in the confidence levels of individual performers and in the development of collective self-efficacy. The conductor might capitalize upon this collaborative process by maximizing the strengths of the team in order to build choral confidence. Individual voice placement could be judiciously used by conductors to optimize the contribution of choral “team leaders”. By placing strong singers and readers next to less confident performers the identification of “senior learners” could be used to contribute to “human compatible learning” (Thurman and Welch 2000). It may also be advantageous to experiment with different choir formations in rehearsals in order to foster adaptability to different acoustics and positions (Durrant 2003). Earlier studies indicated that an optimum self-to-other ratio allows choral singers to hear their own voices (Ternstrom 1999), and that this can be facilitated by wider spacing between performers, combined with a mixed voice formation (Daugherty 1999). However, for the adult amateur singers in this study, formations that enabled them to hear other singers were paramount. It is worth noting that previous research on choir formation and position has largely prioritized assessments of choral blend rather than the subjective experience of the singers (Daugherty 1999, Ekholm 2000). The current study suggests a dual-pronged strategy for enhancing amateur choral confidence, combining a flexible approach to choir formation and placement with an understanding of the collaborative situated learning that is taking place in this context.

Finally, data gathered during this research confirmed that confidence is a significant issue for some amateur choral singers. This is a pity, as the benefits of ensemble singing have been well-documented (Clift and Hancox 2010). It is therefore hoped that this on-going study will suggest additional strategies to enable less confident singers to participate to their full potential, and to reap the full rewards of choral activity.

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Thematic session:  
Piano performance II



# Fingers as individuals: The pianist's art of choosing the right fingering

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From the very early stages of keyboard playing, the question of how to choose which fingers to use was definitely a major concern. Fingers were divided into the “good” and “bad,” and used in accordance with the desired emphasis upon the musical text. The development of the keyboard instruments and the growing challenges of the repertoire led to the creation of numerous exercises and studies, with the indubitable purpose of achieving perfect equality and strength among the fingers. The ever-increasing rich, full-sounding tone of the modern piano inspired the pursuit of new strategies for improving keyboard technique. Awareness of the anatomical differences between the fingers was present, only now used to full advantage by pianists like Chopin, who recognized the possibility of using their characteristics to achieve distinctive musical results. The analysis of different types of fingerings and their implications may lead to solutions that will help to more effectively reach desired musical outcomes.

*Keywords:* keyboard; fingering; substitution; individuality; Chopin

Fingering was a major issue from the very early stages of keyboard playing. Fingers were named “good” or “bad” in accordance with what were considered metrically significant or non-significant notes, and their use influenced above all the emphasis upon the articulation of the musical text. Ferguson (1975) provides examples of scale-fingering according to Girolamo Diruta and the English virginalists, in which the “good” fingers varied from being the 2nd and 4th in Diruta, and the 1st, 3rd, and 5th in the virginalists. At another level, Couperin did acknowledge by 1716 that there were differences among the fingers, advising that “the better...fingers should be used in preference to the poorer ones...in favour of the proficiency of execution...” For him, fingering was a decisive issue, contributing “much to good playing.” He went on

to emphasize that “a certain passage, if executed in a certain way produces a different effect on the ear of a person of taste” (Couperin 1933, p. 13).

A profusion of treatises went on throughout the 18th century with C. P. E. Bach’s 1753 *Essay on the True Art of Playing keyboard Instruments* standing out, Bach now claiming a new function for the thumbs, which “rose from their former uselessness to the role of principal finger” (Bach 1949, p. 42). New methods and treatises followed, alongside with the development of the forte-piano, seeking to accompany the growing challenges of the new instrument and its repertoire. A thorough survey of the period from Clementi to Czerny is given by Luca Chiantore in his *Historia de la Técnica Pianística*, starting from the 16th century to the present. The author notes that by the time Chopin was conceiving his *Op. 10*, in approximately 1830, Czerny’s name was becoming internationally known, thanks to his *School of Velocity, Op. 299* (Chiantore 2001, p. 220). Jean-Jacques Eigeldinger reports that, while most of the pedagogues that descended from the classical generation “regarded the acquisition of virtuosity as a collection of recipes...in a daily regime consisting of long hours of digital gymnastics and stubborn repetition of *Etudes de mécanisme*,” Chopin was creating a new paradigm, “resolutely turning his back on many piano professors of his time...whose teaching [was] based on a mechanistic conception of instrumental playing” (Eigeldinger 1987, p. 16). Chopin therefore felt compelled to create his own method, in order to pass on his doctrine to future generations. Although he never got to complete it, the principles contained in its sketches, together with printed evidence and the accounts left by his pupils and contemporaries, thoroughly reveal the essence of his thought. This work intends to show how many of Chopin’s clues, notably on fingering, influenced the following generations of pianists and may contribute to a reflection toward an effective and artistic rendering of the comprehensive musical repertoire.

## MAIN CONTRIBUTION

### **Chopin’s *Projet de Méthode***

Eigeldinger’s words above are not mere speculations on Chopin’s clash against most of the ruling pedagogues of his day: in his sketches for the *Méthode* he wrote: “people have tried out all kinds of methods of learning the piano, methods that are tedious and useless and have nothing to do with the study of this instrument.” He goes on by saying that the kind of difficulty practiced in those methods is not the one encountered in the music of the great masters, being “an abstract difficulty, a new genre of *acrobatics*” (Eigeldinger 1986, p. 193). Later on in his sketches, Chopin points out that “a

well-formed technique...is one that can control and vary a beautiful sound quality.” He then says: “as many sounds as there are fingers—everything is a matter of knowing good fingering.” Regarding the individuality of the fingers, Chopin writes, again with an implicit criticism to the above mentioned methods: “for a long time we have been acting against nature by training our fingers to be equally powerful. As each finger is differently formed, it’s better not to attempt to destroy the particular charm of each one’s touch but on the contrary do develop it. Each finger’s power is determined by its shape.” Together with the correct use of the conformation of the fingers, Chopin emphasized the need to also employ the “rest of the hand, the wrist, the forearm and the arm” (Eigeldinger 1986, p. 193). The example of this combined use of the characteristics of the fingers with the suppleness of hand and wrist (not so much the forearm and arm in this case), is clearly perceptible in the right-hand fingering of bars 26 to 28 of his *Nocturne, Op.9, No. 2* (see Figure 1).

### **Adapting Chopin’s principles to different repertoire**

These fingerings clearly must have influenced one of the most relevant of the last generation of Liszt’s disciples, the Portuguese José Vianna da Motta. Da Motta edited the complete Nocturnes for Sassetti in Lisbon, and clarified in a footnote: “Chopin’s special fingerings” (Vianna da Motta n.d., p. 7). In his autograph edition of Beethoven’s *Sonata Op. 7* he fingers the right-hand passage of bar 142 of the 4th movement employing the alternation between the 4th and 5th fingers together with a consecutive use of the 5th finger in a very similar way to Chopin. It is also interesting to notice how Vianna da Motta uses in bar 141 the full extension of the hand to achieve a maximum legato by putting the 5th finger on a black key (*Eb*) and turning the thumb under into a white key (*E* natural), a technique Chopin also employed in his playing (see Figure 2).

Chopin’s fingerings, according to Jan Kleczinski, were “so original that they shocked old pianists,” not only allowing the thumb to pass under the fifth finger when necessary, even from white to black keys, but also permitting the longer fingers to cross over the shorter ones, with the object to keep the hand in its proper position (Eigeldinger 1986, pp. 38-39). Examples from Mozart’s and Schubert’s sonatas show how it is possible to avoid the turning under of the thumb, keeping it prepared to strike the subsequent notes without changing the shape of the hand (see Figure 3).

In his characterization of the fingers, Chopin describes the thumb as having “the most power, being the broadest, shortest, and freest” (Eigeldinger 1986, p. 195). An excerpt from Rachmaninov’s *Etude Tableaux Op. 39 No. 5* is

Figure 1. Chopin's *Nocturne Op. 9, No. 2*, bars 26-28 with Chopin's fingerings, according to the original French edition (Eigeldinger 1986, p. 47).

Figure 2. Beethoven's *Sonata Op. 7, IV*, bars 141-142; fingering by Vianna da Motta (Pipa 2004, pp. 94-95).

Figure 3. Mozart's *Sonata K. 322, III*, bars 83-84; Schubert's *Sonata Op. 143, II*, bars 51-52 (Pipa 1992, p. 32).

Figure 4. Rachmaninov's *Etude Tableaux Op. 39 No. 5*, bars 53-54.



particularly suited to employ the thumb's power with great effect, emphasizing the melody over the dense chords of the harmonic parts (see Figure 4).

Chopin also reportedly used abundantly the technique of silently changing fingers on the same key, "as often as an organ player," also advising his students to "substitute fingers as much as possible" (Eigeldinger 1986, p. 48). Couperin had already pointed out the importance of finger substitution to "bind" the notes, but Chopin's practice appears to have also to do with the concern of maintaining a well-balanced hand position, and at the same time to allow the most suitable fingers to strike the notes. Kravitz (2009) emphasized the importance of finger substitution for the professional pianist, believing also that it may, in certain contexts, contribute to avoid tension in performance (p. 25). The fingering suggestion for the beginning of the second movement of Schubert's *Sonata Op. 143* can sum up these principles. Apart from the silent substitution technique, the author proposes in this example that in the first chord the right-hand *A* be played with the first and second fingers simultaneously in order to "feel" the bottom of the key and achieve with it the best possible control of the tone (see Figure 5).

### IMPLICATIONS

The legacy of Chopin is of extreme relevance to an all-embracing pianism, one that can be at the same time technically effective and musically controlled. Chopin's uncommon use of fingering strategies may have had to do with the fact that he was mostly self-taught on the piano, as his principal teacher was a violinist. Free from the restraints imposed by a conscious keyboard tutor, he was free to come up with solutions that are still today, in many ways, revolutionary. In some manner Chopin returned to the principles of his ancestors, using strategies that had been long banned, only now, instead of assigning the

Figure 5. Schubert's *Sonata Op. 143, II*, bars 1-2 (Pipa 1992, p. 25).

fingers as “good” and “bad,” he considered each one to have its own merits, and, when used appropriately, to be capable of being the best finger in a suitable occasion.

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# Piano touch, timbre, ecological psychology, and cross-modal interference

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The piano has a wide timbral range, and performance quality is often judged in timbral terms. Yet, despite decades of research, there are still fundamental disagreements about the nature and origin of piano touch. Scientists (acousticians) maintain that the timbre of a single tone cannot be varied independently of its loudness. Performers, humanities scholars, and concert audiences take the opposite for granted: timbre and loudness can be independently varied by gestural means. Both sides are right, but their implicit definitions of timbre differ, and both fail to clearly distinguish between physical measures and descriptions of subjective experience. Scientists assume that timbre depends only on physical sound parameters, but experiential parameters *generally* depend on concurrent input from other senses, the listener's relevant knowledge and expectations, and immediately preceding and following events. The paradox of timbre disappears if we accept, based on empirical evidence, that timbre generally depends on input from more than one sensory modality (weak synesthesia). Embodied corporality and conceptual metaphors are the norm, not the exception. Gestural and ecological approaches to timbre perception pose existential challenges to disembodied cognitive orientations.

*Keywords:* timbre; piano; touch; ecology; synesthesia

The piano has a remarkable timbral range. Piano timbre depends strongly on pitch (higher is brighter) and loudness (louder is brighter) in ways that are unique to the instrument. Piano timbre is also affected by complex physical interactions (among strings, soundboard, internal resonances) and perceptual interactions (among sensations and emotions), which in turn depend on timing, dynamics and pedaling.

The way a pianist strikes a key (“touch”) seems to influence timbre, even when loudness (key velocity) is constant. In fact, the hammer hits the string in free flight, so any such effect must be tiny; empirical studies suggest that if such an effect exists, it is inaudible. We can sometimes hear fingertips hitting keys (“touch precursor” or “early noise” in “staccato touch;” Goebel *et al.* 2004) but that is a small and probably negligible aspect of “touch.”

## MAIN CONTRIBUTION

### Weak synesthesia

To account for the richness of piano timbre and demystify piano touch, we need an ecological, multimodal concept that acknowledges the role of vision, proprioception, the somatic sense, and gesture. Weak synesthesia, or cross-modal interference, occurs when perceptual input in one modality (seeing, hearing, tasting, and so on) influences perceptual judgments in another. Weak synesthesia can occur in all perceptual modalities (Martino and Marks 2001) and is probably innate (Walker *et al.* 2010).

Although we physically pick up information via different sensory modalities, and within each modality there are separable sensations (e.g. pitch, timbre), we cannot completely separate modalities or sensations. The reason is that ecological and evolutionary: sounds are only interesting (and consciously perceived) if they carry information about environmental interaction that could affect survival or reproduction. We tend to perceive environmental objects holistically, focusing on their affordances—what we can do with them (Gibson 1979).

Both sport and music performance can benefit when attention is directed to the effects of movements (external focus of attention: distal stimulus) rather than the movements themselves (internal focus of attention: proximal stimulus; Wulf and Prinz 2001). Golf players make faster progress when their attention is directed to the ball and its goal rather than body movements. Pianists can be more successful if they concentrate on sound rather than technique. The sophisticated motor control mechanisms that regulate our movements are largely unconscious, which allows us to focus on external goals. But the perception of a motoric goal cannot be separated from proprioception (kinesthesia)—perception of the relative position of body parts and corresponding muscular effort. Similarly, pianists’ perception of timbre cannot be separated from their perception of the gestures used to achieve it. Research on audiovisual mirror neurons (Kohler *et al.* 2002) and auditory-motor interactions (Zatorre *et al.* 2007) further implies that listeners at a piano recital share the performer’s proprioception.

Cognition is embodied when it is “deeply dependent upon features of the physical body of an agent” (Wilson and Foglia 2011)—a central issue in music psychology (Leman 2008). Understanding sound via the body is an example of conceptual metaphor: ideas in one domain are understood in terms of ideas in another (Lakoff and Johnson 1980).

### **Weak synesthesia in perception and performance**

The feel of the piano keys under the fingers of a concert pianist can change with the hall acoustics, even if the piano is identical (Brendel 1976). Pianists are highly sensitive to the touch-sound relationship; that is a major aspect of their art. For a pianist, the sense of touch—the sense of the keys under the fingers—is *generally* inseparable from the produced sound.

There are many examples of weak synesthesia in music. For example, musical pitch is understood in spatial terms: it rises and falls. The timbre of a jazz voice is compared with familiar environmental objects (e.g. “round”) or the body of the singer (e.g. “relaxed;” Prem and Parncutt 2008).

Unlike pianists, wind and string players have a high degree of independent control over the exact pitch and timbre of individual tones. But even the best performers do not clearly separate intonation from timbre (Ely 1992, Platt and Racine 1985); musicians who play with good timbre are judged by experts and amateurs to have good intonation and vice versa. Another example: in the best performances of Renaissance choral music, intonation is close to 12-tone equal temperament (Devaney *et al* 2011), perhaps because 12ET offers an optimal compromise between the clarity of Pythagorean tuning (in which scale steps are clear and stable) and just tuning (in which roughness and beats are minimized). The special feel of just intonation as idealized by Renaissance music aficionados (Duffin 2007) may be a timbral illusion—another example of synesthesia.

Ecological psychology is also relevant for musicology and aesthetics. An example: acousmatic music is abstract, electronically synthesized sound heard from loudspeakers. Listeners constantly guess and imagine sources or causes of musical sounds—just as we do in everyday life when we hear a sound that could be important. Electronically generated sounds sound less strange and more “musical” when we notice their similarity to familiar sounds and imagine their sources. “[T]he acousmatic curtain does not merely serve to obscure the sources of sounds. Indeed, it can be seen to intensify our search for intelligible sources, for likely causal events” (Windsor 2000, p. 31).

Modern approaches to music theory and the psychology of musical structure have been disembodied by cognitive epistemologies, ignoring envi-

ronmental interaction. An ecological approach might start instead with an empirical study of the relationship between physics and experience, as we perceive complex tones in real speech and music (Terhardt 1984).

### Redefining timbre

These diverse examples suggest that weak synesthesia is the rule rather than the exception. Anything that we experience in any sensory modality can be influenced by any other modality. If that is true, we need a new, explicitly ecological definition of timbre. Timbre depends *generally* on input from other senses (weak synesthesia)—not to mention the listener’s relevant knowledge and expectations, as well as immediately preceding and following events. These dependencies are not errors—they are *intrinsic* to timbre.

Discussion of musical timbre often begins by apologizing for current definitions. A more appropriate definition might include the following:

- (1) Like pitch, loudness, and (in vision) color, timbre is purely *experiential*. It has no physical existence, but *corresponds* to physical states and events.
- (2) Timbre is a *holistic* property of a sound source or auditory image that can depend on concurrent input from all relevant senses: hearing, vision, touch, gesture perception. Our ability to consciously separate sensory inputs is limited. Timbre often depends on feelings in the body while performing, or an audience’s projections of those feelings. Timbre can also be affected by acoustic or other aspects of a listening space, emotional reactions, and associations with other music or events.
- (3) A complete description of timbre includes *quantitative and qualitative* elements. Both are indispensable, and both are intrinsically vague and intangible. From a quantitative viewpoint, timbre is multidimensional; the axis labels are part of timbre’s qualitative description. More generally, timbre descriptions refer to the physical environment and the human body, including speech (Traube 2004).
- (4) Like loudness, timbre is a mixture of *sound quality* (proximal perception) and *sound source quality* (distal perception). Psychoacousticians traditionally study proximal loudness and timbre in experiments with artificial sounds heard on headphones, and then consider neural foundations. But in everyday life and music, loudness and timbre usually refer to sound *sources*—not sound as sensation. Timbre generally depends on imagined visual and tactile properties of sound sources, and the listener’s past experience of those sources. An example: the temporal and spectral characteristics of the clarinet sound vary enormously from one register to an-

other, but we still recognize the sound as belonging to one category called “clarinet.” That in turn suggests that our experience of timbre is also generally influenced by spontaneous, learned categorizations.

### IMPLICATIONS

The long-standing failure of scientists and musicians to agree about touch in piano music may be part of a broader failure to come up with a realistic operational definition of timbre. This failure is inhibiting interdisciplinary interaction. One solution might be to inform both sides about basics of experiential psychophysics and ecological psychology. Another might be to agree on a new definition of timbre. Scientists may be the most resistant to change, given the current dominance of the philosophical worldview known as materialism, according to which the only things that exist are matter and energy as defined by physicists. But with that worldview it is impossible to study artistic experience. You cannot study something that does not exist.

The impression that piano timbre depends on gesture, arm weight, and touch is valid if we accept that experiences exist in their own right, and are generally multimodal. But we must also agree that in the physical world, the spectral and temporal envelopes of an isolated piano tone cannot be changed independently of physical intensity. A rational discussion of the relationship between physics and experience will become possible when both sides agree that the previous sentences are complementary and not contradictory. A new interdisciplinary platform will enable more effective and realistic investigations of musical interpretation in practice, on the basis of subjective interactions among performers’ proximal sensations (tactile, auditory, visual, proprioceptive) and distal perception and cognition (performance space, communication with the audience, cultural context).

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# A sustainable playing technique for piano performance: Movement science and implications for curricula

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A sustainable technique is required for longevity in performing. However, factors in the music environment such as heavy action keyboards and repertoire with repetitive movements at high tempi and sound levels predispose body tissues to injury. A century ago, music pedagogues realized economy of muscle use was needed for an efficient technique and proposed theoretical concepts to take advantage, wherever possible, of the natural mechanical laws such as the ever-present gravity and rotational arm movement. Despite these hypotheses and recent empirical research demonstrating the value of using arm weight and forearm rotation, relevant significant findings proving their role in economic movement lack application generally to curricula, resulting in an ongoing high injury rate among pianists. Movement sciences are important in the analysis of technique and injury, thus this paper explores their application to piano playing, focusing on neural processes producing movement and structural and mechanical limitations of body tissues, plus the potential of mechanical laws. Implications are discussed for warming-up before playing, training children in technique methods, and employing music ergonomics as a model for teaching at graduate and post-graduate levels to cater to performers, teachers (and their professional development), researchers, and applied science writers.

*Keywords:* efficient piano technique; music curriculum; motor learning; injury prevention; music ergonomics

Piano performance must have an underpinning efficient technique created by natural movement, emanating from a highly organized neuromuscular system (MS) with a complex control mechanism. Comprehending technique delivery requires a multi-disciplinary approach incorporating the movement sciences

(MacKie 2007). Playing technique changed over time with newer approaches needed for adaptations in the pianoforte action, larger concert spaces, demands on performer-composer piano virtuosos by an avid musical public, and more numerous competitions. Newer approaches pioneered a century ago (e.g. Matthay 1903) included the use of whole-arm action, not just hand and fingers, termed *use of arm weight*, leading to the concept of *efficiency* with economic muscle use. Following was the proposal that rotational forearm movement aided efficiency by placing the fingers in a strategic position to play (Bernstein 1967). Technique must be sustainable while performing to prevent fatigue, and daily hours of practice over the years also makes it vital in the long-term. However, the reality is that many pianists experience pain while they play, or suffer injuries (Zaza 1998) with complex causal factors such as repetitive movements of the forearm-hand and static postures involving neck and upper back flexion. Despite earlier theoretical concepts and recent empirical research delivering new awareness of the potential of the neural and MS systems to generate motor skills, a lack of application to curricula has allowed growth in quasi-scientific “approaches” and “techniques.” This paper reviews neurological and bio-physiological systems by assessing their application to playing technique and injury processes.

## MAIN CONTRIBUTION

### Neurological processes

Neurological processes are central to music interpretation by the brain, which communicates with the MS to execute movement leading to the development of motor skills facilitating the playing action. Brain structures are plastic, responding to environmental changes and music tasks by enlarging several areas including: the *corpus callosum*, joining both hemispheres for information exchange; the *cerebellum*, controlling balance and timing; the *auditory cortex*, monitoring tone, timbre, and phrasing of notes; and the *motor cortex*, with the hand-area exhibiting little difference between hands (Altenmuller and Gruhn 2002). Changes are optimized if music training begins before eight years. Technique is gradually automated through integration of motor, somatosensory, and auditory areas of the brain (Jabusch *et al.* 2009). Developing motor patterns relies on perception via sensory faculties including: (1) *audition*, always necessary to control the mentally imaged-sound through an ear-fingers feedback loop triggering a sound that influences the next sound; (2) *proprioceptors* in all MS tissues, working with audition and vision sense the position, orientation, and ongoing movement; (3) the *tactile* sense responsible for touch and later reproduction also relies on audition;

and (4) *vision*, which is important early for hand-eye coordination but then declines with greater reliance on proprioception, audition, and touch. Understanding the role of sensory faculties helps in planning practice for gradual skill acquisition.

### **Biophysiological structures, functions, and mechanics**

The architecture, movement potential, and limitations of the MS are central to producing economic movement, as it is more efficient to use body segments and tissues according to their design. The upper limb tapers distally with largest muscles situated proximally, and is constructed of linking segments from sternum to fingertips which act as a kinetic chain (Furuya *et al.* 2009) with energy produced by larger proximal muscles and transferred distally. Proprioceptors transfer information from movement-generating and transmitting tissues for ongoing motion.

#### *Skeletal structures*

Bones and joints are critical to technique because movement direction and path shape are delineated by joints enveloping paired bones connected by ligaments, and bone architecture influences how force is delivered in the playing action. It also determines how movement paths are curved because: (1) most joints act as lever systems with arms similar to a compass; (2) horizontal trajectory movement stems from the hand following a curvilinear path; and (3) the forearm rotates round an imaginary longitudinal axis with the long bones (*radius* and *ulna*) crossing each other to produce different playing positions for the wrist/hand. The hand maintains a pronated playing position producing elbow lateral rotation through upper arm lateral movement, facilitating the anti-clockwise rotation of the forearm. The architecture of the hand bones supported and strengthened by three arches means the hand can shape itself with curved MP joints, little finger and thumb under and fingers curved (the close hand), allowing larger and rapid force transmission. Curved fingers on the keys have relatively equal length and produce faster playing.

### **Muscle structure and composition**

Muscles provide the internal energy necessary for movement, and they vary in size, shape, and function, giving different endurance qualities. Muscles have different proportions of fiber type with *fast* twitch fibers more plentiful in small muscles designed to generate short bursts of strength or speed. However, they fatigue faster than *slow* twitch fibers which use oxygen for energy

and are more numerous in large muscles, making them more efficient in prolonged use. In addition, tolerance to muscular fatigue increases with muscle cross-sectional area (Herzog 2000) so, functionally, larger proximal muscles are best to generate and transfer energy to smaller muscles such as those operating the fingers.

### *Connective tissues*

Support, strength, and elasticity for greater flexibility are offered by connective tissues located around individual and bundled muscle fibers and in joint capsules, tendons, and ligaments. The mechanics of MS structures are affected by increasing core body temperature which amplifies blood flow to the MS and brain, oxygen delivery, muscle contractile properties, and joint flexibility (Sapega 1981).

### **Biomechanics**

Understanding the natural physical laws is valuable because neuroscience researchers have confirmed the significance of their strategic use to increase muscle efficiency. Vertical downward movements are assisted by gravity, making possible the downswing from above the keyboard with relaxed muscles, similarly with trajectory landings (Furuya *et al.* 2009), and having curved fingers to strike keys (Kuo *et al.* 2006). A longer downswing increases acceleration rate producing greater *momentum* and *impact force* for key depression energy, so important in playing because pianists automatically modulate force to vary loudness and tone timbre. Maximum force is conveyed with the last finger joint vertically shortening force transfer time and aiding loud, fast playing. Fast delivery returns a larger *reaction force* for a rebound movement to lift the forearm. Conversely, extended fingers are required for *cantabile* playing through longer force transmission time attenuating the sound (Furuya *et al.* 2010).

Rotational paths are produced by *lever systems* formed by pairs of long bones as *lever arms* with joints acting as *fulcrums*. For the elbow, the distal forearm provides the resistance, upper-arm muscles the force to move the forearm, and the close hand reduces the forearm resistance, so decreasing muscular energy moving the hand (Furuya and Kinoshita 2008).

*Momentum* is transferred via the kinetic chain from proximal muscles decreasing energy from hand-forearm muscles (Furuya and Kinoshita 2008). The multi-joint arm kinetic chain involves *wave motion* with the translation of proximal muscle energy, with momentum increased additively at each joint increasing final finger force shown by the proximal-distal temporal organiza-

tion (Furuya *et al.* 2011). Forearm *angular rotation* round an imaginary longitudinal axis is produced by elbow-spanning muscles which generate the muscular energy to produce rotational velocity. The close hand lessens the wrist load and vertical final finger joints deliver more force to the key(s) (Furuya and Kinoshita 2008) and reduce the *radius of rotation*, optimizing the rotational velocity for increased tempo and sound (Furuya *et al.* 2011).

## DISCUSSION AND IMPLICATIONS

The evidence supports using arm weight and forearm rotation to increase physiological efficiency, implying that pianists must develop motor skills to relax muscles during downward movement for gravitational action to take over, and to use whole-arm action to transfer muscular energy from proximal muscles. As all natural movements are curved, advantage must be taken of rotational movement where possible because linear movement requires muscular control to vary the natural movement path. The elastic energy storage capacity of the muscle-tendon unit means slightly stretched muscles contract faster with implications for elbow posture at an 80-degree joint angle which produces the most efficient movement. As piano technique involves repetitive continuous movement, a warm-up should precede practice to increase MS efficiency and reduce injury potential (James 2012) with periods of silent score rehearsal and analysis to separate those of playing activity (Bravo and Fine 2009). To maximize musical brain structure potential, specialist pedagogy for children is necessary with training methods planned with consideration of maturation of sensory faculties and body dimensions. Motor skills must be developed early to use a relaxed downswing which children learn easily (Furuya *et al.* 2009), plus forearm rotation with close hand posture. Music students themselves need movement analysis competence for their futures as (1) professional pianists or teachers understanding technique and injury mechanism, (2) specialist researchers in particular sub-disciplines, and (3) music generalists integrating science and technique to inform the music fraternity. *Music ergonomics*, the science of fitting technique to body tissue potential and limitations, could encompass knowledge for comprehending playing action from all perspectives.

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Thematic session:  
Analyzing the performance of  
contemporary music





# Exploring multi-temporalities: An orchestration of Luigi Nono's .....*sofferte onde serene*...

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Collaborative creative practices between composers and performers have a long history. Famous examples include collaborations between Giovanni Gabrieli and Girolamo dalla Casa, Johannes Brahms and Joseph Joachim, Peter Tchaikovsky and Hans von Bülow, or, in the twentieth century, Luciano Berio and Cathy Berberian, and Luigi Nono and Maurizio Pollini. In .....*sofferte onde serene*... (1974-77) for piano and tape—written with and for Pollini—several new elements emerged in the musical language of Nono, including new modes of organizing “multi-temporalities,” with the piano and the tape following different paths on the same journey. As a result, renderings of this piece involve various degrees of uncertainty and unpredictability of sonic combinations—an aspect that is reinforced by the use of “shadow” sounds: similar sonorities that come sometimes from the piano, sometimes from the tape and that generate a perceptual (con)fusion for the listener. The author’s own transcription of this piece for orchestra in four groups aims at further exploring and developing specific practices of multi-temporality, focusing on the collaborative creative performance, where two conductors, reading two fully independent scores, have to develop a sense for a “chamber musically oriented” performance. Recently premiered in Cologne (Germany), this orchestration points to new modes of exposing and performing multi-temporal pieces.

*Keywords:* Luigi Nono; multi-temporality; transcription; differential repetition; tape music

In September 1971, Luigi Nono (1924-1990) started working with Maurizio Pollini (b. 1942) at the Studio di Fonologia della RAI, in Milan, for the composition of *Como una ola de fuerza y luz* (1971/72) for piano, soprano, or-

chestra, and tape. Having recently returned from an extensive South-American tour, Nono was excited about the idea of creatively collaborating both with Pollini, as well as with Claudio Abbado (b. 1933), with whom *Como una ola de fuerza y luz* would be premiered almost two years later, on June 28 1972: “Claudio Abbado and Maurizio Pollini: their new musical activity is the development of an artistic partnership into the acquisition and adoption of musical responsibilities that result from the human necessities of our time” (Nono, in Stenzl 1975, p. 143). As this quotation makes evident, Nono was fascinated not only by Pollini and Abbado’s impressive musical and technical qualities, but also by their strong commitment to society, to their engagement in sociopolitical causes, and to their strong, outspoken political positions. Before and beyond the mere making of music was a human component that proved to be quintessential to Nono’s creative collaboration with them, particularly Pollini.

Four years later, starting in December 1975 and in several diverse shorter recording sessions during the year of 1976, Nono and Pollini collaborated on another piece—.....*sofferte onde serene...* for piano and tape—a fundamental work in understanding Nono’s late style and his polemically debated aesthetic and ideological turnabout. The working sessions with Pollini at the Studio di Fonologia della RAI in Milan concerning both pieces (*Como una ola de fuerza y luz* and .....*sofferte onde serene...*) are extensively documented through working tapes and sketches preserved at the Foundation Archivio Luigi Nono, in Venice. A detailed description and analysis of the concrete modalities of the Nono-Pollini collaboration would be out of the scope of this paper and has formed an extensive part of the author’s research (see Assis 2006). Here, however, the focus is on .....*sofferte onde serene...* and how, in this work, several new elements emerged in Luigi Nono’s musical language, namely a new understanding of the use of vertical sound-aggregates (“chords”), the exploration of complex variational and canonical procedures, and, crucially, new modes of organizing “multi-temporalities,” with the piano and the tape following different paths on the same landscape. This piece—written in a moment of personal and artistic crisis for Nono—marks the beginning of his late creative period. It was conceived experimentally (especially the tape production), as its concert rendering involves various degrees of uncertainty and unpredictability of sonic combinations. Nono achieves this, in the first instance, through the use of “shadow” sounds: similar sonorities that come sometimes from the piano, sometimes from the tape, and that generate a perceptual (con)fusion for the listener. This (con)fusion is enhanced by relatively free time relations between piano-live and tape, allowing the performer on

the piano and the performer controlling the sound-projection to intertwine a great variety of sonic rappings.

From an analytical perspective (see Assis 2006, particularly pp. 208-237, and Linden 1989) the piece might be seen as a succession of five units, each with its specific sound material and employing different compositional tools and strategies. Taking into account the durations in the tape and the bars in the score, the five sections of *.....sofferte onde serene...* appear in Table 1.

To provide an example, let us briefly consider the first section. It is made of five different presentations (“variations”) of the basic sonic material—a transparent constellation of twelve pitches. Following the sketches pertaining to the recording sessions (ALN 42.01 and ALN 42.02, see Figure 1), Nono asked Pollini to play these pitches in diverse combinations and successions. The results were recorded almost as a basic sample of sounds, which would be mixed and assembled later by Nono at the mixing desk. It was the concrete recorded sounds that slowly, progressively, defined the precise sequence of sonic events. And if it is very clear that the score and the writing of it is the complete responsibility of Nono (who remains “the composer” in an orthodox sense), it is also true that the sonic input produced by Pollini was of the utmost importance for the definition of the music.



Figure 1. Sketch of recording session ALN 42.04/02.

Table 1. *.....sofferte onde serene...* form synopsis.

Section	Tape	Bars in the score
1	0'00"-2'32" [2'32"-2'45"]	1-25
2	2'45"-4'50" [4'50"-5'00"]	26-49
3	5'00"-9'17"	50-101
4	9'18"-11'49"	102-137
5	11'50"-13'40"	138-155

Beyond the creative collaborative practice between Nono and Pollini is their collaborative performance practice. There has been much discussion (among performers and sound technicians) about how far one might go in the acoustic level of the tape. In recent years the tendency has been to overemphasize the tape, to make it an equally important part as the live piano. This tendency seems to contradict early recordings, including the world premiere, whose recording is preserved in Salzburg at the *Luigi Nono Archiv Jürg Stenzl*, and where the tape plays the role of a soft background: a shadow of a shadow. Independent of that important question, a major feature of the piece is the correspondence between tape and live piano, i.e. the problem of synchronization. Nono, liberating the music from strict prefixed temporal grids (as he still used in *Como una ola de fuerza y luz*) creates for this piece an extremely flexible system based on eight “reference numbers for the tape” (Nono 1977, p. 4). If we consider that, between these reference points, there are time slots of up to two minutes, it becomes clear that there is room for flexibility in terms of vertical coordination. This aspect is extremely relevant, since it creates the basic structure for a concrete multi-temporality where the “live” part (the piano) gains a new dimension—that of being able to generate real differential repetition from one performance to the next. Piano and tape, both built around the same sonic materials (pitches, rhythms, and timbre), enter a dialogue full of echoes and resonances but also of announcements and foreshadowings. That these relations should not be fixed once and for all is a consequence of Nono’s (contemporaneous) new orientation, both aesthetically and politically.

Almost four decades after the premiere of *.....sofferte onde serene...* this work is well established in the broad concert repertoire. Many pianists performing it, however, do not reflect the profound component of multi-temporality that pervades this music. Moreover, the question of reconsidering the piece, of critically rethinking the unpredictability of sonic combinations for every new performance, remains widely unaddressed. It seems pertinent to revisit such questions, particularly from the perspective of new collaborative practices, and particularly on the following topic: how do we establish new layers of collaborative performing activity on top of pieces already originally conceived collaboratively?

### MAIN CONTRIBUTION

After many performances of *.....sofferte onde serene...* (between 1995 and 2012) as a pianist, after a doctoral thesis (1999-2003), and after the realization of a critical edition of its score (2009, supported by the Orpheus Institute

Ghent), the author decided to revisit this work from a completely new angle, making an orchestration both of the piano part and of the tape. In order to further explore and develop specific practices of multi-temporality, two completely different scores were written down: one for the orchestra (on stage) playing what was the piano part, and another one for three groups (positioned around the audience) performing on acoustical instruments what was originally the magnetic tape. The two conductors—reading two completely different and partially independent scores—have to develop a sense for a “chamber musically oriented” performance while conducting over sixty musicians. The focus is thus placed on the collaborative creative performance. Every rehearsal and concert rendering will be concretely different, while retaining the basic musical structure. An aspect that reinforces the fundamental idea behind this orchestration is the concept of “differential repetition,” inspired by the philosophy of “permanent becoming” (Deleuze 1994). Beyond the flexible coordination of temporalities established by the two conductors, the individual orchestral musicians have certain degrees of freedom, especially in the many notated suspensions: spots where their creativity is “locally” demanded. In such moments, the conductor stops conducting for a moment and gives space to the individuals.

Another crucial element of the original composition is the specialization of the tape projection. According to the evidence from the sketches and from the LP produced by the *Deutsche Grammophon* (with Maurizio Pollini) Nono composed a stereophonic tape with some sections in mono. Sections 1, 4, and 5 (see Table 2) were in stereo, whereas the central sections 2 and 3 were in mono. This means that the return of the sound materials from section 1 in section 4 coincided also with a re-opening of the acoustic horizon—from monophony to stereophony. This aspect is currently lost, given the fact that the existing tape is completely monophonic. In the author’s orchestration it is brought back to life: sections 1 and 4 are played by the two external groups (left and right), while sections 2 and 3 are played by the centrally positioned group. For the last section all groups play together. Table 2 summarizes this aspect.

## IMPLICATIONS

This orchestration of *.....sofferte onde serene...* was commissioned by the WDR Cologne and premiered on the 9th of November 2012 at the Kölner Philharmonie with the WDR Sinfonieorchester Köln, conducted by Peter Rundel and Léo Warynski. During the rehearsals several possibilities of vertical coordination between the two musical entities (orchestra on stage and groups

Table 2. Luigi Nono/Paulo de Assis .....*sofferte onde serene...* for 4 orchestral groups.

Section	Bars in the score	Original tape	Orchestral groups
1	1-25	Stereo	Left and right
2	26-49	Mono	Front
3	50-101	Mono	Front
4	102-137	Stereo	Left and right
5	138-155	Stereo	All

in the space) were tried, explored, and worked out. For all the musicians involved in the project this seemed to be an innovative exploration of different temporalities running parallel to each other but coinciding in basic structural points. By re-working a composition that resulted from a collaborative creative practice and that enacted multi-temporalities through the articulation “piano-tape,” this orchestration suggests new modes of presenting and performing multi-temporal music pieces: works with multiple, independent, smoothly-varying tempi. These concrete artistic investigations—where the practice of art functions as a research tool—may lead to new kinds of collaborative *creative practices* and to extended collaborative *performing practices*.

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# The role of texture and musicians' interpretation in understanding atonal music: Two behavioral studies

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Two experiments aimed to inquire: (1) the role of performance and texture in the segmenting of a musical composition during the listening; (2) whether the structure perceived by the listeners depends on processes developing simultaneously with the listening or on an *a posteriori* synthesis; and (3) the role of expertise in segmentation. For each experiment 30 subjects were asked to attentively listen to two versions of an atonal composition, identify the architecture underlying the piece, and mark the boundaries between different segments by pressing the spacebar. The order of presentation of the two versions was balanced. In the first experiment the two performances differed in duration and in many dynamic aspects. In the second experiment the two performances differed only in duration. For both the first and the second experiments results showed a good number of coinciding segmentations in the two performances irrespective of the order of presentation. Musicians indicated a lower number of segmentations than not-musicians, even if many of the chosen boundaries remained the same. The results suggested that texture provided all of the necessary information for representing the pieces during the first listening.

*Keywords:* Music cognition; grouping; segmentation; music representation; auditory perception

In the 1980's Deliège proposed a simple but effective theory: the *Cue Abstraction Hypothesis* (Deliège 1987, Deliège and El Ahmadi 1990, Mèlen and Deliège 1995, Deliège 1996, Deliège and Mèlen 1997). In listening to a piece

some elements stand out, themselves becoming a guide to the processes of categorization and representation of the musical surface. These elements, which Deliège calls *cues*, allow the listener to form a mental plan of the piece by dividing it into chunks on multiple hierarchic levels. The cues represent prototypes of redundant elements; the music would then be analyzed with reference to similarities and differences between the chunks. Deliège's conception of cues is strictly related to the model of categorization elaborated by Eleanor Rosch (2002), which distinguishes two levels in categorization: the horizontal level, based on relations of similarity and contrast between elements; and the vertical level, related to hierarchic levels. Unfortunately, Deliège's model does not take into account the role of the musician's performance. To fill this gap, it is first necessary to define the features of a musical performance depending on the performer. Gingras *et al.* (2011) showed that local tempo modulation is the main variable involved in characterizing the performer's expressive style. This point is in agreement with Palmer (1989). Gingras also found differences between performers in onset asynchrony. These variables (tempo modulation, onset asynchrony) coincide with what a musician can read in the dynamic indications of a score. We can hence define "texture" as the simple sequence of notes that a musician can find on the score of the piece, regardless of the dynamic indications. Another problem related to segmentation is the choice of composition: using tonal music can indeed introduce a bias related to cultural factors. In his model, Lerdahl (1989) suggests that the prolongational structure (strictly linked with dynamic features) has a main role in segmenting atonal music. A segmentation paradigm applied to atonal pieces, then, represents the best way to examine these ideas (Imberty 2000). Concerning expertise, differences in the number of segmentations done by musicians and non-musicians are examined not only in classic segmentation studies but also in analyzing the performance of the same composition by expert musicians (Ordoñana and Laucirica 2010). Koniari *et al.* (2001) found differences in segmentation accuracy with regard to groups of 10 to 11-year-old children with different degrees of training. Olivetti Belardinelli (1996) found differences in musical aptitude among genders with naïve but not with expert subjects. These experiments aim to inquire whether the segmentation of a composition mainly depends on texture or performance. Other variables examined include gender, expertise, first versus second listening, and serial order of presentation.



## FIRST EXPERIMENT

### Participants

30 subjects (M=12, F=18, mean age=27.46, SD=8.86) with normal hearing volunteered. All of the subjects were right-handed and had never received formal musical training.

### Materials

Two versions of *Sequenza VI per viola solo* by Luciano Berio, performed by Christophe Desjardins (1998) and Garth Knox (2006), were used. The performances differed in duration (12'13" versus 13'14") and in dynamic aspects.

### Procedure

Subjects were asked to attentively listen to each version of Berio's piece to capture the structure and press the spacebar in order to mark boundaries between different parts. The order of presentation was balanced across subjects. Metaphor was used to explain the task to the non-musicians. A tutorial trial, with a different and shorter piece, was administered before starting the test. A graphic interface was realized using the software Max/msp (Cycling74) in order to administer the instructions, a tutorial piece, and the test and to collect the data. Analyses were performed using R-packages.

## RESULTS

The effect of independent variables on the number of segmentations was examined through MC analysis. Empiric p-values were calculated using the formula  $p=(r+1)/(n+1)$  (Davison and Hinkley 1997). Results showed an effect of gender ( $N_M=568$ ,  $N_F=1153$ ,  $p<0.001$ ) and a decrease from the first to the second listening ( $N_I=999$  and  $N_{II}=722$ ,  $p<0.001$ ). Each version of Berio's *Sequenza VI* was divided into 24 classes of equal width (average width for performance: A=30.512s, B=34.519s). A new MC simulation was used to study the behavior of a randomized distribution of 852 (performance A) and 869 (performance B) answers in 24 classes. In a macro-analysis, we identified the classes collecting the highest numbers of answers (right tail of the distribution:  $p<0.1$ ). Analysis showed 3 main segmentation areas (MSAs) for performance A (classes 4, 5, and 7) and 3 for performance B (classes 4, 5, and 8). In order to examine the possible overlapping of the segmentations in the two performances, we temporally mapped the score on the basis of the performances. Then, we could mark the relevant segmentations obtained with the

two versions of the piece in the overlapping areas of the MSAs. Analysis showed 15 peaks in version A and 14 in version B, with 12 common pivots (82.75%). For the correlation analysis each performance was divided into 100 temporal classes. The analysis focused on the number of segmentations per class compared to the whole sample. Concerning the two performances, data showed a significant correlation in the zero/shift point ( $r=0.251$ , two-tailed,  $p<0.05$ ), and other significant correlations with the LAGs surrounding the zero point. A stronger correlation ( $r=0.805$ , two-tailed,  $p<0.001$ ) was found between the first and the second listening.

## DISCUSSION

The cross-correlation between the two performances, along with the overlapping found both in the macro and the microanalyses, suggest that segmentation depends on texture more than on dynamics. The very strong correlation between the first and the second listening suggests that the knowledge of the piece plays a weak role in structuring the mental plan of the composition. The only difference found relates to the number of answers in each hearing, in particular to the false alarms, which decrease from the first to the second listening. The difference related to gender could be explained following Olivetti (1996), considering that none of the subjects were professional musicians.

## SECOND EXPERIMENT

To better investigate the effect of gender a second experiment was carried out with participants of varying experience. Two performances by the same singer were used to focus on the role of duration and to attenuate the influence of dynamic variables. The procedure remained the same as above.

### Participants

30 right-handed subjects ( $M=15$ ,  $F=15$ , mean age=34.16,  $SD=10.64$ ) with normal hearing volunteered. Ten were professional musicians and twenty were non-musicians. Mean years of formal musical training for musicians was 5.4 ( $SD=4.35$ ).

### Materials

Two versions of *Sequenza III per voce solo* by Luciano Berio, both performed by Cathy Berberian (1966, 1969), were used. The performances differed in duration (8'48" versus 6'55").

## RESULTS

Data were analyzed with the same methods used in the first experiment. Analysis showed an effect of duration ( $N_A=499$ ,  $N_B=408$ ,  $p<0.01$ ), order of presentation ( $N_{AB}=524$ ,  $N_{BA}=383$ ,  $p<0.001$ ), expertise ( $N_{MUS}=226$ ,  $N_{NOMUS}=681$ ,  $p<0.001$ ), and first versus second hearing ( $N_I=532$ ,  $N_{II}=375$ ,  $p<0.001$ ). No effect of gender was found. For non-musicians, women tended to indicate fewer segmentations than men ( $N_F=351$ ,  $N_M=330$ ,  $p<0.1$ ), while the opposite occurred for musicians ( $N_F=121$ ,  $N_M=105$ ,  $p<0.001$ ). Data showed 4 MSAs for performance A (classes 1, 3, 5, and 12) and 5 for performance B (classes 3, 5, 12, 15, and 20), with three common areas. We isolated 4 peaks in performance A and 5 in performance B, with three common pivots (67%). Cross-correlation analyses between the performances showed significant results in LAG 0 and 2 ( $r=0.242$  in LAG 0, two-tailed,  $p<0.05$ ). As in the first experiment, we found a very strong correlation between first and second listening ( $r=0.773$  LAG 0, two-tailed,  $p<0.001$ ).

## DISCUSSION

The second experiment supported the results of the first, with additional information. First, a longer work increases the number of segmentations if not merged into a wide set of different dynamic features. Second, differences due to gender only pertain to naïve listeners.

## GENERAL DISCUSSION

We present here a quick summary of the main results of our study. The auditory segmentation of a composition mainly depends on the texture, while the dynamic features only have a weak influence on this task. Segmentation depends on the detection of patterns of similarity. The only difference between the first and the second listening is in the number of segments indicated by the subjects, not in their placement. Duration of the piece can influence the number of segmentations. Finally, expertise reduces the number of segmentations, perhaps because it allows the listeners to represent the composition to higher hierarchic levels. Expertise also modifies the differences between genders, nullifying the gap between the number of segmentations marked by males and females.

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# Collaborative understandings in the preparation of a new work for viola and piano

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The interpretation of a musical work can draw on multiple sources, including aural experiences, metaphors, written texts, and other works by and interactions with the composer. These “experiential anchors” resonate with previous musical experiences to inform an “interpretive platform” from which a performer’s practice and performing process develops. As such, the first stage of learning a new work is vastly different for canonic repertoire than it is for a piece that is newly composed. This paper reports findings from a project of commissioned works that were received without explanatory program notes from the composers. This enabled a unique interrogation of the process through which an interpretive platform is built and negotiated. Focusing on a work for viola and piano composed by one of the authors, the collaborators share their individual interpretive frames with each other for the first time as part of the paper-writing process. The subsequent response and rethinking of the work, when underlying compositional thinking is given, is described as dialogue. The paper uncovers some of the differences and intersections that may lead to a collaborative interpretive platform. They also reveal insights into the hierarchical relationship between creator and interpreter.

*Keywords:* new music; collaboration; interpretation; practice-led research

Collaborative understandings within a chamber music duo are concerned with seeking an interpretation of the work that is satisfying to both performers. This paper investigates the collaborative understandings that developed while learning a new viola and piano work titled *Into the Sun* (Blom in press). One of several works commissioned for a project titled *Australia East and*

*West*, it was submitted without explanatory program notes from the composer. Delaying any conversation about compositional thinking enabled the researchers to interrogate the interpretative process as it occurred individually and, later, as it developed into a collaborative understanding. The project, therefore, considered the interpretation of the musical artifact in terms of output and process at each of its stages.

While there is a growing literature on learning a work new to the performer (Hallam 2001), less emphasis has been placed on approaching music that is newly composed. One exception is Clarke *et al.*'s (2005) study of preparing the piano work *entre-temps* by Bryn Harrison. The study prompted pianist Philip Thomas to advocate for further research into "...the relationship between notation and intention, and how performers take an active role in the creative act of forming the material" (Clarke *et al.* 2005, p. 41). Little evidence was found of "any substantial change in Philip's approach [interpretation] over the rehearsal period" (p. 61). This led to questions about whether there was not some situation in which the performer "thinks it his responsibility to change in this piece," and to ask whether there was a "lack of imagination? Or even the abdication of a performer's responsibility?" (p. 61).

Feld (1994, p. 86) argued that as one listens to music, one works through "the dialectics in a series of 'interpretative moves', developing choices and juxtaposing background knowledge." As such, "we rarely confront sounds that are totally new, unusual, and without experiential anchors. Hence, each experience in listening necessarily connotes prior, contemporary, and future listenings" (p. 83). In line with this, Viney and Blom (2013) identified the need to build an "interpretative platform" from which to learn new and conceptually challenging works.

## METHOD

### Participants and materials

The study adopted a practice-led research approach. The participant status of the two researchers presented a unique opportunity to research the development of an interpretative platform from within the practice. In order to expose the process and reveal the collaborative dialogue, the practice-led research was positioned within analytic autoethnography. Accordingly, the participant researchers were each: "(1) a full member in the research group or setting, (2) visible as such a member in published texts, and (3) committed to developing theoretical understandings of broader social phenomena" (Anderson 2006, p. 373).

*Into the Sun* (2010) was written for a project of new music for viola and piano. It draws on traditional styles yet still requires the establishment of an “interpretative platform” from which the performers shape the work.

### **Procedure**

Drawing on the successful approach employed by Clarke *et al.* (2005), data were amassed through journaling, email dialogue, and face-to-face discussion. While Ginsborg and King (2007) focused beyond the individual reflective journal to analyse discussion between members of duos involving both professionals and students, in this paper the written dialogue takes the first-person form used by Määttänen and Westerlund (2001).

## **RESULTS**

### **The viola player**

“I have worked with the pianist-composer as a research collaborator. Through these interactions I have heard several of her works. Learning *Into the Sun* means reorienting existing interactions so that the collaborative writing ceased to be about the practice and began to come from within it.

The lack of program notes has prompted some assumptions: for example, the title of the work and the broader project led me to imagine the Western Australian sunset. Similarly, mid-way through the work there is figure reminiscent of Brahms’ *Sonatasatz* (the scherzo from his F.A.E. sonata). Unsure as to whether this reference was intended, I went back to the score to look for hints about the length and weight of each note. I finally determined to ‘play it like Brahms’ and see what happened! It was this heavy interpretation that prompted the suggestion of a double-stopped note for some iterations of the figure. Similarly, the rhythm of one passage reminded me of Ross Edwards’ *Ecstatic dance II*, familiar in its arrangement for viola and cello. This resulted in a playful, dance-like interpretation of the passage.

The haunting opening phrase reminded me of early 20<sup>th</sup> century works for viola by Fürst and Hindemith, who drew uniquely sonorous tones from the instrument; hence there were works of reference. Most works in the classical music repertoire have multiple interpretations from which the performer can draw, but these can also be constraining factors. My experience of rebelling, with new interpretations of canonic repertoire, is that this sense of freedom takes confidence to uphold. This is partly because explaining and defending new interpretations is difficult for performers, who often have little voice beyond program notes and introductions.”

## The pianist-composer

“*Into the Sun* was begun late in 2008. In this year I had written *Phoebus Fire*, which brings together texts about the sun. One text drew on the image that opens Julian Barnes’ novel *Staring at the Sun*. The text describes a WWII airman who is flying back to the UK. Becoming dazzled and confused as the sun appears to rise twice, he plunges to his death in the sea below. This ‘airman’ section became part of *Into the Sun*. Driving in Sydney and flying west to Perth can often be into the sun, so I am pleased to know of Dawn’s similar thinking.

The work is in four sections, and harmonically it bases itself on the initials of the two performers, D and B. The opening has some evocation of the sun rising and briefly references chords that ‘represent’ clouds. These references were drawn from my short piano works titled *Cloud Studies*. The moving-quaver second section has the idea of changing meters, creating the ‘heavy’ dance quality of progressive rock.

I remembered a work for viola and piano where the piano is above the viola in a reversal of roles, so to speak. We eventually discussed the influence because I wanted to identify the piece, which was Brahms’ *Sonata* for viola and piano. The lyrical third section is the ‘airman’s’ song. After its even softer reprise, the work reintroduces the ‘progressive rock’ briefly before returning to the ‘setting of the sun’ in the final bars. After reading Dawn’s comments, I am interested to see if the ‘sunset’ in question, that of the airman, is of interest to her.”

## The viola player

“I’m shocked, because the ending of *Into the Sun* is so peaceful and tranquil. I have prepared this closing section to create a mood of near stillness, and in my mind I had a serene image of the setting sun; but the passage is actually about someone’s death. There is no doubt that this will change the way I see this section, and in fact the whole piece. I need to play through the work to see the extent to which it will influence my thinking....

Playing through the work again, I am surprised at the impact this new knowledge has had on every aspect of my interpretation. The Ross Edwards-like dance figure was not part of Diana’s compositional thinking. It now appears to me as a startled moment when it was not possible for the pilot to see ahead; more like a dance with death. The Brahms-derived figure is now much more serious, and there is an element of danger from the moment the second section starts. The ending now represents the silence that falls when, in day-



light, the pilot and his aircraft have disappeared into the ocean. I am mindful that I have replaced one set of assumptions with another.

I discovered that ‘double sunset’ relates to WWII Catalina seaplanes, which took off from the Swan River in Perth. I would like to ask whether this was part of Diana’s interpretive frame. If not, does this knowledge add to the frame or distort it? It is evident that performers can take a descriptive title and completely misinterpret a work. I reflect that we can also ‘bow’ to the thinking of the creator and to the ‘accepted’ interpretation of someone other than the creator. Allowing this to lead our interpretation and thinking effectively locks us out of the creative process.”

### **The pianist-composer**

“I didn’t have this knowledge about the seaplanes. Please don’t take the airman story too literally in the music—don’t read too many deep and dark details into it.”

## **DISCUSSION**

The collaborators have now rehearsed the work with a shared dialogue, and the piece has developed a strong sense of mood, dynamic range, and momentum. However, the comment about whether to work, with one’s own interpretation of the title, will ‘bow’ to knowledge that has been given is at the heart of this discussion. In the first stage of learning, and working directly with the composer, the viola player was cautious about making suggestions that altered the score. Once these were accepted, the violist began to act as a collaborator. This was far removed from the “lack of imagination” noted by Clarke *et al.* (2005) and led to the realization that the performer’s experience of autonomy is often diminished by the expectations of an established work or the “finality” of a written score. Indeed, performers in the Western classical tradition are rarely given opportunities to be part of the creation itself.

In this study, the process through which individual and then collaborative understandings were built and negotiated to shape an “interpretative platform” brought the players face-to-face with the issue of how much compositional knowledge is useful and how much becomes dangerous. Eventually, tempering was required as part of the collaborative discussion, which led to a shared understanding. Both collaborators found the experiential anchors useful initially, but their roles faded as the piece took on its own shape and life. This process is what is required when performers, who are also listeners, approach a piece of music that is new to them. Of course, the nature of the piece influences the complexity of the approach.

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Thematic session:  
The science of singing



# Effect of singing training on total laryngectomees wearing a tracheoesophageal voice prosthesis

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The aim of this study was to assess the effect of a program of singing training on the voice of total laryngectomees wearing a tracheoesophageal voice prosthesis, considering the quality of alaryngeal phonation, vocal extension, and the musical elements of tuning and legato. Five laryngectomees wearing a tracheoesophageal voice prosthesis completed the singing training program over a period of three months, with exploration of the strengthening of the respiratory muscles and vocalization and with evaluation of perceptive-auditory and singing voice being performed before and after 12 sessions of singing therapy. After the program of singing voice training, the quality of tracheoesophageal voice showed improvement in the persistence of the general degree of dysphonia for the emitted vowels and for the parameters of roughness and breathiness. For the vowel “a,” the pitch was displaced to grave in two participants and to acute in one, and remained adequate in the others. A similar situation was observed also for the vowel “i.” After the singing program, all participants became in tune and most of them showed the presence of legato. The vocal extension improved in all participants. Singing training seems to have a favorable effect on the quality of tracheoesophageal phonation and on singing voice.

*Keywords:* alaryngeal voice; voice training; vocal extension; singing training; laryngectomy

Perceptive voice pitch and loudness represent aspects of the dynamics of the spoken or singing voice that can be explored and used as expressive resources for the rehabilitation of individuals submitted to ablative larynx surgery due to cancer. The spoken voice differs from the singing voice in terms of the utilization of vocal resources resulting from specific adjustments for different emissions that may help promote the quality of life and the refinement of speech of total laryngectomees.

The multidisciplinary conduct in cases of surgical oncology should favor not only the excision of the tumor and oncologic control, but also the rehabilitation of the individual for life in society (Blom 2000). Thus, multidisciplinary work involving the head and neck surgeon, a speech therapist, and a singing teacher is relevant for total laryngectomees speaking with a tracheoesophageal prosthesis in order to favor their oral communication and to elicit or refine the musical profile of those who have it, contributing to their quality of life. The process of alaryngeal voice rehabilitation needs to advance in terms of the quality of communication, permitting the acquisition and utilization of a satisfactory alaryngeal emission capable of reproducing the intentional and emotional aspects of these individuals during conversation with their interlocutors.

The objective of the present study was to evaluate the effect of a program of singing training on the tracheoesophageal voice of total laryngectomees rehabilitated with a tracheoesophageal prosthesis, considering the quality of alaryngeal voice, the vocal extension, and the musical elements of tuning and legato.

## METHOD

### Participants

Five total laryngectomees aged on average 49.8 years (two women and three men, ranging from 33 to 63 years old), completed the program of singing training

### Materials

The voice material of all laryngectomees was collected and recorded using a Sony® digital video camera adapted to a tripod.

After recording the voice for perceptive-auditory analysis, each total laryngectomee had their singing voice recorded while using a Yamaha® PSR E403 keyboard.

## Procedure

### *Evaluation of tracheoesophageal voice quality*

The participants were instructed to emit the prolonged vowels “a,” “i,” and “u” after inspiration in the maximum phonation time with habitual vocal intensity, velocity, and pitch. The validated categorical scale GIRBAS (Dejonckere *et al.* 1996) was used to characterize the voice quality of total laryngectomees wearing a tracheoesophageal prosthesis. The pitch parameter was rated as adequate (A), grave (Gr), or acute (Ac) for gender and age, with Gr and Ac being accompanied by the degree of severity of deviation, i.e. mild (1), moderate (2), or severe (3).

### *Evaluation of singing voice*

To determine the vocal extension within one octave, i.e. a scale of eight notes (do, re, mi, fa, sol, la, ti, do), each participant was instructed to emit the vowels “a,” “i,” and “u” after inspiration, in the same tone presented on the keyboard. The type of breathing was evaluated visually during the emission of the vowels “a,” “i,” and “u” during the training session. Next, the participant was asked to sing *Happy Birthday* for analysis of the musical elements of tuning and legato. These parameters were characterized before and after the 12 training sessions as “Absent,” “Present,” or “Present Plus.”

### *Singing voice training*

Each total laryngectomee was submitted to singing training consisting of a weekly trial of 30 minutes for a period of three months (12 sessions) based on the following hierarchically arranged techniques: (1) exercises for the strengthening of respiratory muscles for singing and (2) training to perform the vocalizing exercises executed within a musical scale of eight notes (do, re, mi, fa, sol, la, ti, do), accompanied by the keyboard.

## RESULTS

The perceptive-auditory evaluation of the quality of tracheoesophageal voice after the program of singing voice training revealed improvement or permanence of the general degree of dysphonia (G) for the vowels emitted as well as for the parameters of roughness (R) and breathiness (B). Asthenia (A) continued to be absent after the proposed training, and strain (S) was found to be worse only for the emission of the vowel “i.” After singing training the insta-

bility parameter (I) was found to be moderate for all participants during the emission of the vowel “i.”

Before singing training, the pitch parameter was characterized as adequate for most of the participants according to the speech therapist raters. After training, pitch shifted to grave (Gr2) for the vowel “a” in two participants and to acute (Ac2) in one, continuing to be adequate in the remaining ones. A similar situation was also detected for the vowel “i,” with one case of acute pitch (Ac2) and one case of grave (Gr1) pitch, and the remaining ones being adequate after training. An acute pitch was not detected only for the vowel “u.”

Regarding the evaluation of the musical elements, before singing training, good tuning was considered to be absent in three individuals and present in two. After the singing program, all participants presented good tuning. Before training, legato was present in three participants and absent in two. After the training program, three participants showed a greater presence of legato and only one individual continued not to present it according to the evaluation of singing voice.

The mean extension obtained for the vowels “a” and “u” was 14.7 semitones and the mean extension obtained for the vowel “i” was 15.7 semitones.

## DISCUSSION

For the participants who completed the program of singing voice training, the perceptive-auditory evaluation demonstrated maintenance or improvement of the parameters of the general degree of dysphonia, roughness, and breathiness after the 12 sessions of singing therapy. This fact suggests that the program offered was favorable for these vocal parameters, influencing the new anatomical conformation of the sound source, considering the individual clinical characteristics that might have influenced the distinct responses of improvement, such as time of surgery, radiotherapy, and cervical dissection.

A worsening of vocal strain for a minority of participants was identified only for the vowel “i” after the singing program, justified by the greater difficulty of the pharyngeal musculature to adapt to the conditions necessary for its production, with excessive contraction and with an effort in the reproduction of the sound compared to a higher pitch. A similar situation was also observed regarding vocal instability in the production of the vowel “i,” which appeared to require more in terms of the behavior of the new sound source to reach phonatory balance. Thus, it would be necessary to evaluate the therapeutic limits versus the duration of the singing program; in other words, the 12 sessions possibly were not sufficient for some of the participants, or they



were sufficient but the anatomophysiological conditions of the subjects represented a limitation.

In the pre-training condition, most of the participants presented adequate pitch, with a minority being characterized as Gr1, as commonly observed in the literature, which demonstrates that the pitch of this population is more grave (Oliveira *et al.* 2005, Hilgers *et al.* 2006). Because this is a new sound source and because it is necessary to understand its behavior during the emission of the different sounds, the vowels “a,” “i,” and “u” were contemplated for the analysis of the vocal parameters explored in the present study, based on the basic physiology of laryngeal phonation.

After singing voice training, the emission of the vowel “u” did not present acute pitch in any of the participants, probably due to the more grave nature of its production and possibly due to the anatomical conformation favorable for this behavior. However, for the remaining vowels there was a characterization of pitch Ac2, possibly related to the greater effort of the pharyngo-esophageal muscles for its production, resulting in vocal strain and in more acute pitch perception.

Perhaps the analysis of the type of breathing and air pressure threshold of total laryngectomees before and after singing may contribute to the quality of the vocal findings.

Singing training had a favorable effect on pitch modulation and vocal extension, showing the importance of this work with pitch for the adapted behavior of the new sound source, the digestive tract, for the production of sound with an appropriate pitch adjustment during conversation, and with the voice being no longer monotonous. There is no literature regarding the vocal extension of total laryngectomees for comparison with our data, with studies in this area being necessary since this is an important parameter for the evaluation of the physiological limits of the vocal mechanism (Speyer *et al.* 2003, Costa *et al.* 2006).

Despite the improvement achieved with singing voice training, vocal extension was lower compared to literature data, which report values of 4.5 to 5 octaves for individuals with intact vocal folds (Vargas *et al.* 2005, Rocha *et al.* 2004).

Both legato and tuning improved, with most participants showing “Present Plus” characterization after singing voice training. Legato was absent in only one participant after training, perhaps owing to his anatomofunctional limitations after complementary radiotherapy following surgery.

The present proposal led to a reduction of the degree of roughness and to improved pitch in the subjects studied, in addition to permitting the inclusion

of a total laryngectomy in the choir of the local church formed by individuals with an intact larynx.

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# Breathing imagery moderates vibrato rate

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This study investigated acoustic change in singers' vibrato following imagery and non-imagery tasks. One task, involving breathing imagery, produced significantly more moderate and regular vibrato rates. Another task, involving imagery unrelated to breath function, produced erratic but significantly slower vibrato rates. A non-imagery task related to breath function produced no significant changes. Sound pressure level results indicated that dynamic changes were not responsible for the changes observed in vibrato. The findings of this study indicate that breathing imagery regulates singers' vibrato in a manner consistent with that of a more proficient, warmed-up voice.

*Keywords:* breathing; imagery; vibrato; warm-up; tone quality

Imagery in which the breath or an abstract concept of energy is directed high into the head or deep into the body has played an important role in voice teaching since at least the sixteenth century (Stark 1999). Similar imagery is used by instrumentalists and dancers, and is also found in Middendorf technique, Qigong, meditation, and traditional Chinese healing (Moorcroft 2007). It is claimed to assist with spinal alignment (Brünner 1993, Sweigard 1975), diaphragmatic breathing (Baeumer 2004, Brünner 1993), stress and relaxation (Baeumer 2004), mental focus, performance anxiety (Langeheine 2004, Nordin and Cumming 2005, Stoyva 2000), and panic attacks (Bartley and Clifton-Smith 2006). Vocalists suggest that such imagery also balances the upward and downward forces in the stylo-pharyngeal muscle complex, raises the soft palate and lowers the larynx, and maintains larynx stability while freeing laryngeal constriction to create an "open throat" (Patenaude-Yarnell 2003, Vennard 1968, Yurisich 2000). Thus, tone quality improves (Dunbar-

Wells 1999, Miller 1977, Vennard 1968) and, if used pre-performance, it serves as a silent warm-up (Linklater 1976, Rodenburg 1992).

The recent discovery of the mirror neuron system supports claims that imagery activates neural responses triggering physical adjustments that are often beyond conscious control (Aziz-Zadeh and Ivry 2009, Filamon *et al.* 2007). Furthermore, mirror neurons show greater activation the more the individual has a strong sense of the goal to be achieved (Gazzola *et al.* 2007, Johnson-Frey *et al.* 2003), and pedagogical wisdom suggests imagery of sensations directed both upwards and downwards, far from the larynx, presents the singer with a proprioceptive goal. Only the singer with an inefficient, poor quality voice senses the voice solely at vocal fold level (Titze 2001). The accomplished singer's perception of a resonant voice involves sensations throughout the entire body (Brünner 1993, Robison 2001). As reported by baritone Thomas Quasthoff: "it is very important to feel the breathing inside your entire body, and not only in a separated part of your body. The whole human being is the instrument, not only the larynx" (Holmes 2003, p. 264).

If imagery influences stress and relaxation, has a warm-up effect, and enhances tone color, it follows that imagery may affect singers' vibrato. Stress and relaxation levels influence vibrato (Miller 1977, Titze 1994, Vennard 1968, Westerman 1938), and vocal color is determined above all by vibrato (Bartholomew 1937). A stable (Bartholomew 1934), moderate (Miller 1977) vibrato rate is essential for vocal beauty. Mürbe *et al.* (2007) classify vibrato below 5.20 cycles/second as slow, and vibrato above 5.80 cycles/second as fast. Titze (1994) notes that 5.5 cycles/second is the average frequency of Pavarotti and is perceived as particularly desirable by today's audiences. Vocal warm-up exercises facilitate more moderate, stable vibrato rates (Moorcroft and Kenny 2012). This study, therefore, investigated the acoustic effect of imagery and non-imagery tasks on singers' vibrato, and whether any changes observed resembled those generally associated with vocal warm-up.

## METHOD

### Participants

Six classically trained female singers, each from a different studio, participated. Three were studying tertiary level singing, and three had completed tertiary studies and sang professionally (mean age=29 years, SD=7 years; mean years of vocal study=13, SD=5).

## Materials

Singers were asked to learn a set eight bars from Villa-Lobos' *Bachianas Brasileiras* No. 5 Aria (range= $D_4$  to  $F\#_5$ ), given the print music and a recording of the accompaniment, and requested not to warm-up on the recording day. To ensure singers perceived all interventions as equally valid, the project was described as investigating the vocal effect of varying levels of relaxation.

For the recording, singers were fitted with a head-mounted AKG C-477 microphone connected to a DAT Marantz CD recorder model 640 via a Behringer Ultragain Pro MIC-2200 preamplifier. A pre-recorded accompaniment heard through Beyerdynamic DT331 free-field earphones enabled the voice to be recorded without accompaniment. Singer sound pressure level (SPL) was calibrated using two different dB readings of a 1000 Hz pure sine wave tone and a Rion Integrating Sound Level Meter model NL-06. Recordings were converted to graphic form using Phog Interactive Phonetography System Version 2.0 and assessed using Soundswell Core Analysis Version 4.0.

## Procedure

Singers recorded the excerpt before and after three non-vocal, 25 minute tasks. Each singer performed the tasks in a different, randomized order in a single sitting. One task involved imagery of the breath directed up and down as far from the larynx as possible. Another task used Braille music code, enabling the singer to engage in imagery related to music. A third task was a non-imagery activity requiring the completion of a cloze passage about breath function. For a full account of each intervention see Moorcroft (2011).

Spectrograms of the partials were produced from the 11 longest notes in each solo. A cursor was manually placed on the peaks and troughs of the vibrato undulations, and the time and frequency automatically recorded. Vibrato rate and extent were compared with SPL, which was established from the graphic representation of upper and lower calibration tones.

## RESULTS

Only the more experienced singers produced mean vibrato rates for the solo between 5.35 and 5.75 cycles/second for all three pre-intervention conditions. The less experienced singers produced mean vibrato rates that were either faster or slower. However, after the breathing imagery, faster mean vibrato rates became slower, slower mean vibrato rates became faster, and even the more experienced singers' mean vibrato rates compacted to between 5.4 and 5.6 cycles/second. Although no significant change occurred in the group

mean (mean change=0.13,  $p=0.15$ ) or median (mean change=0.06,  $p=0.47$ ) vibrato rates, there was a significant reduction in the range of mean vibrato rates for the group (mean change=0.52,  $p=0.02$ ). Also, within individual solos, the mean vibrato rate SD from the 11 longest notes showed a significant decrease (mean change=0.17,  $p=0.02$ ). Thus vibrato rates became more moderate and even, resembling the acoustic changes that follow a vocal warm-up. In contrast, after the Braille music imagery, there was a significant reduction in the group mean (mean change=0.17,  $p=0.01$ ) and median (mean change=0.18,  $p=0.01$ ) vibrato rates, and no significant reduction in the range of mean vibrato rates for the group (mean change=0.19,  $p=0.10$ ). Within individual solos, the mean vibrato rate SD from the 11 longest notes increased for all but the most experienced singer in the group (mean change=0.07,  $p=0.07$ ). After the cloze passage on breathing, no significant changes were found in either the group mean (mean change=0.0,  $p=0.87$ ) or median (mean change=0.03,  $p=0.38$ ) vibrato rates, nor in the range of mean vibrato rates for the group (mean change=0.05,  $p=0.64$ ) or the SD of vibrato rates within individual solos (mean change=0.01,  $p=0.71$ ).

Paired t-test results showed that after the breathing imagery, notes with vibrato rates slower than 5.00 cycles/second became significantly faster ( $t=-5.31$ ,  $p=0.001$ ), while notes with pre-test vibrato rates 6.00 cycles/second or faster became significantly slower ( $t=3.63$ ,  $p=0.002$ ). After the Braille music imagery, notes with vibrato rates slower than 5.00 cycles/second became slower still ( $t=2.34$ ,  $p=0.044$ ), but not notes with vibrato rates 6.00 cycles/second or faster ( $t=1.41$ ,  $p=0.180$ ). For the cloze passage on breathing, no significant pre to post-test findings resulted from either sub-group.

In addition, within individual notes the cyclic undulations comprising the vibrato became more regular after the breathing imagery. A significant reduction in notes with vibrato rate SDs greater than 0.50 cycles/second was found after the breathing imagery ( $t=-3.90$ ,  $p=0.002$ ) but not after the Braille imagery ( $t=-0.13$ ,  $p=0.902$ ) or cloze passage ( $t=1.10$ ,  $p=0.288$ ).

Overall, although the breathing imagery consistently impacted the less experienced singers the most, the vibrato rate of all singers improved after the breathing imagery in a manner normally observed in voices following vocal warm-up (Moorcroft 2011, Moorcroft and Kenny 2012) and extensive training (Mürbe *et al.* 2007). Vibrato extent was not significantly affected by any intervention. SPL results showed no consistent association with either vibrato rate or vibrato extent, indicating that pre- to post-test changes in dynamics were not responsible for the changes observed in vibrato rate.

## DISCUSSION

Traditional vocal imagery in which the breath is directed both as far above and below the larynx as possible appears to moderate singers' vibrato rates in such a way as to reflect a more warmed-up, proficient voice. Although an image may serve many purposes, because vibrato rate is closely linked to singers' stress and relaxation levels, it is hypothesized that one purpose of breathing imagery is to prepare mind and body by balancing the performer's levels of mental and physical activation according to the demands of the task ahead. Future research will need to test this hypothesis.

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# Position of the larynx during lyrical singing in professional and amateur female singers: Preliminary results

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The aim of this study was to analyze the position of the larynx of professional and amateur singers during singing using measurements of the longitudinal distance between vocal folds and the hard palate. In the study 36 female singers were analyzed; 18 of them were professional singers and 18 were amateur, classified as soprano or mezzo-soprano. In order to obtain anatomical images, each participant underwent video-fluoroscopy, being instructed to sing vocalizations in *do*, *re*, and *mi* major with an extension of one octave with the vowels “A,” “I,” and “U” sustaining the superior note. Descriptive statistics were adopted. There was no difference in the longitudinal distance between the vocal folds and the hard palate between sopranos and mezzo-sopranos in either the amateur or the professional group, and when the two groups were compared, identical values were detected. Amateur singers showed, while in rest, they had a shorter distance in the vowels “A” and “U” in tones *re* and *mi* and in the vowel “I” in tones *do*, *re*, and *mi*. Professional singers had the largest distance between the vocal folds and palate compared to the rest in all images, demonstrating the domination of extrinsic muscle adjustments for the production of singing voice.

*Keywords:* voice quality; voice training; position of the larynx; professional singers; amateur singers

The characteristics of the singing voice depend on the anatomofunctional interaction between the components of the larynx and of the vocal tract, influenced by the morphophysiological particularities of each individual associated with acquired factors such as vocal well-being and the phonoarticulatory adjustments, and the adjustments of the extrinsic musculature of the larynx

achieved with speech therapy and singing work for voice enhancement (Lovetri *et al.* 1999).

The physiological bases of singing and the mechanisms of the singing voice can be investigated by various methods in order to permit the analysis of vocal production (Shipp and Izdebski 1975, Sundberg 1974, Morozov 2002, Dmitriev 2004). Over the last few decades, computerized programs have been used in order to obtain normative data, a better acoustic comprehension, documentation and monitoring of the efficacy of training, and an instrument for the early detection of vocal and laryngeal problems of the singing voice (Sundberg 1977, Titze 2001). Analysis of radiological images of singers during singing has confirmed that each voice type has a determined length of the vocal tract, showing conformity between vocal classification and position of the larynx (Dmitriev 2004). After a certain time of training, singers, often unconsciously, maintain their larynx in a determined position in their neck, leading to a shorter or longer vocal tract. The dimensions of the vocal tract are influenced by individual morphology and by articulatory adjustments and are thought to be relevant for the characteristics of the singing voice and possibly for vocal classification (Roers *et al.* 2009a, 2009b).

In addition to the individual morphophysiological differences, voice tests used for the analysis of the source and filter, time, and type of training of the singing voice, as well as being a professional or amateur singer, among other aspects, seem to influence the mode of utilization of the phonoarticulatory structures for sound production (Pehlivan and Denizoglu 2009, Iwarsson and Sundberg 1998).

Despite the very large number of aspects that act on the production of the different qualities of the singing voice, it is necessary to identify and standardize the more relevant ones for a better understanding of the cause and effect factors related to the singing voice, providing guidance for the work of voice enhancement, also taking into consideration the individual morphophysiological limits. Based on the hypothesis that movement of the larynx differs among singers with distinct vocal experience, the aim of the present study was to analyze the position of the larynx of professional and amateur singers during singing, using measurements of the longitudinal distance between vocal folds and the hard palate.

## METHOD

### Participants

Participants were 36 female singers from choirs and soloists from the region; 18 of them were professional singers and 18 were amateur singers. There

were 9 sopranos and 9 mezzo-sopranos in each group. The average age was 33, with a minimum of 18 and a maximum of 45 years old. All of the selected participants were in the phase of vocal efficiency (after voice change and before menopause), were nonsmokers, and did not show any laryngeal and/or hormonal change (Boulet and Oddens 1996).

## Materials

*Philips®-BV* equipment was used for the research (Pulsera, Amsterdam, The Netherlands), linked to the image recording apparatus *Philips® MDVDR-100-Medical DVD Recorder* (Amsterdam, The Netherlands).

## Procedure

All singers were submitted to evaluation of the dynamic physiological image of the larynx by videofluoroscopy. During examination, each participant remained sitting comfortably in a chair in a profile position in relation to the radiation ampoule. A five-cent *real* coin was fixed on a tiara placed on the singer's head to serve as a fixed point which was used as a parameter for the measurements. Each participant was first instructed to remain silent during the videofluoroscopy procedure. Next, each one was asked to sing the vocalization, which involves an extension of one octave, with the vowels "A," "I," and "U," in the *do*, *re*, and *mi* tones, sustaining each time the higher note (see Figure 1).

Ten images of each singer were selected using the *Vegas®* software, one of them obtained at rest and nine obtained during the execution of vocalization, one for each vowel in *do*, *re*, and *mi*. The longitudinal distance between the vocal folds and the horizontal lamina of the hard palate was measured in each image and recorded in millimeters with the *ImageJ®* software always by the same examiner, who was trained for this analysis. For data analysis, we adopted descriptive statistics.



Figure 1. Vocalization used during the exam.

## RESULTS

The results of the measurements showed that, at rest, the mean longitudinal distance from the vocal folds to the hard palate in amateur singers was 70.97 mm for the sopranos and 68.08 mm for the mezzo-sopranos. During singing, the mean ranged from 65.75 to 71.69 mm for the sopranos and from 63.24 to 69.83 mm for the mezzo-sopranos (see Table 1).

In the professionals, the distance from the vocal folds to the hard palate at rest was 63.95 mm for the sopranos and 65.75 mm for the mezzo-sopranos. During vocalization, the mean ranged from 70.47 to 72.8 mm for the sopranos and from 70.68 to 75.56 mm for the mezzo-sopranos (see Table 2).

Comparing the overall means of the amateur singers to the professional singer groups, at rest, in each of the top notes vocalized, we can see that the amateur singers presented a shorter distance in the vowel "A" and "U" in *re* and *mi* and in the vowel "I" in all tones. The professional singers showed a greater distance in all images (see Table 3).

Table 1. Means of length of the vocal tract of amateur singers.

Voice classification	Mean of length of the vocal tract (mm)									
	Rest	"A"do	"A"re	"A"mi	"I"do	"I"re	"I"mi	"U"do	"U"re	"U"mi
Soprano	70.97	71.69	71.07	70.79	66.69	66.44	65.75	69.87	69.45	67.81
Mezzo-soprano	68.08	69.83	66.11	68.05	67.74	67.52	63.24	69.34	67.00	65.66

Table 2. Means of length of the vocal tract of professional singers.

Voice classification	Mean of length of the vocal tract (mm)									
	Rest	"A"do	"A"re	"A"mi	"I"do	"I"re	"I"mi	"U"do	"U"re	"U"mi
Soprano	63.95	70.99	72.80	72.33	71.43	71.38	70.47	72.48	72.42	70.50
Mezzo-soprano	65.75	72.04	73.37	73.04	71.29	72.03	71.02	75.58	75.56	70.68

Table 3. General means of length of the vocal tract of amateur and professional singers.

Voice classification	General mean of length of the vocal tract (mm)									
	Rest	"A"do	"A"re	"A"mi	"I"do	"I"re	"I"mi	"U"do	"U"re	"U"mi
Amateur singers	69.52	70.76	68.59	69.42	67.21	66.98	64.49	69.61	68.22	66.73
Professional singers	64.85	71.56	73.09	72.69	71.36	71.71	70.75	74.03	74.04	70.59

## DISCUSSION

Improvement of joint work between speech therapists and singing teachers is necessary to refine the quality of the singing voice, considering the methods of evaluation and the respective vocal training. Within this context, we emphasize the need for singing teachers to understand the anatomophysiological basis of the production of determined sounds in order to facilitate students' learning, which is often limited to auditory perception and to trial and error attempts (Lovetri *et al.* 1999).

Complementing the perceptive-auditory evaluation with visual and quantitative analysis of vocal production by means of laryngeal images (Roers *et al.* 2009a, 2009b, Lovetri *et al.* 1999) it tends to favor the learning and refinement of singing voice and may contribute to the scientific sphere, allowing methodological reproduction and the establishment of normative and reference values for this population.

The professional singers maintained the larynx below the rest position during vocalization for all vowels and tones, with a significant difference for the vowel "U" in the *do* and *mi* tones. According to the vocal classification, the soprano professionals had shorter vocal tract during the singing voice when compared to mezzo-sopranos in the same condition, in agreement with the study of Roers *et al.* (2009a, 2009b) in which such significant difference was attributed mainly to the length of the pharyngeal cavity. However, the professional singers, both sopranos as mezzo-sopranos, presented the greatest distance between the vocal folds and the hard palate compared to the rest moment in all images, inferring that the technique of singing and training time promoted the field of extrinsic adjustments for a long-term feature associated with more serious tone and vowels employed, reflecting the lower position of the larynx and stretching the vocal tract during the singing.

On the other hand, the amateur singers did not present the same pattern as observed in the professionals; sopranos had a shorter distance compared to the rest in the vowel "A" in *mi* and the vowels "I" and "U" in all tones. The mezzo-sopranos had a shorter distance in the vowels "A" and "U" in *re* and *mi* and vowel "I" in all tones. These results may be related to the more acute pitch and to the articulatory nature of the vowel "I," whose production involves anteriorization of the tongue accompanied by laryngeal elevation.

Considering the importance of improving the methods for evaluation and the teaching-learning methods, more studies are needed in the area, including the recruitment of a control group consisting of non-singers in order to compare the morphophysiological findings involved in vocal production and

to establish normative values that might be associated with perceptive-auditory evaluation.

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Thematic session:  
Theoretical perspectives





# Mirror neurons: Imitation and emulation in piano performance

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Research in performance science has grown considerably during the last ten years. But despite the potential for this field to inform educational and professional practice across the arts, its application in the field of piano performance has been largely neglected. This neglect is not surprising, since the area is steeped in traditional methods of performance practice, and suffers also from a mind/body dualism. The pilot study described in this paper will suggest that skilled pianism cannot be achieved exclusively by pursuing the traditional route, in which the student and the teacher sit side by side throughout the piano lesson. It may be better achieved by including some collaboration with other disciplines such as musical analysis, neuroscience, and dance.

*Keywords:* mirror neurons; piano performance; musical analysis; choreography; ballet

Recent research by the neuroscientist Rizzolatti, amongst others, shows that mirror neurons in the brain respond not only when a subject performs a given action, but more significantly when the subject observes someone else performing the same action. This study was designed as a preliminary test of the relevance of this idea to musical performance. In it a pianist, a music analyst, a choreographer, and two dancers from the Royal Ballet, Covent Garden, collaborated in assisting the pianist to control the pacing of the ebb and flow of *Clair de lune* by Debussy through imitation and emulation of the dancers' movements. The study—which spanned a three hour period—began with the analyst who provided the musical template for discussions with the pianist and the choreographer. At the end of the final performance, seven delegates who attended the workshop at the *London International Piano Symposium* (London, February 2013) were asked to assess whether or not there was any

notable improvement in the pianist's control of the pacing of the piece through the imitation and emulation of the dancers' movements.

### MAIN CONTRIBUTION

How *do* mirror neurons mediate understanding of actions performed by others? Rizzolatti and Craighero (2004) suggest that:

The proposed mechanism is rather simple. Each time an individual sees an action done by another individual, neurons that represent that action are activated in the observer's premotor cortex. This automatically induced motor representation of the observed action corresponds to that which is spontaneously generated during active action and whose outcome is known to the acting individual.... [In this way], the mirror system transforms visual information into knowledge (p. 172).

Their evidence is based on examinations of the ventral premotor area of the frontal lobes of monkeys, where they found that certain neurons in the macaque premotor cortex will fire when the monkey performs a specific action with its hand such as grasping or putting food in its mouth. In 2006, Rizzolatti observed that "in humans, as opposed to monkeys, the mirror neuron system codes transitive and intransitive acts and keeps precise track of the temporal aspects of the acts observed" (p. 150). From this evidence it may be viable to assume that "humans with their superior motor repertoire have greater potential for imitation, and above all for learning by imitation" (Rizzolatti 2006, p. 150). This research underpins, in part, the approach taken in the study described here.

In this pilot study, the pianist and the dancers each required a template to work from. The inherent problem for the pianist in performing *Clair de lune* is twofold: first, it is divided into different sections with seemingly unconnected material in each; second, Debussy's temporal instructions need some clarification so that the tempo is controlled without arbitrary fluctuations from one section to the next. With these issues in mind, the first analysis exposes the musical line, and the second presents a pitchless representation of Debussy's notation of the rhythm, which paces the ebb and flow from one section to the next. At the same time the choreographer designed the movement template for the dancers after listening to recordings of the piece by other performers.

## First analysis: Exposing the musical line

Throughout *Clair de lune*, Debussy employs the scale of  $D\flat$  major, either in full or in part, in ascending or descending form. This technique enables the musical line to connect one section to the next in a coherent way, as we shall see. For example (see Figure 1), in bars 1-14 Debussy uses a single descending scale of  $D\flat$  in the treble clef in full, or in part, and again in bars 15-18 where the same scale is artfully embedded in the triple octaves. In bars 19-27, the same scale ascends in octaves in the bass from  $A\flat$  (with an added  $A$  natural in bar 20), before closing on the tonic  $D\flat$  in bar 26. The analysis of bars 38-42 exposes also a descending scale in the bass, which shows Debussy's continuing dependence on scale patterns to produce the musical line, which otherwise would be too fragmented.

**Clair de lune**

SECTION 1  
Andante tres espressif

Claude Debussy

SECTION 2  
Tempo rubato

SECTION 3  
un poco mosso

SECTION 4  
Calmato

SECTION 5  
a Tempo I

Recapitulation of Bars 9-13

morendo jusqu'a la fin

Figure 1. First analysis.

## Second analysis: Connecting the sections

With the musical line established it remains to understand Debussy's temporal instructions which appear at the beginning of each section. Clarifying the meaning of these instructions is essential if the piece is to cohere from one section to the next. For example, the opening of section 2 is marked *tempo rubato*. There is no evidence of Debussy's own views on tempo, but historical evidence is provided by the American pianist Robert Schmitz (1966), who was both a colleague and a life-long friend. He writes that understanding tempo is essential when interpreting Debussy's music, "for an overabundance of rubato, or arbitrary fluctuations in tempo, has long been current" (p. 38). He notes appositely, "what is needed is a basic tempo, which is exact for each succeeding section or break in texture, determined by Debussy's indications" (p. 38). This evidence helps to underpin the view here that the piece should be performed without an abundance of rubato, or arbitrary fluctuations in tempo. On this basis, the author extracted the rhythm (see Figure 2), represented by a single headless note on Bb in the bars on each side of the sections, to show that Debussy's rhythmic notation allows for increases or decreases of movement without altering the tempo.

For example, in bar 14 (see Figure 2a), Debussy uses duplets on the second and third beat of the bar to give a sense of a small *ritenuto*. He continues writing a duplet on the first beat of bar 15 (see Figure 2a) in the second section marked *tempo rubato* and then writes triplets on the second and third

**2a** RHYTHMIC LINK BETWEEN SECTIONS 1 & 2  
Tempo rubato  
Bar 14 Bar 15  
pp

**2b** RHYTHMIC LINK BETWEEN SECTIONS 2 & 3  
dim molto un poco mosso  
Bar 25 26 27

**2c** RHYTHMIC LINK BETWEEN SECTIONS 3 & 4  
dim Calmato  
Bar 42

**2d** RHYTHMIC LINK BETWEEN SECTIONS 4 & 5  
ppp a Tempo 1

Figure 2. Second analysis.

beats to give a sense of an increase in the movement without having to increase the tempo. Between sections 2 and 3 (see Figure 2b) a subtle *ritenuto* is built into the rhythmic notation which is underpinned also by the expression *dim molto*. This tempo may be sustained through the beginning of the third section (bar 27) marked *un poco mosso*, and may remain so until bars 35-41 where a nuanced *accelerando* in the tempo is indicated by the *crescendo* (see Figure 1). Thereafter, a subtle increase in the tempo may continue to be applied until bar 42 where a *diminuendo* suggests slowing down using the rhythm of the left hand semiquavers to smoothly connect to the semiquavers at bar 43 marked *calmato* at the beginning of section 4 (bar 43). Through bar 50 the performer may hear the opening triplets of bar 1 against the semiquavers to link the tempo smoothly into section 5 (see Figure 2d, bar 51) and establish *a tempo 1* as marked. With the musical line revealed in the first analysis, and the suggestion in the second that the increase and decreases of the tempo between the sections should be imperceptible, the template is ready for the pianist to rework their performance.

### **The collaboration**

In the first meeting the pianist and the dancers met for one hour to rehearse their movements to the accompaniment of *Clair de lune* played by the pianist in the traditional way. During the final workshop of two hours duration, the pianist, the analyst, the choreographer, and the dancers met again to discuss the findings of the analysis. This showed that the tempo, which is “exact for each succeeding section” (Schmitz 1966, p. 38) should be maintained throughout, albeit with subtle alterations. This produced some tensions in the discussion between the analyst and the choreographer, who had visualized the development of the movements of the *pas de deux* against recordings of *Clair de lune* by other performers, which he considered were interpreted with greater feeling but, as was pointed out by the analyst, had little regard for Debussy’s temporal intentions. A consensus was eventually reached between the pianist, the analyst, and the choreographer, and they agreed that an overabundance of *rubato*, or arbitrary fluctuations in tempo, did indeed reduce the sense of coherence throughout the piece.

The rehearsal was limited to two hours, during which time the pianist attempted to control her own pacing of the ebb and flow of *Clair de lune* through imitation and emulation of the dancers’ movements as they practiced connecting one section to the next with subtle fluctuations only in the tempo. The study concluded with an uninterrupted performance of the whole piece and at the end the audience of delegates was clearly moved and gave raptur-

ous applause. However, two weeks later, when seven delegates were asked to give their views, four found an improvement in the pianist's performance and three did not address the question at all. The pianist observed that "the challenge for me is to be able to be fully aware of what the dancers are doing, rather than sticking to my own playing, which was the audience's criticism as well."

This pilot study has suggested that the pianist might learn to control the pacing of the ebb and flow of *Clair de lune* from one section to the next through imitation and emulation of the dancers' movements. While the analyses and the historical evidence provide some useful insights apropos the pacing of the ebb and flow from one section to another, it is difficult say whether or not the pianist developed a greater control of the pacing of the ebb and flow between the sections through imitation and emulation of the dancers' movements, since the responses by the participants were too subjective, and in some cases the question was not fully understood. This inconclusive result suggests the necessity for applying more appropriate performance assessment criteria in the future.

## IMPLICATIONS

In the domain of sport, applied research has long informed its practitioners by collaborating with other disciplines in order to develop innovative methods which will enhance their performance. Until now, this has not been the case in musical performance, however change is afoot and collaboration between different disciplines is being positively encouraged. Furthermore, software is becoming available which may make it possible to deliver a more quantifiable result in the future.

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# Communicating music: Structure, cognition, and expression

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Although expressive deviations have been shown to bear a close relation to music structure, as represented by generative theory, models are less accurate as the structural level decreases. The three empirical studies reported here were aimed at testing Lerdahl's Tonal Pitch Space (TPS) theory at phrase level on the performance and reception of the nine initial measures of Beethoven's *Waldstein Piano Sonata*, second movement. Results show (1) the relevance of TPS on the understanding of individual expressive behavior and (2) expert and naive listeners' higher rating of recordings in which expressive deviations correlate to music structure as represented by TPS.

*Keywords:* Tonal Pitch Space; timing; agogics; performance; perception

The consistency and regularity of expressive deviations has been shown (e.g. Repp 1990, Repp 1992) as well as expressive deviations' relation to music structure (e.g. Gabrielsson 1987), as represented by Lerdahl and Jackendoff's (1983) *Generative Theory of Tonal Music* (GTTM). Todd (1985, 1992) has notably modeled such expressive behavior with results that globally fit well with human performance (Windsor and Clarke 1997). The accuracy of models, however, lessens as the structural level decreases (Repp 1992). In the meantime, Lerdahl (2001) brought forward Tonal Pitch Space (TPS): a refinement of GTTM which provides algorithms to calculate local and global tension (harmonic degree of deviation from a given tonic), as well as attraction (melodic factors). Given its numerical character, TPS seems fit for empirical testing and was used to enlighten performers' expressive deviations at phrase level, as well as listener's preferences of recorded interpretations, in three empirical studies (Martingo 2005, 2006, 2007, 2011), which are summarily presented here. Study 1 aimed at evaluating Lerdahl's theory of tension and attraction as an instrument for understanding performers'

expressive deviations. Study 2 was designed to evaluate Lerdahl's theory of tension and attraction as an instrument for understanding expert listeners' preferences. Study 3 aimed at evaluating Lerdahl's theory of tension and attraction as an instrument for understanding naive listeners' preferences.

## METHOD

### Study 1

#### *Materials*

23 recordings (see Table 1) of Beethoven's *Waldstein Sonata (Piano Sonata No. 21 in C major Op. 53*, initial nine measures of the second movement) were used.

*Table 1.* List of recordings analyzed.

<i>Pianist</i>	<i>Reference</i>	<i>Year</i>
Arrau	Deutsche Grammophon DG456709-2	1963
Ashkenazy	Decca 425590-2	1974
Backhaus	Fonit Cetra CDE 1005	1954
Barenboim [DG]	Deutsche Grammophon DG 435100-2	1981
Barenboim [EMI]	EMI C25762863-2	1968
Braaten	APR Music Productions. Victoria VCD19002	1989
Brendel	Philips 446909-2 (CD7)	1993
Cziffra	Ermitage ERM143	1963
Fischer	Hunt Productions HUNT CD 513	1954
Genov	Chamber CH CD 106	1998
Gieseeking	Philips 456790-2 (disk 2)	1938
Guilels	Deutsche Grammophon DG 419162-2	1972
Horowitz	Sony 518802-2	1972
Kempff	Deutsche Grammophon DG 429306-2	1964
Kovacevich	EMI 562700-2 (CD6)	1992
Nat	EMI CDH 7610122	1954
Pollini	Deutsche Grammophon DG 435472-2	1997
Schnabel	EMI References 0777 763765 2 3	1932-7
Sequeira [1]	Vianna da Mota Foundation VMF050299-1	1998
Sequeira [2]	Vianna da Mota Foundation VMF 10197-3	1940s
Solomon	EMI Testament SBT 1190	1952
Tipo	EMI 74788625 PM518	1986
Yablonskaya	ProPiano Records PPR 224516	1996



### *Procedure*

The initial nine measures of Beethoven's *Waldstein Sonata* were reduced into thirteen chords. The segmentation, as well as tension and attraction value for each chord, was Lerdahl's, as indicated in Smith and Cuddy (2003). Agogics and dynamics were analyzed with recourse to *Sound Forge* (Version 7) and compared to Lerdahl's assigned tension (local and global) and attraction values (see Martingo 2006).

## **Study 2**

### *Participants*

67 university music students took part, chosen as expert listeners (11 years of aural training and 10 years of instrument training, on average).

### *Materials*

Six commercially available recorded interpretations of Beethoven's *Waldstein Sonata* (nine initial measures of the second movement) by world class pianists in which the existence, or not, of significant correlations between timing, dynamics, and music structure had been identified in Study 1: namely, two presented a correlation between dynamics and tension and/or attraction (Kempff, Deutsche Grammophon DG 429306-2, Recording B; and Barenboim, EMI C25762863-2, Recording F); two presented a correlation between timing and tension and/or attraction (Guilels, Deutsche Grammophon DG 419162-2, Recording D; and Gieseking, Philips 456790-2, Recording E), and two presented no significant correlations between expressive deviations and tension (Solomon, EMI Testament SBT1190, Recording A; and Genov, Chamber CH-CD 106, Recording C).

### *Procedure*

Participants were asked to rate on a 7-point scale (1=minimum, 7=maximum) the coherence, control of timing, control of dynamics, expressivity, tension, fluency, and global evaluation of each recording. Data analysis was carried out with Exploratory Factor Analysis using the Principal Components method to reduce the original parameters (seven criteria per recording) into factors (see Martingo 2007).

### **Study 3**

#### *Participants and materials*

76 university students took part, chosen as naïve listeners (0.54 years of aural training and 0.62 years of instrument training, on average). Materials were the same as in Study 2.

#### *Procedure*

Subject to the methodology used in Study 2, students rated on a 7-point scale the expressivity, fluency, and global evaluation of seven commercially available recorded interpretations of Beethoven's *Waldstein Sonata*. The seventh recording was the same as the sixth (see Martingo 2011).

## **RESULTS**

### **Study 1**

Average dynamics (23 pianists) correlated significantly to attraction values ( $r=628$ ,  $p<0.05$ ). Individual cases showed distinct configurations: in 15 out of the 23 cases, either tension or attraction (or both) correlated at a significant level either to dynamics or agogics (or both; Martingo 2005, 2006).

### **Study 2**

Recorded interpretations in which such correlations occurred were rated systematically higher than interpretations in which such correlations did not occur. Notwithstanding the extensive music training (11 years of aural training and 10 years of instrument training, on average), the total percentage of variance explained by each one of the factors extracted in each recording (>70%, <75%) showed that individual listeners did not discriminate the seven selected parameters, rating instead according to a global assessment (Martingo 2007).

### **Study 3**

Recorded interpretations in which such correlations occurred were rated higher than interpretations in which such correlations do not occur, when an index for each pair of similar characteristics recordings was considered (significant correlations between agogics and/or tension and attraction; significant correlations between dynamics and/or tension and attraction; no signifi-

cant correlation between expressive deviations and neither tension nor attraction; Martingo 2011).

## DISCUSSION

The results show Lerdahl's concepts of tension and attraction as a valuable instrument for understanding performers' expressive deviations, namely at phrase level, where current models are less accurate. In particular, more than globally subsuming performance deviations, TPS helps understanding of individual expressive strategies, showing whether the performer is guided by melodic or harmonic (tension) factors and, in this case, in a note-to-note (local tension) or hierarchical basis (global tension). Secondly, the perception studies carried out showed that expert and naive listeners rate higher the recordings in which there are significant correlations between expressive deviations and Lerdahl's TPS tension or attraction. This would indicate not only the relevance of TPS but also that performers and (expert and naive) listeners share the same cognitive framework. Additionally, it was found that neither expert nor naive listeners discriminate individual factors, rating according to an overall assessment.

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# Mental representation of music performance: A theoretical model

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Different coexisting definitions regarding mental representation cause difficulties in the provision of a comprehensive theoretical model that can conceptualize mental representation in music performance contexts. Mental representation has been understood as an anticipatory plan of the actual music performance. It has been recognized to affect the quality of the performance; a greater refinement is likely to increase performance quality. Despite its additional suggested pedagogical importance to instrumental learning, its development, from practice to performance, is still poorly understood. Grounded in a systematic literature review, a theoretical model is here proposed aiming at the clarification of the concept of mental representation and its application in performance practices.

*Keywords:* mental representation; artistic ideal outcome; mental imagery; performing; instrumental learning

Conceptualizing mental representation is difficult, as the phenomenon possesses a certain degree of ambiguity (Lehmann 1997). Thus, there have been several attempts in the literature to define it (Neuhaus 1973). However, a consensual definition that could be transversal to all performance domains and that could promote the acquisition of strategies to optimize performance practices is still missing (Gabrielson 1999, Clark and Williamon 2011).

Since early years, the phenomenon of mental representation has been explored in several areas, namely cognitive psychology, education, sports, philosophy, and cognitive neuroscience. In music performance, mental representation has been considered an internal image of musical aspects, including musical gestures (Lehmann 1997), symbol interpretation (e.g. meter, dynamics, etc.; Palmer and Krumhansl 1990), and emotional communication (Ga-

brielson 1999). In other words, mental representation can be defined as “our mental capacity for imagining sound in the absence of a directly audible sound source” (Haddon 2007, p. 301). However, there have been other authors considering mental representation as a phenomenon directly associated with artistic imagery, i.e. an aesthetic desired outcome that serves as a plan to guide performance preparation (Chaffin *et al.* 2003, Gabrielson 1999, Neuhaus 1973).

Concerning the pedagogical implications of a mental representation, previous studies have suggested that instrumental learning should be orientated so as to assist the student in establishing a mental representation as part of performance planning. The results of comparisons between music students and expert musicians suggest that differences exist in terms of their ability to create a mental representation as an artistic desired outcome (Jorgensen and Hallam 2010). However, research focused on clarifying what this artistic desired outcome is and how it is related to mental representation is still missing in the literature (Gabrielson 1999). The proposed theoretical model constitutes the first step to such an investigation. It aims at conceiving a broader conceptualization of mental representation based on decoding the essence of mental representation in different domains.

### MAIN CONTRIBUTION

A qualitative selection of the items for a systematic literature review was undertaken using three databases: Web of Science, JSTOR, and Scopus. Also, the catalogues of two online libraries, one in Portugal and one in the UK, were searched. The keywords selected to undertake this search were chosen among the most-used terminology in cognitive psychology: (1) mental representation, (2) imagery, and (3) knowledge representation. The search stopped when all combination of keywords was tried and when theoretical saturation was achieved concerning the definition of mental representation.

A total of 26 articles emerged; from these, a further selection of articles was undertaken, taking into account the following inclusive criteria, ordered according to level of importance: (1) acknowledgement of the phenomenon of mental representation in performance, (2) description of mental representation conceptualization, (3) definition of mental representation, and (4) exploration of mental representation development. Items selected could be included in groups, according to areas of research: (1) cognitive psychology (including theories of mind), (2) cognitive neuroscience, (3) sports psychology, (4) education, and (5) music. The inter-relationships found among these areas are discussed below.

## The phenomenon of mental representation

The most recurrent definition of mental representation found in domains other than music was *represented knowledge in the brain*. In cognitive neuroscience, mental representation is regarded as the product of an internal psychophysiological processing of the results of the interaction between several organic systems (e.g. endocrine, immune, and nervous) and the brain (Damásio 2010). This interaction results from (and influences) individual social and cultural features, i.e. the self (Damásio 2010), enabling the realization of environment, actions, and thoughts as mental images. Consequently, these images will feed the psychophysiological processing in a feedback loop, i.e. a reaction from the images themselves (Damásio 2010).

According to cognitive psychology, the psychophysiological process described by cognitive neuroscience should not be mistaken with mental imagery (Stenberg 1999). Theories of mind organization propose mental representation as an outcome of complex interactions between concepts and imagery (Novak 2010). A perceived regularity, or pattern in events or objects, by which one organizes knowledge constitutes concepts, whereas imagery is an individual experience that one may have in the absence of the real stimuli (Cumming and Ramsey 2008). According to this point of view, another person besides the performer cannot inculcate the development of mental representation in performance. However, mental representation benefits from the stimulation and guidance of others. Thus, one might infer that mental representation can be developed only when it is essentially based in acquired knowledge.

This assumption is also accepted in educational contexts, where mental representation develops as part of the learning process (Jorgensen and Hallam 2010). In line with theories of mind organization, learning the definition of a word, for example, is essentially *representational learning*, i.e. one can have an image as a definition for something, but not a clear idea on its meaning (Novak 2010). To learn the meaning of the word, which is the regularity or the pattern that the word or symbol stands for, is *conceptual learning*, i.e. the image reflects an internal perception of a pattern and the possible elements involved. Both educational and cognitive psychological views on mental representation shed light on the fact that, for example, many may understand mental representation as an artistic image. However, few have acquired a deeper understanding of it as a concept.

This might be the case of musicians, for whom approaches of inculcating a defined image of interpretation, instead of guidance towards the development of the students' own concepts and representations, have been the prime scen-

ery in instrumental lessons. This is perhaps related to the fact that, in music, many terms have been used as synonymous of mental representation, including performance cues (Chaffin *et al.* 2003), performance plans (Gabrielson 1999), artistic imagery (Neuhaus 1973), and mental imagery (Clark and Williamon 2011).

Based on the contributions of all areas described above, one might argue that mental representation results from the organization and storage of knowledge as concepts. These concepts are represented as mental images, which underlie human expression and enable life management (Cumming and Ramsey 2008). In sports psychology, this network between concepts and images, i.e. mental representation, constitutes the primarily mediator of performance and the degree of its refinement determines the level of performance quality (Ericsson 2003). The following section further discusses the importance of the interaction between concepts and images, proposing it as a theoretical model of conceptualizing mental representation in music performance contexts.

### **Theoretical model**

Bridging the conceptualization of mental representation from all the above domains, three main components emerge as fundamental to the development of a mental representation (see Figure 1): (1) environment, (2) performer (i.e. individual), and (3) music making activity. The first component concerns individual social and geographic conditions (Durrant and Welch 1995, Jorgensen and Hallam 2010). The second component refers to a set of features that define the individual (Damásio 2010). Finally, the last component involves all activities carried out in music making, including efforts involved in performance preparation (Elliott 1995). Both *environment* and *performing* elements are constantly feeding the *performer* element with input information received by the sensory channels. This input is concomitantly processed by the body and the mind; the result is an emotional phenomenon which emerges from the knowledge previously acquired and which is affected by neurophysiological processes. This network of concepts and representations expresses behavior according to the performer's level of engagement (i.e. volition; Elliot 1995).



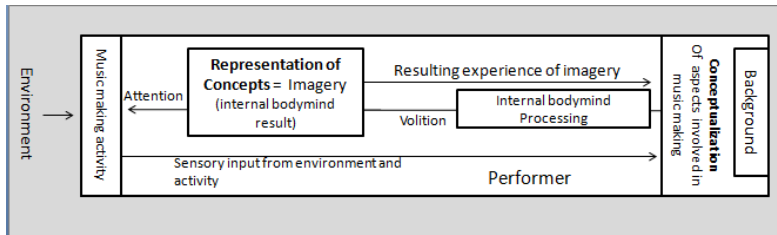


Figure 1. A theoretical model for mental representation in music performance.

## IMPLICATIONS

The present model takes into account mental representation as a complex relationship between several life aspects, i.e. perception, behavior, environment, and music making. Hence, it assumes that concepts, which form the acquired knowledge, are of paramount importance to mental representation: they influence action making. The conceptualization of this model has been based also on the idea that mental representations (concepts and imagery) are mediators to performance quality (as a desired outcome to be achieved).

The model here proposed, i.e. mental representations are concepts previously acquired and represented in the mind, can be taken into account to introduce programs of mental training with students aiming at performance optimization. Images are essentially an individual experience, so cannot be exactly reproduced among all individuals. However, the concepts behind the images can be explored in order to facilitate the creation of certain images.

The next step in this investigation is to assess how well the model fits the students' conceptualizations and representations of a desired artistic outcome in music performance.

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Keynote paper



# Rhythm, meter, drumming, and dance: A predictive systems view of an ancient aspect of music

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Although the majority of research in music cognition concerns melody and harmony, rhythm and meter are some of the most fundamental aspects of music, particularly in a performance context. They have deep roots, since music and dance are closely connected in virtually all of the world's cultures. Furthermore, the distribution of isochronic music (with a steady beat or tactus) versus so-called "free rhythm" without such a pulse, suggests that isochronicity plays an important role in group synchronization rather than being a necessary component of melody. I first examine the isochronic pulse from the viewpoint of predictive systems theory (sometimes termed dynamical systems theory or nonlinear dynamics), suggesting that the fundamental function of isochronicity is to allow a group of individuals to synchronize their behavior, whether playing an instrument, singing, or dancing. I then turn to the biological and neural bases of rhythmic behavior. Despite a long tradition of belief that the ability to entrain to a musical beat is uniquely human, I review recent convincing evidence of entrainment in several non-human animal species (especially parrots and sea lions). This opens the door to experimental investigations of the ontogeny and neural basis of pulse entrainment that would be difficult or impossible in humans. Nonetheless, regarding meter (which I interpret as a hierarchically-structured interpretation of a pulse), there is much less work on animals, and it remains unclear whether animals interpret a pulse stream in terms of metrical structure. Finally, neural imaging data in humans shows a clear link between rhythmic perception and motor regions of the brain, suggesting a close link between rhythm and prediction/preparation in time. However, much of this work does not clearly distinguish between pulse perception and meter perception. There are some indications that perceiving meter (and coping with syncopation and other deviations from simple, superficial meter) may involve different brain regions from those involved in

pulse entrainment, regions more classically associated with linguistic syntax. This suggests that a hierarchical model of meter is of more than notational convenience, but rather a fundamental component of rhythmic cognition.

*Keywords:* music cognition; rhythm perception; meter; dance; animal music perception

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