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des Conservatoires,
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Preface and acknowledgments

The third International Symposium on Performance Science, ISPS 2011, explored the theme *Models of Performance*, ranging from models of good practice and performance (e.g. research into inspirational performers, teachers, or learners) to scientific models of performance processes and products. Hosted by the Faculty of Music at the University of Toronto, this volume reflects the breadth of performance science research presented at the event and provides a glimpse into the engaging discussion and debate that ensued.

The 117 articles published here report original research on topics such as learning and teaching; creativity and performance evaluation; movement, communication, and embodied knowledge; and performers' health and well-being. They offer a wide range of empirical, theoretical, and artistic insights into a most multifaceted and ubiquitous endeavor: performing.

We wish to acknowledge the input, support, and generosity of several individuals and organizations that have made ISPS 2011 possible. Firstly, we thank the many delegates who created lively discussion at the conference and the authors who contributed their work to this volume. We are also grateful to the University of Toronto, Royal College of Music, and members of the Scientific Committee for supporting this event from the outset. We are delighted to acknowledge the support of Canada's Social Sciences and Humanities Research Council (SSHRC), as well as the following ISPS 2011 partner societies: the International Association for Dance Medicine and Science (IADMS), International Society for Music Education (ISME), Performing Arts Medicine Association (PAMA), and Society for Music Perception and Cognition (SMPC). Finally, we should like to thank the following people for their expertise and tireless work in bringing ISPS 2011 together: Doreen Ostrowski for her acute conference planning skills, Terry Clark, Rosie Burt-Perkins, Lisa Aufegger, and Eulalie Charland for their invaluable help in editing and revising the proceedings manuscript, and our conference assistants who skillfully navigated delegates through a tightly packed symposium schedule.

Aaron Williamon
Darryl Edwards
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Keynote paper

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Science in the concert hall? Music in the lab? Perspectives on the role of research in higher music education

Don McLean

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What is the position of musical training and research in higher education? Conservatoires and university schools of music face new accountability expectations in professional productivity and research outcomes. How are we to cope with these new challenges? How are we to lead them? What happens when science hits the concert hall? When music meets the lab? This presentation reviews the current change state of scientific inquiry in higher music education. It is in part an international overview of the field, one that briefly examines some past models and surveys developments currently underway in the United States, Canada, Europe, and Australia. It is also a shared reflection of the author's personal experience in helping to build CIRMMT (the Centre for Interdisciplinary Research in Music Media and Technology) at the Schulich School of Music of McGill University from 2001-10. It ultimately returns to a consideration of the fundamentals of musical experience, creativity, and research. Paths and pitfalls, organizations and infrastructures: what do we need to do to ensure a strong future for the scientific study of musical performance and for the place of music in higher education and society?

Keywords: music; research; performance; CIRMMT; Schulich

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Symposium:
Musician's dystonia: Psychological and behavioral findings and their consequences for therapy

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Behavioral retraining in focal dystonia: Results of a long-term follow up in 72 pianists

Eckart Altenmüller[1], Laurent Boullet[2], Maricruz Gomez-Pellin[1], and Hans-Christian Jabusch[3]

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Focal dystonia in musicians (MD) is a task-specific movement disorder with a loss of voluntary motor control. Several treatment options are available. Besides pharmacological intervention with anticholinergic drugs or local injection therapy with botulinumtoxin, behavioral re-training has been increasingly applied in different groups of MD-instrumentalists. Results have been mixed and a valid long-term follow-up is still missing. Seventy-two pianists with MD were included in the study. Motor control was assessed using MIDI-based scale analysis. Temporary unevenness of inter-onset intervals (IOI) in scale playing was previously found to be a reliable and valid indicator of motor control in pianists with and without MD. After the first measurements, pianists entered a re-training program, developed by the second author. Basic principles of the retraining procedure can be divided in a "deprogramming" phase, in which incorrect movements at the instrument are identified. A "correct" posture of the hand is established using basic exercises. Subsequently, in a second phase, strengthening of weak muscle groups and the acquisition of an internal representation of simple movements is achieved. The third part of the retraining course starts after establishing a muscular equilibrium and control of exaggerated involuntary flexion. During this procedure, the basic constituents of piano technique are re-established. The retraining process is done under visual feedback from unusual perspectives using digital cameras. During the observation period (mean=42 months, range=3-72 months), 50% of the pianists improved according to objective measures. Complete restoration of the motor abilities was rarely achieved. However, with reduced workload, adapted practicing strategies, and change of repertoire, even in patients who did not display objective improvement of motor control on the piano, resumption of professional activities such as public performance and recordings was possible. In conclusion, while behavioral retraining is a valuable therapeutic option, prognostic factors determining the rate of success in an early stage of this long procedure remain to be identified.

Keywords: musician's dystonia; behavioral retraining; pianist; repertoire; prognosis

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Improved motor control after alteration of somatosensory input: Prognostic value of "glove effect" in pianists with dystonia

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Musician's dystonia (MD) impairs motor control and musical performance. Alteration of somatosensory input (e.g. by wearing a latex glove) may improve motor control in some MD patients. The potential association between this so-called sensory trick phenomenon and the outcome after consequent treatment with botulinum toxin and/or pedagogical retraining was assessed in 24 pianists with MD using objective performance measures. Outcomes were significantly better in those patients with a significant pre-treatment sensory trick response (positive glove effect) than in others. The glove effect seems to have a prognostic value in the treatment of patients with MD.

Keywords: musician's dystonia; sensory trick; glove effect; retraining; botulinum toxin

Focal dystonia in musicians (MD) is a task-specific movement disorder which presents itself as a loss of voluntary motor control in extensively trained movements while the musician is playing the instrument (Altenmüller 2003). For those who are affected, the disorder is highly disabling, and in many cases it terminates musical careers. MD is still difficult to treat. Therapeutic options mainly include botulinum toxin injections, pedagogical retraining, and anticholinergic medication with trihexyphenidyl (Jabusch *et al.* 2005). Until today, the pathophysiology is not fully understood. Defective inhibition on different levels of the central nervous system is discussed to be involved in the pathophysiology (Lin and Hallett 2009). Maladaptive neuronal plasticity leads to a fusion of the digital representations in the somatosensory cortex of patients (Elbert *et al.* 1998). Evidence for the crucial role of the afferent somatosensory input in the pathophysiology of MD comes from the so-called sensory-trick phenomenon. This phenomenon has been reported in patients with various forms of focal dystonia (e.g. with cervical dystonia): alteration of the somatosensory input by touching the face may reduce or even abolish involuntary muscle activity (Wissel *et al.* 1999, Schramm *et al.* 2004). Analogously, in patients with MD, alteration of somatosensory input (e.g. by wearing a latex glove) may result in short-term improvement of motor control of the affected hand (Altenmüller 2003). According to clinical observations, we hypothesized that the extent of this improvement ("glove effect") may predict the long-term outcome after treatment in patients with MD.

Pianists represent a large fraction of musicians with dystonia (Altenmüller 2003). For reliable assessment of motor control in pianists with MD and for monitoring of treatment effects in these patients, MIDI- (music instrument digital interface) based scale analysis has been evaluated and established (Jabusch *et al.* 2004). Using this protocol, the present study was designed to investigate the potential association between the "glove-effect" and the long-term outcome after treatment in pianists with dystonia.

METHOD

Participants

Thirty professional pianists (22 men and 8 women; mean age=40.5±13.1 years, range=21.4-68.5 years) suffering from MD were enrolled in the study. Patients were diagnosed at the outpatient clinic of the Institute of Music Physiology and Musicians' Medicine (IMMM) of the Hanover University of Music, Drama, and Media and underwent complete neurological examination by a neurologist specialized in movement disorders (EA). Dystonic symptoms occurred in the typical manner as painless cramping of one or more fingers while patients were playing the piano. One pianist suffered from MD in both hands. Data from both hands of this patient were included in the statistical analysis as two separate cases.

Procedure

Assessment of motor control: Motor control at the piano was assessed in scale playing because this motor task is early affected during onset of MD. MIDI-based scale analysis was done according to the following protocol

(Jabusch *et al.* 2004). Scales were performed with the affected hand on a digital piano, which was connected to a computer. Sequences of 10 to 15 C major scales were played over two octaves in both playing directions. Scales were played using the conventional C major fingering. The tempo was standardized and paced by a metronome (one keystroke every 125 ms) in 26 patients. Due to severely impaired motor control in four patients, the desired IOI was 187.5 ms in three patients and 250 ms in one patient. The temporary unevenness of inter-onset intervals (IOI) has previously been identified as a valid, reliable, and precise indicator of the impairment of motor control in pianists with dystonia (Jabusch *et al.* 2004). For each participant, temporary unevenness of IOI was analyzed for the affected hand and for both playing directions by calculating the median standard deviations of IOI (mSD-IOI) of all scales. The mSD-IOI score of the more severely affected playing direction was used for further analyses. Performance tests were carried out separately under three conditions: (1) baseline test before treatment (termed "baseline"), (2) playing with latex glove (sensory trick) before treatment (termed "glove"), and (3) follow-up test after treatment (termed "follow-up").

Treatment protocol: Therapeutic approaches, as monotherapies or in combination, included the following options: Botulinum toxin injections (BT) were applied in those patients in which primary dystonic movements could be clearly distinguished from secondary compensatory movements. Target muscles were identified by visual inspection of the dystonic movement patterns while patients were playing their instruments. A lyophilized botulinum toxin A powder (Dysport®, Ipsen Ltd., Berkshire, UK) was injected using an EMG-guided technique. Pedagogical retraining (PR) was taking place under the supervision of the piano instructor Laurent Boullet specialized in dystonia retraining. PR included elements based on the following principles reported previously (e.g. Boullet 2003): (1) movements of affected body parts were limited to a level of tempo and force at which the dystonic movement would not occur, (2) compensatory movements were avoided, partially under the application of splints, and (3) instant visual feedback with mirrors or monitors helped patients to recognize dystonic and non-dystonic movements. Trihexyphenidyl (Trhx) was frequently applied in addition to BT or PR if no contraindication was present. Adjustment of the dosage was made depending on beneficial effects and side effects.

Statistical analyses: Glove-effect and outcome of individual patients were analysed by Mann-Whitney U tests using the respective mSD-IOI values. Group differences were analysed by Mann-Whitney U tests. The alpha level was set at 0.05.

RESULTS

The mean age at onset of dystonic symptoms was 33.5 years; median duration of symptoms at the time of the baseline and glove performance tests was 3 years (range=0.2-44.6). Follow-up tests were conducted on average 4.8±2.5 years after baseline tests. Scale analysis tests revealed the following results: median $mSD\text{-}IOI_{baseline}$ was 20.0 ms (range=10.4-58.0); median $mSD\text{-}IOI_{glove}$ was 20.3 ms (10.3-56.7); median $mSD\text{-}IOI_{follow\text{-}up}$ was 21.8 ms (10.4-37.4).

Sensory trick, glove effect: Mann-Whitney U tests showed significant improvement of fine motor control through wearing a glove in six cases (19%) in comparison with the baseline (positive glove-effect [PGE]; all p-values<0.05), significant deterioration in nine cases (29%; all p-values<0.05), and no significant effect in 16 cases (52%; both groups considered as displaying no PGE). The glove-effect (GE) was described as $mSD\text{-}IOI_{glove}–mSD\text{-}IOI_{baseline}$. Median GE was 1.3 ms (range=-34.1–21.1), negative values indicating improved motor control with the glove compared to baseline.

Details of treatment: Eight patients (27%) were consequently treated with BT (consequent treatment was defined as minimum 3 BT injections); 21 patients (70%) consequently took part in PR (defined as minimum 4 months PR); 7 patients (23%) were consequently treated with Trhx (defined as minimum 4 months Trhx application). None of the patients treated with Trhx showed a PGE; therefore, further statistical analyses were made on patients who were consequently treated either with BT or PR or both (n=24). This group of 24 patients will be referred to as "treated group." The treated group included five patients with a PGE and 19 patients with no PGE (deterioration with the glove n=6; no differences n=13).

Long-term outcome and its association with glove effect: Mann-Whitney U tests revealed significant improvement of MD symptoms in 12 cases (39%; all p-values<0.05), significant deterioration in seven cases (22%; all p-values<0.05), and no significant change in 12 cases (39%) in the follow-up test. Outcome was defined as $mSD\text{-}IOI_{follow\text{-}up}–mSD\text{-}IOI_{baseline}$ (outcome value). Median outcome value was -2.0 ms (range=-20.6–12.4). In the treated group, patients with a PGE showed significant better outcome values compared with the patients with no PGE (Mann-Whitney U test; p=0.03). Mann-Whitney U tests for therapy details revealed that patients with a PGE and those with no PGE did not differ in the duration of follow-up as well as in treatment details regarding the following variables: duration of treatment (BT), number of injections and dosages (BT), duration of treatment (PR), number of sessions, and intervals between sessions (PR); all p-values were>0.05.

DISCUSSION

The present study investigated the potential association between the sensory trick phenomenon and the outcome after treatment in patients with MD. To provoke the sensory trick, patients played wearing a latex glove on the affected hand. The study focused on affected professional pianists only. The selection of affected professional pianists as study participants warranted a high homogeneity of the sample. Playing with glove, only six patients (19%) showed a statistically significant improvement of motor control compared with baseline. This finding is in agreement with other publications reporting that only a minority of patients with focal dystonia exhibited a reduction of dystonic muscle contractions by using a sensory trick maneuver (e.g. Gómez-Wong *et al.* 1998, Schramm *et al.* 2004).

Patients were treated with currently available treatment options, using BT, PR, and Trhx. Outcome tests after an average follow-up period of 4.8 years indicated that 39% of patients showed a significant improvement while 39% displayed no change of symptoms and 22% had a significant deterioration. The percentage rate of patients with an improvement in the follow-up test is lower in the present study than that in a previous follow-up study showing improvement in 71% of patients (Jabusch *et al.* 2009) using the same performance measures. The following reasons may be responsible for this observation: (1) different samples with only partial overlap were investigated in both studies, (2) sample sizes were relatively small in both studies, (3) performance measures may be distorted in the abovementioned four patients with severely impaired motor control because no adjustment procedure was available to correct for increased target-IOI values, (4) average follow-up duration in the present study was more than twice as long as that of the previous study. A review of the literature on outcome studies reveals that longer follow-up periods seem to be associated with worse outcomes.

The subgroup of patients who were treated consequently (either by a minimum of 3 BT injections or by a minimum of 4 months of PR) displayed an association between the glove effect and the outcome: patients with a PGE showed significant better outcome values compared with the patients with no PGE. This finding strengthens the clinical impression that a positive glove effect has a prognostic value in the treatment of patients with MD. Patients who displayed a significant pre-treatment response to the sensory trick had a better long-term outcome after treatment than those with a little initial sensory trick response. We speculate that a strong response to the sensory trick may indicate that the dystonic movement patterns might be easier to modulate and that therefore treatment might be more effective in these patients.

Further research has to be conducted to clarify if pathophysiological alterations in patients with MD such as blurring of receptive fields in the somatosensory cortex are less pronounced in patients with a stronger sensory trick response.

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Phenomenology of dystonic and task-specific tremor in musicians: A descriptive study

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Dystonia is a movement disorder characterized by an involuntary contraction of antagonist muscles leading to a flexion or extension, which occurs in musicians in the context of a highly over-trained fine motor task. A sensory trick is sometimes observed, leading to an amelioration of symptoms. In certain musicians suffering from dystonia, a tremor of the affected body part can be observed. Our aim is to describe two tremor syndromes that have been defined in the context of dystonia: (1) dystonic tremor as a focal, mainly postural- or action-tremor in one body part affected by dystonia, showing an irregular amplitude with a frequency mostly below 7 Hz and (2) dystonia-associated tremor as a tremor in musicians suffering from dystonia but in a body part not affected by dystonia. A second form of tremor in musicians is the "primary bowing tremor" in string instrument players, a task specific tremor that occurs only while playing the string instrument. No signs of dystonia are present in these musicians.

Keywords: dystonia; tremor; task-specificity; musicians; primary bowing tremor

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Musician's dystonia and comorbid anxiety: Two sides of one coin?

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We sought to characterize anxiety and other psychological conditions in musicians with focal dystonia (MD) and to determine whether a significantly higher degree of these conditions is present in musicians with MD compared with healthy musicians and non-musicians. Psychological conditions were studied in 44 professional musicians with MD, 45 healthy musicians, and 44 healthy non-musicians using the State-Trait Anxiety Inventory (STAI) and NEO-Five-Factors Inventory (NEO-FFI). Musicians with MD displayed significantly increased levels of anxiety and neuroticism compared with healthy musicians and non-musicians. The observed lack of correlation between anxiety and the duration of dystonia suggests that anxiety may not be a psycho-reactive phenomenon and is consistent with the hypothesis that anxiety and MD share a common pathophysiological mechanism.

Keywords: dystonia; musician; psychology; anxiety; State-Trait Anxiety Inventory

Focal dystonia (FD) in musicians, also called musician's dystonia (MD), is a task-specific movement disorder characterized by a painless muscular incoordination of extensively trained movements (Altenmüller and Jabusch 2009). Involuntary flexion or extension of individual fingers or loss of control of the muscles involved in the embouchure in affected musicians can lead to impaired technical performance on the instrument. Musicians with FD are therefore often unable to continue their careers as performing artists (Schuele and Lederman 2004).

Although several published studies have examined psychological conditions in patients with FD, only two studies have focused specifically on psychological conditions in musicians with FD (Jabusch *et al.* 2004, Jabusch and Altenmüller 2004). These studies reported that musicians with FD more commonly exhibited specific phobias, anxiety, and perfectionism than healthy musicians. However, sample sizes in these studies were relatively small, and questionnaires used to evaluate the mentioned psychological characteristics had not been validated.

The present study was designed to investigate psychological abnormalities in a larger group of musicians with FD, as compared with healthy musicians and healthy non-musicians, using validated questionnaires (Enders *et al.* 2011). We hypothesized that a significantly higher degree of anxiety and other psychological conditions is present in musicians with FD.

METHOD

Participants

Three groups of participants were enrolled in the study: (1) 44 musicians with MD, recruited from the outpatient clinic of the Hanover Institute of Music Physiology and Musicians' Medicine; (2) 45 healthy professional musician controls, recruited from German orchestras and music schools; and (3) 44 healthy non-musician controls, who were university graduates. All patients underwent complete neurological evaluations and were diagnosed with MD by at least one of the authors (E. A.). Patients with other neurological disorders or secondary dystonias or psychiatric diseases were excluded from the study. Potential controls were excluded if they reported a history of neurological or psychiatric diseases. All groups were matched for age and sex, and healthy musicians were additionally matched by instrument family to the MD group. Details of the three groups are shown in Table 1.

Materials

Assessment of personality and anxiety were performed using the revised German version of the validated self-administered NEO-Five-Factors Inventory (NEO-FFI) (Costa and McCrae 1992), and the validated State-Trait-Anxiety Inventory (STAI) (Spielberger and Gorsuch 1983), respectively. The NEO-FFI is a multidimensional personality inventory that consists of 12 items (descriptions of behaviors), scored on five point Likert-type scales, in each of five

Table 1. Patient and control characteristics.

Parameter	*MD*	*HM*	*NM*
n	44	45	44
Sex (male/female)	26/18	27/18	27/17
Age in years (M±SD)	40.2±9.2	41.5±12.6	41.7±16.2
Age in years (min/max)	23/64	20/68	21/76
Woodwind instruments (n)	16	15	-
String instruments (n)	14	14	-
Brass instruments (n)	4	6	-
Plucking instruments (n)	5	5	-
Keyboard instruments (n)	4	4	-
Drums (n)	1	1	-
Age at onset of dystonia in years (M±SD)	30.9±8.9	-	-
Duration of dystonia in years (M±SD)	9.3±8.1	-	-

Note. MD=musicians with dystonia, HM=healthy musicians, NM=healthy non-musicians. MD presented as hand dystonias in 40 and as embouchure dystonia in 4.

personality domains: (1) extraversion, (2) agreeableness, (3) conscientiousness, (4) neuroticism, and (5) openness to experience. The STAI distinguishes chronic, or trait anxiety from temporary, or state anxiety. The STAI has 20 trait and 20 state anxiety statements, each scored on 4-point scales, that assess how respondents feel “generally” and “right now, at this moment.”

Procedure

Questionnaires were distributed and collected by mail and were accompanied by written instructions in the German language. All subjects were able to speak, read, and write German fluently. Informed consent was obtained from all subjects before study participation. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Comparison of NEO-FFI and STAI scores between the dystonia and control groups was performed using the Kruskal-Wallis test and the post-hoc Tamhane’s T2 test. Correlation was determined using Spearman’s rho. P values less than 0.05 were considered statistically significant.

RESULTS

All components of the questionnaires were completed by all subjects. Musicians with dystonia had significantly higher NEO-FFI neuroticism subscale

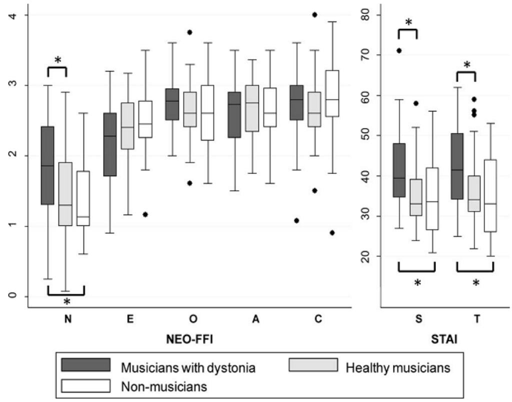

Figure 1. Box plots of NEO-FFI and STAI subscale scores by subject group. *Note.* N=neuroticism, E=extraversion, O=openness, A=agreeableness, C=conscientiousness, S=state anxiety, T=trait anxiety. NEO-FFI scores: 0="strongly disagree" to 4="strongly agree". Overall range of STAI scores: 20-80 points. * p<0.05.

scores than healthy musicians (p=0.018) or non-musicians (p=0.001) (see Figure 1). There was no significant difference in neuroticism scores between healthy musicians and non-musicians (p=0.790) or between subject groups in any of the other NEO-FFI subscales.

Musicians with dystonia had significantly higher STAI state and trait anxiety subscale scores than healthy musicians (p=0.009 and p=0.012, respectively) or non-musicians (p=0.013 and p=0.001, respectively) (see Figure 1). There was no significant difference in state and trait anxiety scores between healthy musicians and non-musicians (p=0.997 and 0.614, respectively).

There was no significant correlation between the duration of dystonia and NEO-FFI neuroticism subscale scores (Spearman's rho=0.005, p=0.976). Negative correlation was found between the duration of dystonia and the openness subscale (Spearman's rho=-0.268), and this correlation approached statistical significance (p=0.079). There was a negative correlation between age and openness in musicians with dystonia (Spearman's rho=-0.363, p=0.016) but no correlation between age and openness in the control groups. There was no correlation between duration of dystonia and state or trait anxiety.

DISCUSSION

In this study of psychological conditions in MD, affected musicians showed a higher degree of state and trait anxiety and neuroticism than healthy musicians and non-musician controls. Our results are supported by conclusions of prior publications that reported significantly greater anxiety in musicians with MD compared with healthy musicians (Jabusch *et al.* 2004, Jabusch and Altenmüller 2004).

The cross-sectional nature of this study precludes a definitive determination of whether or not anxiety or neuroticism was present before the onset of MD. However, trait anxiety and neuroticism scores were significantly elevated in MD patients, and there was no correlation between neuroticism or anxiety scores and MD duration. These results are consistent with studies of non-musician patients with anxiety and other forms of FD which reported that anxiety did not develop after the onset of FD, suggesting that anxiety is not a psycho-reactive phenomenon (Lencer *et al.* 2009).

A shared underlying mechanism for the development of MD and anxiety may exist as reported for some forms of monogenic dystonia, such as myoclonus-dystonia (Doheny *et al.* 2002). Transcranial magnetic stimulation and electroencephalogram studies have provided evidence for decreased cortical inhibition in FD (Ridding *et al.* 1995, Toro *et al.* 2000). Decreased cortical inhibition has also been observed in subjects with trait-related anxiety (Wassermann *et al.* 2001). It has been suggested that reduced cortical inhibition may play a role in the pathophysiology of both FD and anxiety (Lencer *et al.* 2009; Ron 2009). Specifically, abnormal neural activity in motor loops linking the basal ganglia to the frontal cortex via the thalamus may additionally influence limbic loops, resulting in both altered motor and also affective processing (Lencer *et al.* 2009).

In conclusion, musicians with FD showed significantly higher values of neuroticism, state anxiety, and trait anxiety than healthy musician and non-musician controls. The observed lack of correlation between anxiety and the duration of dystonia suggests that anxiety may not be a psycho-reactive phenomenon. The hypothesis of a potential common pathophysiological mechanism of anxiety and MD should be further investigated.

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Thematic session:
Performance analysis I

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An accent-based approach to performance rendering: Music theory meets music psychology

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Accents are local events that attract a listener's attention and are either evident from the score (immanent) or added by the performer (performed). Immanent accents are associated with grouping, meter, melody, and harmony. In piano music, performed accents involve changes in timing, dynamics, articulation, and pedaling; they vary in amplitude, form, and duration. Performers tend to "bring out" immanent accents by means of performed accents, which attracts the listener's attention to them. We are mathematically modeling timing and dynamics near immanent accents in a selection of Chopin Preludes using an extended version of *Director Musices* (DM), a software package for automatic rendering of expressive performance. We are developing DM in a new direction, which allows us to relate expressive features of a performance not only to global or intermediate structural properties, but also accounting for local events.

Keywords: piano; expression; accents; timing; dynamics

Accents are local events that attract a listener's attention and are either evident from the score (immanent) or added by the performer (performed). Immanent accents are associated with grouping (phrasing), meter (downbeats), melody (peaks, leaps), and harmony (or dissonance; Parncutt 2003). In piano music, performed accents involve changes in timing, dynamics, articulation, and pedaling; they vary in amplitude, form (amplitude as a function of time), and duration (the period of time during which the timing or dynamics are affected). Performers tend to "bring out" immanent accents by means of performed accents, which attracts the listener's attention to them. For example, a performer may slow the tempo or add extra time in the vicinity of an immanent accent, or change dynamics or articulation in consistent ways. This relationship is complex and depends on musical and personal style, local and cultural context, intended emotion or meaning, and acoustical and technical constraints.

In a previous study, we asked ten music theorists to analyze a selection of Chopin Preludes by marking immanent accents on the score and evaluating their relative importance (salience). Agreement among participants was higher at phrase boundaries (grouping accents) than at melodic and harmonic accents. Phrase boundaries were determined by inter-onset interval (greater between than within phrases), contour (expected rise-fall arch shape), and meter (tendency for phrases to start on the beat).

In this study, we are mathematically modeling timing and dynamics near immanent accents in the central section of Chopin's *Prelude Op. 28 No. 13* using an extended version of *Director Musices* (DM)*,* a software package for automatic rendering of expressive performance (Friberg *et al.* 2006). DM implements performance rules (mathematically defined conventions of music performance) that change the timing, duration, and intensity of individual tones. By manipulating program parameters, meta-performers can change

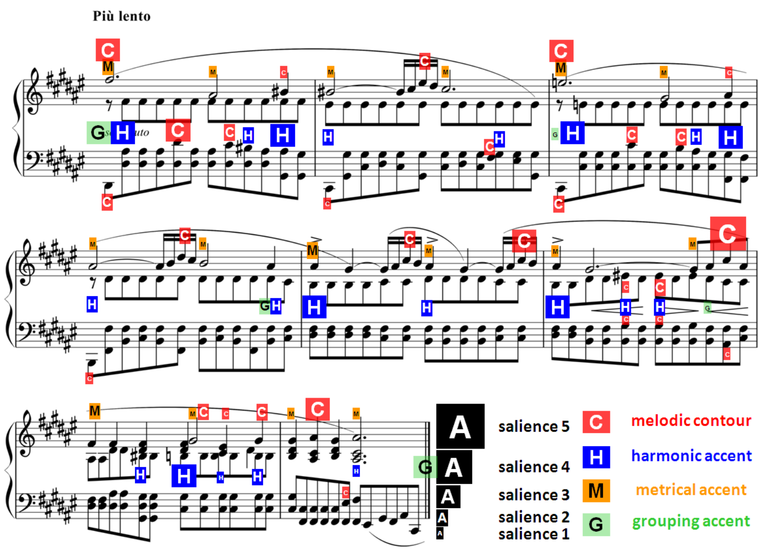

Figure 1. Subjective analysis of accents in the central section (bars from 21 to 28) of Chopin's *Prelude Op. 28 No. 13*. (See full color version at www.performancescience.org.)

the degree and kind of expression by adjusting the extent to which each rule is (or all rules are) applied.

In its previous formulation, the main structural principle of DM is phrasing (Sundberg *et al.* 2003). The *Phrase Arc* rule assigns arch-like tempo and sound-level curves to phrases that are marked in the score. DM also models aspects of tonal tension. The *Melodic Charge* rule emphasizes tones that are far away from the current root of the chord on the circle of fifths, and the *Harmonic Charge* rule emphasizes chords that are far away from the current key on the circle of fifths.

Several of the rules presented in DM can be interpreted in terms of Parncutt's (2003) taxonomy of accents, suggesting that a conflation of the two models may yield new insights into expressive performance and artistically superior computer-rendered performances. We are developing DM in this direction, which allows us to relate expressive features of a performance not only to global or intermediate structural properties (i.e. different levels of phrasing), but also accounting for local events (individual notes corresponding to accents) in a systematic way (Bisesi and Parncutt 2011).

MAIN CONTRIBUTION

Music analysis

The degree of accentuation of a note varies on a continuous scale which we call "salience." In Figure 1, immanent accents are divided into four types: melodic (or contour), harmonic, metrical, and grouping. The authors have subjectively assigned a salience rating between 1 and 5 to each accent, which is indicated by the size of the squares.

Melodic accents occur at the highest and lowest tones of the melody and at local peaks and valleys. For example, the first accent in the upper voice in the first bar is a local peak relative to previous and following tones; because the peak is relatively prominent we have assigned salience 3. As peaks normally have more salience than valleys, and the melodic theme is played by the upper voice, the simultaneous melodic valley in the lower voice has low salience (2). The second melodic peak in the inner voice of bar 1 is preceded by a smaller interval than the previous one, so the melodic accent has lower salience.

The harmonic accent of a chord in a chord progression depends on its roughness, harmonic ambiguity, harmonic relationship to context, and familiarity or expectedness. The first chord in bar 1 feels new by comparison to the preceding context, so we marked a harmonic accent of salience 3. The harmonic accent at the end of bar 1 is a roughness accent.

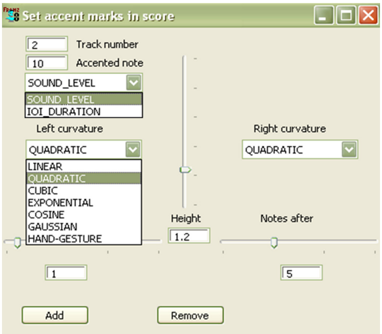

Figure 2. Graphical interface in the accent-based formulation of *Director Musices*.

Metrical and grouping accents depend on hierarchical metrical and phrasing structure. At the highest level, Figure 1 is one long phrase. It can be divided into two 4-bar sub-phrases of nominally equal importance, which in turn can be divided into sub-sub-phrases of two bars. In this case, the hyper-metrical structure is indistinguishable from the phrasing structure.

Mathematical and computational model

We are modeling the timing and dynamics in the vicinity of an accent by two separate mathematical functions. Once the accents are marked in the score, the *Accent-Sl* and *Accent-Dr* rules give to them arch-like tempo and sound-level curves (here, the suffixes *Sl* and *Dr* respectively stand for sound level and duration). Each function admits five free parameters: the height of the peak, the duration before and after the peak, and the shape before and after the peak. Shapes may be linear, quadratic, cubic, exponential, Gaussian, cosine, or hand-gesture (Juslin *et al.* 2002). A graphical interface enables the performer to choose any combination of parameters (see Figure 2).

We are systematically evaluating different combinations of these parameters in given musical contexts, based on our artistic and professional experience as pianists. Different combinations of height, width, and curvature of both timing and dynamics can account for different performance qualities. The perceptual salience of the performed accent function depends on the area under a graph of beat duration or loudness against time. The greater the accent salience, the greater the height and/or width of the function. The curvature is not only connected with the perceptual salience, but also with the motion and emotional content (Juslin *et al.* 2002). We model the relationship among width, height, musical function, and expressive content in the follow-

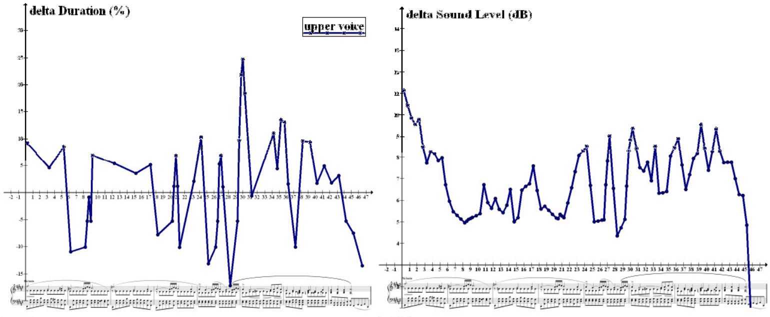

Figure 3. Example of mathematical modeling of timing (left panel) and dynamics (right panel) in the central section of Chopin's *Prelude Op. 28 No. 13*, according to the analysis of Figure 1. See text for description.

ing way: for linear function, we associate a combination of peak and width to a given salience according with the algorithm P+(W1+W2)/2=S+1, where P is the peak amplitude, W1 is the width interval preceding the accent, W2 is the width interval following the accent, and S is the salience. Units for P, W1 and W2 are defined so that a value of 1 corresponds to an increment of 4 dB in the sound level and 20% timing deviations, respectively. According to the algorithm above, any value of salience can correspond to many combinations of peak and width. For non-linear functions, salience is modeled by adapting any combination of peak and width to provide the same area below the graph as in the linear case (for each combination of P, W1, and W2). When a tone or a chord has more than an accent, profiles in timing and dynamics account for the root mean square of all the accents.

Figure 3 provides an example of rendition of the central section of Chopin's *Prelude Op. 28 No. 13*, according with the analysis of Figure 1: left panel shows the duration relative to the nominal duration of each note of the upper voice as a function of its position in the score, and right panel corresponds to the difference in sound level from the default value as a function of the note position (here, values of different voices are superimposed).

IMPLICATIONS

In a future study, different renditions of selected passages and pieces will be evaluated by pianists, theorists, and musicologists, and model parameters will be adjusted accordingly. We will map out possible ranges of parameter values or fields in multidimensional parameter space that correspond to musically acceptable performances. We will also specify small parameter ranges that correspond to particular qualities of performance as expressed by words obtained from a separate qualitative study, such as bright and dark, joyful and sad, static and dynamic, expected and surprising.

The theory can be applied in expressive music performance pedagogy. Students can learn the theory by working with a computer interface to create renderings of pieces that they are currently studying. In the process they will select immanent accents for accentuation and adjust the corresponding model parameters to achieve a desired result. They will then be in a position to apply the ideas behind the model in their performance and teaching.

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Automated performance analysis of virtuosic music for string instruments

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We present an interactive program for analysis of performance possibilities for violin, viola, and cello music. The user is offered the full range of fingering options, together with structured methods for exploring, interpreting, and ultimately narrowing the possibility space to a few desirable choreographies for an entire piece. Fingerings are suggested based on performance structures such as *arpeggiation*, *axis* fingerings in which fingers are prepared in advance, and *bariolage* (patterned bowings). The program, which can be obtained at www.computingmusic.com, is intended as an aid for novices and composers, as an analytical resource, and as a component of an autonomous composing program.

Keywords: performance; bowed instruments; computer analysis; pedagogical software; music analysis

Previous research in automated fingering for guitar and piano has been based on the ergonomic principle of minimizing performance difficulties (Sayegh 1989, Parncutt *et al.* 1997). Treating fingering as an optimization problem, these programs assign difficulty costs to fingering positions and transitions between positions and then look for a *least-cost path* through the piece. Finding a least-cost path can be done efficiently using a standard computer science technique called *dynamic programming*. Similar ideas have not yet been applied to bowed instruments.

A more complete program must allow for musical and interpretive considerations along with ergonomic ones: an open string might create the right or wrong sonority, a shift of hand position may force a slight break in the music which ought to have musical grounds, playing on one string or two has musical consequences, and so on. One generally cannot tell what kind of performance is called for without grasping the underlying music, but computers are currently very poor at this sort of analysis. This makes the goal of autonomously generating "best" fingerings unrealistic.

Very difficult music can often be fingered in a small number of ways, however, and it is useful to understand where and how performance constraints arise. For certain passages, it may turn out that there is one especially clever performance path that minimizes difficulty and that can be recognized computationally. But it may also be that there is no fingering that distinguishes itself: in this case, the program will merely list the possibilities.

The aim of this research is the development of a computer program that offers pedagogical value in presenting the performance possibilities of a piece of music to a novice or composer. The program also offers musicological value in probing the question of the relation of compositional style and performance and creative value in assisting the discovery of virtuosic devices toward the development of potentially new performance idioms.

MAIN CONTRIBUTION

A Java program was developed to investigate ideas concerning performance for violin, viola, and cello. The program presents the user with a conventional music-notation window, offering possibilities for fingering which the user may choose to select or reject. Parameters are provided to adjust for a player's hand size. The system is designed to analyze music of any complexity; in developing the program, special attention was given to the solo sonatas and partitas by Bach and Ysaÿe, the Paganini caprices, the Ligeti violin concerto, and the second string quartet of Brian Ferneyhough. The program can be downloaded for free at www.computingmusic.com.

A first computational problem arises in trying to establish which *chords* are at all possible. Typically, orchestration manuals provide tables showing the finger placements for different notes. The composer uses these to predict playability. One such set of tables is found in Cassela and Mortari's (1958) treatise on orchestration. As an exploratory study for the String Fingering program, we implemented these tables as an algorithm.

It emerged that the rules given in the treatise are insufficient to eliminate awkward contortions of the fingers, leading to essentially unusable fingerings. We would like the program to be able to advise on the difficulty or impossibility of a given fingering. To address this, we developed a system of hand *topologies*. In consultation with instrumentalists, we discovered rough difficulty levels for these topologies. For example, as shown in Figure 1, a topology such as "line-up" in which the stops are consecutively higher from string to

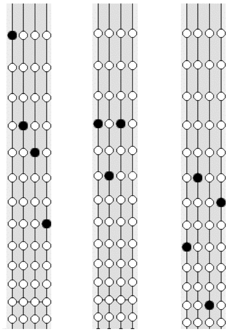

Figure 1. Example chord topologies. From left to right: “line-up” is easy, “triangle-lo” is harder, and “diamond” is very difficult.

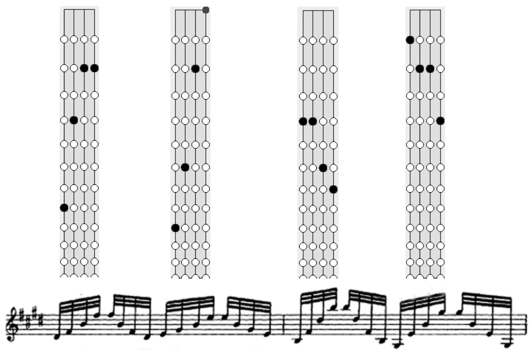

Figure 2. Arpeggio fingering for Paganini’s *Caprice Op. 1, No. 1*, bars 3-4.

string, is easy to play, while “triangle-lo” is harder and “diamond” is very difficult.

For two chords in succession, the number of possible fingerings is the product of the number of ways each chord can be fingered. Whether a caesura is made, or whether the music seamlessly flies from chord to chord now depends on the facility of this transition. There may be an easiest and fastest way to move from one chord to the next, which is suggested by the program.

Generically, an *arpeggio* is a series of notes with one note per string. The String Fingering program proposes groupings of consecutive notes that can be fingered all at once (as though they were a chord) and played as an arpeggio: an example from a caprice by Paganini is shown in Figure 2. The algo-

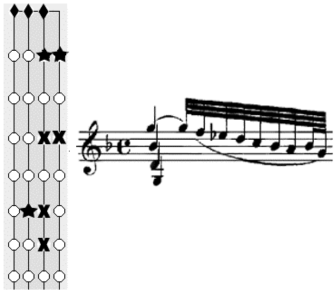

Figure 3. Arpeggio fingering for Paganini's *Caprice Op. 1, No. 1*, bars 3-4.

Figure 4. A bariolage passage in the *Chaconne* from Bach's *Partita No. 2* for solo violin.

rithm to generate all possible arpeggios in a piece is essentially a one-pass algorithm making use of the chord analysis technology described above. The resulting fingerings minimize movement of the hand, since a new configuration is attained after every few notes instead of after every note.

We adopted another promising and general fingering model based on Yampolsky's (1967) concept of the *axis*, in which fingers are prepared ahead of time, allowing notes to be sounded by lifting *occluding* fingers. Figure 3 shows a short passage by Bach that can be played as an axis, by preparing and releasing fingers. After the chord, the second finger holds the G on the first string, while the first finger moves to the F, also on the first string, and the third and fourth fingers prepare the E*b* and D on the second string. While these notes are being played, the first and second fingers reposition themselves on the second string in anticipation of the C and B*b*, and so on.

When the program starts building an axis from a given point in the music, the location of the first few notes constrains the locations of the following notes, so that instead of having a combinatorial possibility space from note to note (5832 ways to play the example case, most of them arguably useless), we have only a few ways (in this case, one) of playing the passage.

Another aspect of creative interpretation is explored in the problem of bowing. Again, there are thousands of conceivable ways of playing the passage from Bach's *Chaconne* shown in Figure 4. A least-cost path algorithm minimizing left hand movement and difficulty almost certainly will suggest playing the sequences of three A5s as a repetition of the same fingering, on the same string. On the other hand, this passage was certainly intended to be played with a structured bowing pattern, or *bariolage*, so that the bow strictly alternates between the open second string and the open or stopped third string (third *and* fourth strings on each downbeat).

Analyzing for performance structures such as bariolage, arpeggiations, and axes, the String Fingering program navigates a middle route between the tyranny of the least-cost path and the combinatorial explosion of raw possibilities. What is offered to the user is the full range of performance options, together with methods for interactively exploring, interpreting, and ultimately narrowing the possibility space to a few desirable choreographies for an entire piece.

IMPLICATIONS

The String Fingering program can assist performers for whom computer-assisted discovery is a natural extension of the Yampolskian concept of "rational" fingering. It can also be used by composers. In cases where ease of performance or even playability is uncertain, composers consult with players (as Brahms did with Joachim, for example), but often the player is unavailable. The String Fingering program can help a composer to grasp the hugely complex technique of the string instruments from within.

The String Fingering program also offers a new analytical venue in which performance and interpretative possibilities can be seen as constituents of the compositional task. A number of avant-garde composers, including John Cage, specified how the instrument is to be played without saying what the result should sound like. In Cage's *Freeman Etudes*, fingering possibilities for multiple stopping make the only contribution to structure. Cage carried out an analysis of chords that can be played on the violin, and used a random process to organize them. What if he had not confined his analysis of the violin to playable chords, but had extended it with details pertaining to other performance structures? The contribution of the instrument to musical structure would have been that much greater. What if the full range of violin technique were (randomly or systematically) deployed? The result could be "music as choreography of the hand," as a correspondent put it.

"Composed performance" has had some life in avant-garde music. But this raises a different sort of question. To what extent do the structure and possibilities of the body and instrument manifest themselves in the standard repertory of eighteenth and nineteenth century music? Can we view the "choreography of performance" in such music as an intrinsic aspect of musical design? Given the influence of virtuosi like Bach, Beethoven, Paganini, Chopin, and Liszt, this seems more than likely. In that case, fingering is more than a dry technical problem. As a theoretical speculation, it de-centers sound and privileges physics and physiology. It proposes a step toward the problem of finding a naturally occurring set of properties that help explain the nature of musical organization.

An autonomous composing program (in fact, our original motivation for developing the String Fingering program), could compose performance directly, guessing that the structure and physics of the violin, together with the player's physiology, will provide unpredictable links to the historical character of violin performance and inform the harmonic and melodic character of generated compositions. If we are correct, we will have demonstrated a rather complex proposition about the potentially prior role instruments play in determining how music goes. Our aim is to engender a style of performance-based composition, in which the implications of (for example, John Cage's) work composing performance, rather than the notes, is fully realized.

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A method to determine the contribution of annotated performance directives in music performances

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Interpreting notated music and performing it expressively is a complex skill that requires years of practice. In the quest for understanding this phenomenon, a question that arises naturally is to what degree performance directives annotated in the score affect expressive variations of tempo and loudness. Computational models of musical expression typically focus on musical structure and do not explicitly take into account annotated performance directives. The objective of the method presented here is to determine the degree to which loudness directives can account for expressive variations in loudness as measured from performances. To this end, we represent loudness directives by mathematical functions and use these to approximate measured loudness curves. This approximation yields coefficient values that represent how strongly each directive is reflected in the performance. Furthermore, the residual loudness curve after subtracting the model fit provides a clearer view on other, non-explicit factors that influence expressive loudness variations.

Keywords: empirical musicology; expression modeling; music performance; performance directives; computational analysis

Interpreting notated music and performing it expressively is a complex skill that requires years of practice. Many empirical studies exist that aim to elucidate the process of expressive performance. A factor that is considered to be of major influence on expressive variations in performance tempo and loudness is the structural interpretation of the music (Clarke 1988). Several computational models have been proposed to hypothesize how structural aspects of music explain expressive performance (Todd 1992, Parncutt 2003).

Composers often give hints as to appropriate loudness and tempo by annotating scores with performance directives, such as *crescendo* and *accelerando*. Such directives are typically not a formal part of computational models of expressive performance. A possible explanation for this is that performance directives are often regarded as incidental to pitch and temporal structure, the latter two being considered the essence of notated music. In some cases this may be true, for example where the expressive hints of composers have led to a performance practice that marks a particular musical genre. In other cases, composers may place highly specific, non-obvious markings to ensure the performance achieves the intended effect. Rosenblum (1988) offers a discussion of the interpretation of expressive markings in composers' works.

In this paper, we present a novel method to disentangle the interpretation of explicitly written loudness directives from non-explicit forms of loudness variation. On the one hand, this allows us to determine how such directives are interpreted by performers; on the other, it may provide a clearer view of expressive interpretation beyond the written directives. The method follows the common intuition that musical expression consists of a number of individual factors that jointly determine what the performance of a musical piece sounds like (Palmer 1996). The goal is then to identify which factors can account for expressive dynamics and to disentangle their contributions to the loudness of the performance.

METHOD

The objective of the presented method is to determine the degree to which loudness directives can account for expressive variations in loudness measured from performances. To this end, we represent each loudness directive by mathematical functions, henceforth called *basis functions*. Each basis function represents loudness as a function of time, over the scope of its corresponding directive. The functions are weighted and summed to approximate loudness curves of performances, as illustrated in Figure 1.

We distinguish between three categories of loudness directives. The first category, *constant*, represents markings that indicate a particular loudness character for the length of a passage. This category includes the familiar markings (*p*, *f,* etc.) and adjectives such as *dolce* and *leggiero*. The second category, *impulsive*, indicate a sudden and brief change of loudness, such as *fp* and *sf (sforzando)*. The third category, *gradual*, contains directives that indicate a gradual change from one loudness level to the other, such as *(de)crescendo*, but also metaphorical descriptors of dynamic evolution, such as *perdendosi* and *smorzando*.

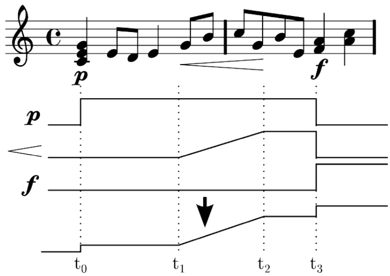

Figure 1. Example of basis functions representing performance directives.

We assign a particular basis function to each category. The markings of the constant category are modeled as step functions that have value 1 over the affected passages, and 0 elsewhere. Impulsive directives are modeled by unit impulse functions, which have value 1 at the time of the directive and 0 elsewhere. Lastly, gradual directives are modeled as a combination of a ramp and a step function, which is 0 until the start of the directive, linearly changes from 0 to 1 between the start and the end of the indicated range of the directive (e.g. by the width of the "hairpin" sign indicating a crescendo), and maintains a value of 1 until the time of the next constant directive.

With this mapping of performance directives to functions, sequences of directives, as read from a musical score, can be translated to a set of basis functions. Finding the weighting coefficients that make the weighted sum of these basis functions approximate a measured loudness curve as closely as possible is an example of linear regression, a well-known algebraic problem. The optimal coefficients can be found using least-squares minimization. This yields one coefficient for each loudness directive, representing the strength of that directive in the performance.

Data

We test the above method on a set of performances of Chopin's piano music, performed by a number of famous pianists. The data have been extracted from CD recordings and used earlier by Langner and Goebl (2003). Perceived loudness calculation from the audio data was done using Zwicker and Fastl's (2001) psychoacoustic model. To eliminate any effects of recording quality, the data was transformed to have zero mean and unit standard deviation per piece, as in Repp (1999). The data set includes multiple performances of four Chopin piano pieces, as listed in Table 1.

Table 1. Performances used for evaluation of the method.

Piece	*Performances*
Op. 15 (1)	Ashkenazy 1985, Rubinstein '65, Richter '68, Maisenberg '95, Leonskaja '92, Arrau '78, Harasiewicz '61, Pollini '68, Barenboim '81, Pires '96, Argerich '65, Horowitz '57, Perahia '94
Op. 27 (2)	Rubinstein '65, Arrau '78, Kissin '93, Leonskaja '92, Pollini '68, Barenboim '81, Ashkenazy '85, Pires '96, Harasiewicz '61
Op. 28 (17)	Sokolov '90, Arrau '73, Harasiewicz '63, Pogorelich '89, Argerich '75, Ashkenazy '85, Rubinstein '46, Pires '92, Kissin '99, Pollini '75
Op. 52	Kissin '98, Pollini '99, Zimerman '87, Horowitz '52/'81, Rubinstein '59, Cherkassky '87, Ashkenazy '64, Perahia '94

RESULTS

The linear basis model was fitted to the measured loudness curves of the performances. An example is shown in Figure 2. The goodness-of-fit is quantified in two measures: the coefficient of determination (R^2), expressing the proportion of variance in the measured loudness curves explained by the fitted model, and the correlation coefficient (r), expressing linear dependence between model fit and measurement. In columns 2 and 3 of Table 2 (*Meas. vs. Fit*), R^2 and r measures are shown per piece, averaged over all performers. Analysis of variance shows that both R^2 and r differ significantly across pieces: $F_{3,8}=30.15$, $p<0.001$, and $F_{3,8}=26.51$, $p<0.001$, respectively. [*Note.* To avoid an unbalanced setup, only the performance of Pollini, Rubinstein, and Ashkenazy were used for the ANOVA.] No effect of performer on goodness-of-fit measures was found. Columns 4 (*Measurement*) and 5 (*Residual*) of Table 2 summarize the correlations between the loudness curves of performers. The r values in column 4 are computed on the measured loudness curves. Column 5 contains the r values computed from the residual loudness curves, after the model fit has been subtracted. The variance of coefficients across pieces appears to be too large to reveal any simple relationships between performers and coefficients, independent of the piece. Within pieces, however, significant effects of performer on coefficients are present for the coefficients of some loudness directives. For example, in Op. 52. there is a performer effect on *ff* coefficients ($F_{7,28}=3.90$, $p<0.005$) and in Op. 28 (No. 17) on *fz (sforzando)* coefficients ($F_{9,90}=25.75$, $p<0.0001$).

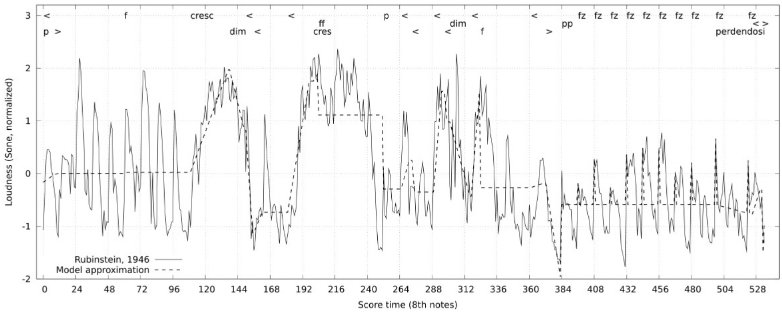

Figure 2. Example of a loudness curve and a fitted model. Solid line=loudness as measured from Rubinstein's performance (1946) of Chopin's Prelude, Op. 28, No. 17; Dashed line=approximation of the loudness curve by the linear basis model; loudness directives are displayed above the curves, where < and > denote "hairpin" crescendi/diminuendi, and *cresc.* and *dim.* denote longer range crescendi/diminuendi.

Table 2. Mean and standard deviation of R^2 and r per piece.

	Meas. vs. Fit		*Measurements*	*Residual*
Piece	R^2	*r*	*r*	*r*
Opus (No.)	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
15 (1)	0.90 (0.04)	0.95 (0.02)	0.88 (0.03)	0.50 (0.11)
27 (2)	0.76 (0.07)	0.87 (0.04)	0.80 (0.03)	0.56 (0.07)
28 (17)	0.66 (0.08)	0.81 (0.05)	0.76 (0.06)	0.61 (0.05)
52	0.86 (0.05)	0.93 (0.03)	0.82 (0.06)	0.48 (0.08)

DISCUSSION

The results show that the proposed model accounts for a large part of loudness variations in music performances. The residual loudness after subtracting model fits is substantially less correlated between performers. The remaining correlation is an indication of factors that are not represented by the model. Obvious candidates are pitch and the number of sounding notes at a specific time. As shown elsewhere (Grachten and Widmer 2011), the model also accommodates for such factors in the form of basis functions.

It is unlikely that the described method in its current form will result in clear "coefficient profiles" of performers—i.e. sets of coefficients that uniquely characterize how a particular performer interprets loudness directives. Many decisions on how to interpret directives will depend on context and on musical understanding of a level that is not easy to capture in a simple mathematical model. Nevertheless, the linear basis model can be a useful tool to compare interpretations of different performers for particular pieces or excerpts. It provides estimates of how strongly each loudness directive has shaped the loudness of a performance. Although one should keep in mind that the model gives only an approximation of performed loudness, these estimates can often be compared across performers in a meaningful way.

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Thematic session:
Learning and teaching I

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"Good music teachers should..." Conceptions of conservatoire elementary level students with regard to teaching string instruments

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Conceptions of teaching and learning (T&L) are becoming more and more relevant in investigations, both with children and with adults. They are important because a constructivist curriculum is demanding for conservatoires, and so teachers and students should reflect on how they conceive T&L, evolving from basic to complex conceptions or approaches to T&L. According to the *direct* conception, the simplest one, learning means getting results or musical products, usually defined as "a good sound" in the technical domain, which is achieved through repetitive practice. The *interpretative* approach, which is slightly more complex than the previous one, assumes the involvement of cognitive activity by the student, even if the processes of a technical procedure are sorted out by the teacher. It is clear and desirable that these two traditional approaches to teaching should be changed in order to promote the *constructive* conception, which focuses on how to coordinate the mental activity of the student with the motor procedures needed for instrumental performance, by means of working with the body and reflecting on practice, with the teacher as a guide. Following our theoretical framework, we developed videos of dilemmas in order to assess the conceptions held by 60 conservatoire elementary level students, according to two variables: *developmental-evolutionary* and *teaching approach* (traditional vs. constructive).

Keywords: conceptions of teaching and learning; music conservatoires; music education; researching materials; string students

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Inspirational teachers: Their role in the development of excellence in professional dancers

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In the study of outstanding performers, research has established the important role of significant people at different stages of excellence development. Specifically, teachers and mentors seem to have a central role in this process, contributing to the investment and persistence of individuals in learning, developing, and mastering a given task, as to professional socialization and influence. In this study, types of support and influence of teachers and mentors at different stages of dancers' excellence pathways are identified and analyzed. Using a case study approach, four dancers nominated for revealing excellence in performance and being actively engaged in their field were interviewed. Results confirm past research on the influential role of teachers and mentors in talent and expertise development. Dancers identify significant teachers and choreographers in their careers, particularly their important support on skill acquisition and mastery. Also, their role on dancers' careers as "inspirational teachers/choreographers" was also referred to. Reflections on future research are discussed.

Keywords: excellence; teachers' role; dancers; case study; qualitative

Research on excellent performance has established the important role of significant people at different stages of excellence development that contribute to the investment and persistence of individuals in learning, developing, and mastering a given task, as to professional socialization and influence (Bloom 1985, Ericsson *et al.* 1993). Several studies on the role and influence of significant teachers in excellence development suggest their impact on the self-esteem and career choices of individuals (Bloom 1985, Gomez *et al.* 2001, Morrow 1991, Schiff and Tatar 2003). In a previous study with gifted adults, Kaufmann and colleagues (1986) identified three main support functions of mentors and teachers: (1) role modeling, demonstrated by teachers considered exemplary, that stimulate students intellectually and transmit values and attitudes; (2) support and encouragement, expressed by teachers' concern for the interests and needs of students; and (3) professional socialization, promoting opportunities for social visibility and career information. Similarly, other authors (Morrow 1991, Schiff and Tatar 2003) highlight teachers' cognitive (facilitator of learning, challenging cognitive abilities, original and open to experience), confidence (respect and trust, scientific and pedagogical competence), and emotional (worry and concern, support and help) characteristics. Different kinds of teacher' support seems to be associated with different phases of learning and talent development (Bloom 1985, Durand-Bush and Salmela 2001). Research has pointed out that, at early stages of expertise acquisition, the motivational and affective support of teachers and mentors contributes to task involvement, curiosity, and pleasure for a given domain activity (Bloom 1985, Moore *et al.* 2003, Sosniak 1997, van Rossum 2001). As individuals get more involved in specialization and improvement in a particular field, rigorous and demanding teachers are more valued. In the latest years, individuals are highly committed to the talent field, to personal improvement, and specialization. Therefore, contact with competitive peers and masters seem to be essential for developing their "own trademark." In general, literature on excellence highlights the role of teachers and significant others in sustaining and regulating persistence, discipline, positive emotions, high expectations, and focus (Bloom 1985, Ericsson and Charness 1994, Durand-Bush and Salmela 2001, Subotnik *et al.* 2003). The aim of this study is to identify and analyze different types of support and influence of teachers and mentors identified by participants as significant, at different stages of dancers' excellence pathway. Particularly, the inspirational role of teachers is highlighted.

METHOD

Participants

Two female dancers and two male dancers were consensually identified by a panel of experts, for revealing excellence on performance and being actively engaged on their respective field. They work at contemporary dance companies, and they also have their own projects. The ages of participants range from 23 to 41 years old.

Materials

Relevant literature and interviews guides successfully used in previous studies with exceptional individuals in different domains (see Araújo 2010) were reviewed, and an interview protocol was created to assess the multiple topics of excellence development paths. A semi-structured protocol covered the following main areas: (1) career path, (2) past achievements and actual performance, (3) expertise acquisition, (4) personal characteristics, (5) role models and significant others, and (6) relationships within each professional community. In the present study, the topic of role models and significant others is analyzed in more detail.

Procedure

Participants were nominated according to the following criteria: awards, participation in international/European dance companies/projects, and professional certification. Identified participants were contacted and interviews were scheduled according to their time and location. Interviews were recorded integrally and transcribed verbatim, and then sent to participants for verification. The data analysis protocol was adapted from several proposals on qualitative analysis (see Araújo 2010) and assisted by Maxqda qualitative analysis software. Validity procedures included triangulation, member checking, and peer-debriefing (Onwuegbuzie and Leech 2007).

RESULTS

Data analysis reveals the singularity of individual paths in dance, including dancers' different familiar backgrounds and, in some cases, unconventional educational paths. For example, one of the male dancers started to dance at the age of fifteen years old, without any previous contact with dance, and is currently one of the most prominent Portuguese dancers. One female dancer also demonstrated an unconventional academic path, stating:

> They [the teachers] told me: "You can never be a dancer because you have twisted legs, and as a classical dancer you will not go far because you do not have the technique" (D1).

Nonetheless, all the participants identify teachers and mentors at different stages of their career development that played an important role. Based on Bloom's (1985) and Durand-Bush and Salmelas' (2001) phases of learning and talent development, we identified several kinds of teachers' support, influence, and inspirational role. In early stages, teachers were important sources of encouragement and motivation, stimulating participants' interest and pleasure in dance activities. But it is their particular role in recognizing participants' potential to excel, contributing to a developing sense of "specialness" and self-confidence that is highlighted. For example, dancer 2 identifies the important role of his dance teacher when he was 9 years old. She identified his potential talent, and his parents were recommended to enroll him in the dance conservatoire. Another dancer also states:

> I was very lucky to have started with this young teacher…because she was very good as a children's teacher, which is something that is not very easy to find…. And she had that knowledge, she was really careful. I think that was really important, to start with her, and it was very important that she recommended me to the other teacher (D3).

When participants started specialization in dance, teachers' knowledge and expertise were crucial to develop expert dance knowledge. At this stage, participants also reveal the central role of some teachers who recognized their talent and originality and helped them to improve their skills. As an example, Dancer 4 identifies a teacher that:

> …also saw my motivation and helped me a lot until the end of conservatoire. Indeed, from then on I began to evolve gradually, with hard work and effort, also with the help of colleagues, but essentially of this teacher (D4).

Also, Dancer 1 refers to the important role of some teachers who "understand that I could not have the technique but I had the will of being on stage," so they helped her to improve her skills and to apply her energy on stage.

After educational training, participants identified significant mentors and their role in professional socialization and career influence. Additionally, participants reported significant events where teachers' and mentors' action was influential to their individual careers. Dancer 3 identifies a choreographer she worked with that was influential to her work: "it opened doors to things I had never done or experienced or knew that existed." Also, dancer 4 reveals that when he started his professional career he had not yet developed the maturity and experience required to dance in a professional company. The company director was one of the significant people that had an influential role in his career and personal development: "It was with them I learned the most in that phase." Participants also stress the value of professional invitations and contacts, in addition to professional advice from mentors for their careers development. Finally, participants highlight the rigor and expert knowledge of their teachers, their motivational competence, and the inspirational role of some choreographers as key characteristics of their mentors. Dancers also identify some choreographers they worked with as "divas," having a strong effect in their personal "trademark" and their careers' development.

DISCUSSION

The present data confirm the literature review on the importance of teachers and choreographers as a facilitating factor of excellence development (Amabile 1983, Bloom 1985, Gagné 2004, Subotnik *et al.* 2003). Particularly, teachers' rigor and technical demand in early stages of expertise acquisition, as well their ability to recognize participants' potential talent and originality were emphasized. Dancers' contact with some "inspirational" teachers/choreographers seem to be influential in developing a sense of "specialness," self-confidence, motivation to persist and improve, and "inspiration" for tracing their own pathways. The influential role of significant others is especially discussed in excellence literature, but research on dance excellence is still developing. Additional data on the specific quality of support and characteristics of teachers and choreographers in different stages of the dance career is needed for more refined and comprehensive conceptualizations on excellence in dance.

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How do I learn to play my instrument? Conceptions about instrumental teaching and learning in woodwind students

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In this article, we analyze the conceptions that woodwind students hold about how we learn to play an instrument and which is the best way to teach it. Conceptions and beliefs about the nature of knowledge and its acquisition have been investigated in several domains. That kind of research helps us to understand how students and teachers conceive their teaching and learning processes, since these ideas underlie the processes themselves. Sixty-eight Spanish woodwind students from three different grades completed a multiple-choice questionnaire. Results showed a relationship among the level of instruction, the age of the participants, and the kind of conception held by them. A complex conception about instrumental teaching and learning, similar to the constructive view developed in the educational and psychological fields, appears associated to the higher grade students, whereas a realistic and direct conception appears related to the lower grade group. These results are consistent with those obtained in previous studies. Further research is needed in order to analyze the relationship between the conceptions and the actual processes and results of instrumental teaching and learning, as well as to work with the teachers in order to enrich their conceptions, which will enable more effective teaching and learning processes.

Keywords: conceptions; implicit theories; musical teaching; musical learning; woodwind students

Conceptions and beliefs about the nature of knowledge and how to teach and learn it have been investigated in several domains, since these conceptions underlie the actual processes of learning carried out by students (Dienes and Perner 1999, Hofer and Pintrich 1997, Pozo *et al.* 2006). Three conceptions, which appear articulated like implicit theories, have been identified in several studies: direct (passive and reproductive vision of instrumental teaching and learning [TL]), interpretative (an active but also reproductive conception of the elements of TL, but including the role of mental processes like attention, learning activities, etc.) and constructive (structural relations among components of TL—conditions, processes, and results—are considered). Constructive theories and methods of TL constitute the most effective way to promote self-reflection and facilitate the student to take the control of his or her learning, as well as reflect more accurately the way that we actually acquire knowledge (Pozo 2008, Pozo *et al.* 2006).

In the last years, the study of conceptions about TL has also been developed in the musical domain from different theoretical approaches (Bautista *et al.* 2009, Bautista *et al.* 2010, Hultberg 2002, Reid 2001, Torrado and Pozo 2006, Young *et al.* 2003, Zhukov 2007).

The main aim of this study was to identify the conceptions about instrumental teaching and learning, from the perspective of the implicit theories, held by woodwind conservatoire students, as well as the differences in those conceptions among students from different levels.

METHOD

Participants

Sixty-eight woodwind students (flute, oboe, clarinet, and bassoon), from 14 conservatoires in Spain and from three different grades took part in the study. The grades were: 4^{th} grade elementary education (10-11 years old), 3^{rd} grade professional education (15-16 years old), and 6^{th} grade professional education (18-19 years old, just before entering a music college).

Materials

We used a multiple choice questionnaire composed of 16 dilemmas about different teaching or learning common situations in instrument lessons, based on one designed by Bautista (2009) for piano students. Each of the three options was representative of an implicit theory (direct [D], interpretative [I], constructive [C]). Students had to choose the option with which they felt the most agreement (MA) and the one with which they felt the least (LA).

Procedure

The questionnaires were completed individually and collected directly by the first author.

Table 1. Observed frequencies (F) and observed percentages (%) in each response category (D, I, C) for each grade.

		4th grade elementary		*3rd grade professional*		*6th grade professional*	
		F	*%*	*F*	*%*	*F*	*%*
	D	109*	27.46%	71	20.17%	59**	18.04%
Most agreement	I	169	42.57%	142	40.34%	139	42.51%
	C	119**	29.97%	139	39.49%	129	39.45%
	D	189**	47.49%	193	55.14%	189*	57.80%
Least agreement	I	60	15.07%	49	14.00%	51	15.60%
	C	149*	37.44%	108	30.86%	87**	26.60%

Note. * Adjusted residuals higher than +1.96 (higher than expected). ** Adjusted residuals lower than -1.96 (lower than expected).

RESULTS

Taking as independent variable the grade levels, we calculated frequencies of choice, percentages, and two Chi-square tests of independence (MA and LA) in order to analyze the possible associations between grade and kind of response (D, I, C). Both Chi-square tests showed statistically significant differences among the grade groups (MA: X^2=14.7, gl=4, p=0.005; LA: X^2=11.1, gl=4, p=0.026). The frequencies which were statistically higher or lower than expected were detected through the adjusted residuals of both Chi-square tests, and highlighted in Table 1.

Basically, lower-grade students preferred the direct options and rejected the constructive ones, whereas higher-grade participants chose mainly interpretative and constructive options and rejected the direct ones more than expected. No statistically significant differences were found for the intermediate grade.

The next analysis, as a previous and necessary step before the ascending hierarchical classification (AHC), was a multiple correspondence factorial analysis (MCFA), in order to identify possible associations among all the possible choices in the questionnaire and the grade and age of the participants. This analysis gave us two main groups of associations: group 1 (direct group), characterized by a third of direct options (related to learning, teaching, and assessment in instrumental lessons), the rejection of the most of the constructive options (14 out of 16 dilemmas), and associated with the lower grade

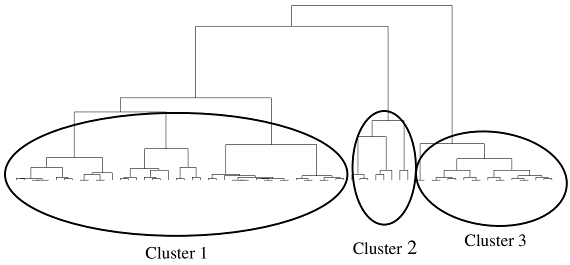

Figure 1. Dendrogram obtained from the ascending hierarchical classification (AHC).

and the first group of age (10-11 years old); and group 2 (constructive group), characterized by a third of constructive options (also related with those issues), the rejection of most of the direct options (13 out of 16), and associated with the higher grade and the age of 16-17 years old.

Finally, we carried out an AHC to classify each student and to identify profiles, in relation to their choices and rejections from the questionnaire. We obtained three classes, as shown on Figure 1.

Clusters 2 and 3, with 8 and 18 participants, respectively, confirm the associations among choices and rejections showed previously by the MCFA. Cluster 1, nevertheless, showed a big group of participants (42) who presented a direct-interpretative theory of teaching and learning. Students from this cluster understand the instrumental lesson as regulated by the teacher, who provides a model of performance. Learning depends on the amount of time devoted to practice and it consists of reproducing what appears on the musical score, trying to combine, with the teacher's help, the different possibilities of interpretation of the piece that are generally accepted.

Cluster 2 corresponds to the "direct group" from the MCFA. For these students, the teacher and the best performers are the ones who possess the correct knowledge about a musical piece. This knowledge can be passed on by the teacher to the student in a one-way dialogue, without considering the psychological aspects involved, and the main activity to fix it is by processes of repetition.

Cluster 3 represents the opposite side: it corresponds to the "constructive group" obtained by the MCFA. These students conceive teaching and learning as processes to promote self-regulation and reflection. The reproduction of the musical score is not enough in order to perform a piece because the student needs to understand it, developing a personal way of interpretation.

DISCUSSION

Analyses showed associations among different ideas regarding the conceptions about instrumental teaching and learning (TL) held by woodwind students, which, taking them together, correspond to the "implicit theories" about TL identified in other domains (Pozo *et al.* 2006). Both the age and the level of instruction seem to be determinant factors in order to reach a more complex theory like the constructive one. Characteristics of the groups identified through the MCFA, as well as those obtained by the AHC, are related to previous research, for example with the approaches to music notation and teaching styles identified by Hultberg (2002) and the levels of learning instrumental music described by Reid (2001), as well as to other studies about implicit theories in the musical domain (Bautista *et al.* 2010, Bautista *et al.* 2009, Torrado and Pozo 2006).

Further research and methods are needed in order to achieve a more complete understanding of these conceptions in the musical context and the way that those influence and determine the daily learning processes of the students. It is also necessary to work with instrument teachers in order to enable enrichment of their conceptions, so that teaching and learning processes become more effective and more appropriate to our cognitive structure and working.

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Thematic session: Performance analysis II

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Toward a model of performance errors: A qualitative review of Magaloff's Chopin

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Musicians at all levels of proficiency must deal with performance errors and have to find strategies for avoiding them. Performance errors have been investigated before, but most studies focus on data gathered under laboratory conditions. We present a study conducted on a unique corpus of precisely measured performances: the complete works for solo piano by Chopin, performed on stage by the Russian pianist Nikita Magaloff, recorded on a Bösendorfer SE computer-controlled grand piano in a series of public recitals in Vienna in 1989. We classify groups of errors, analyze their context and the patterns they form, and discuss probable causes.

Keywords: piano performance; performance errors; error catalogue; error model; Chopin corpus

Performance errors are a perennial issue for musicians, both when practicing in private and when performing in public. Due to the lack of precisely measured performance data, empirical investigations of the phenomenon are limited. Previous studies (Flossmann *et al.* 2009, Flossmann *et al.* 2010b) focused on single-note errors, their immediate context, and their relation to performance tempo. The goal of the present study was to build and analyze groups of errors, the context in which they occur, the patterns they form, and what conclusions can be drawn as to the potential causes.

A study seminal to this approach is Palmer and van de Sande (1993), which relates single-note production errors to units of mental representation of music. The authors conclude that the units in which music is stored and retrieved from memory depend on the musical context. Further, insertion and substitution errors are more likely to involve harmonically or diatonically related notes. Repp (1996) focused on the perception aspect of performance errors and investigated how obvious errors are to a concert audience.

METHOD

The data we analyzed are a unique resource of live piano performances: the Magaloff corpus (Flossmann *et al.* 2010b) comprises the complete works of Chopin performed on stage by the Russian pianist Nikita Magaloff on a Bösendorfer computer-controlled grand piano and recorded in MIDI. The MIDI data were aligned to musicXML representations of the Henle Urtext Edition (Zimmerman 1976-2004) of the score, which resulted in a fully annotated performance corpus. The errors were marked as insertion, deletion, and substitution errors.

For a part of the corpus (4 Ballades, 24 Preludes Op. 28, 24 Études Opp. 10 and 25, 17 Nocturnes), we categorized errors (single errors or groups of errors) manually into error patterns. We identified most likely causes for prototypical instances of the categories (e.g. idiosyncratic interpretation, memorization, technical simplification). We excluded 134 insertion errors with very low MIDI velocities because we cannot exclude the possibility that they were measurement artifacts. We also excluded 229 deletion errors (Op. 25 No. 10, bars 101-102, and Op. 32 No.2, bars 64-69) that are most likely the result of differences between our edition of the scores and that of Magaloff.

In total, 36% of the insertion notes, 44% of the deletion notes, and 44% of all substituted notes in the pieces were assigned to the established categories. The remaining errors could not be distinguished further. Table 1 shows the error categories with their respective error counts.

Table 1. Number of errors in the different categories.

Category	*Insertions*	*Omissions*	*Substitutions*
Omitted inner voice	-	630	-
Forward-related errors	59	9	40
Backward-related errors	75	8	53
Unharmonic errors	694	-	88
Harmonic errors	104	-	69
Tied notes	91	294	-
Repeated notes	123	-	-
Systematic errors	228	555	110
Note order errors	-	-	261
Total	*1385*	*1496*	*635*

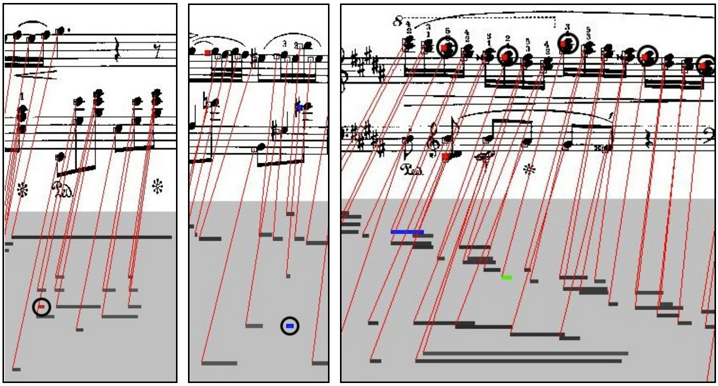

Figure 1. Forward-related insertion in Nocturne Op. 9 No. 2 (left); repeated note in Nocturne Op. 9 No. 3 (middle); systematic deletion in Étude Op. 25 No. 10.

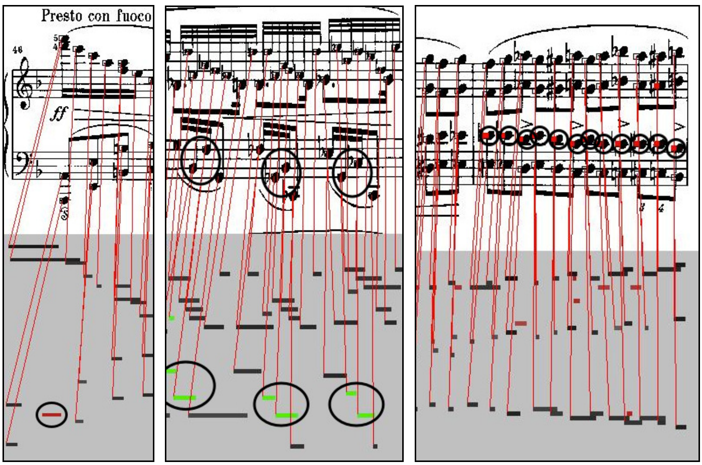

Figure 2. Systematic insertion in Ballade Op. 38, bar 46 (left); note order error in Prelude Op. 28 No. 8 (middle); omitted inner voice in Étude Op. 25 No. 10 (right). (See full color version at www.performancescience.org.)

RESULTS

Several distinct error patterns emerged, covering roughly 40% of the errors in the pieces examined. Below, we provide a brief explanation of the different categories and discuss prototypical examples.

Forward- and backward-related errors

Errors in this category have a clear forward or backward relation. Figure 1 shows a typical example: the pitch B*b* in the immediately following chord causes the insertion. Analogous situations occur for substitutions and omissions with both forward and backward relations. In almost all cases, the most probable cause is a memorization problem.

Repeated notes

Repeated notes are a special form of backward-related insertions that are unrelated to the metrical grid: a note that was (likely unintentionally) played twice. In many cases, one of the performed notes is much softer than the other one. Possible causes include a silent change of fingering for the note where the finger was lifted too high in the transfer, thus striking the note twice. Figure 1 shows a typical example.

Unharmonic errors

Errors that obviously disrupted the harmonic context were classified as unharmonic. This mainly involves insertions at a significant MIDI velocity a semitone above or below the notated pitch. A large percentage (46%) occurred in octave runs in either one or both hands.

Harmonic errors

Insertion or substitution notes associated with this category do not disrupt the harmonic context of the piece. In most cases, these are added octaves in the accompaniment or accompanying notes that were shifted by one octave. While the latter points to a memorization problem, the former could also be deliberate harmonic emphasis. Rare cases involve added figurative elements, such as trills, that were not notated in the score.

Tied notes

Two kinds of errors are related to the concept of tied notes. (1) A tied note might be struck again, resulting in an insertion note; this is either a problem of memorization (mostly in inner voices) or done intentionally to emphasize a melody line that otherwise lacked continuation. (2) Two successive notes of the same pitch might be played only once, as if they were notated as tied, resulting in an omission of the second note; in most cases this seems to be caused by the need for technical simplification.

Systematic errors

We call an error systematic if it occurs in more than 60% of instances of the same or an analogous context. This covers a variety of situations. Figure 2 shows a systematic insertion from Ballade Op. 38: in almost all instances in which the right hand starts with a downward run, accompanied by a rising sequence of octaves in the left hand (e.g. bars 46, 48, 50), Magaloff inserted a note shortly before or after the first octave in the left hand, probably for technical reasons. Étude Op. 25 No. 6 contains several downward runs in thirds. In each of these runs, Magaloff omitted notes from the highest voice at regular intervals (every third or fourth note). The regularity suggests a technical problem with the fingering in this passage. In Étude Op. 25 No.1, Magaloff often omitted the second note of the figure in the left hand. This suggests a weak third finger and a problem covering the large span required in the left hand. A systematic substitution can, for instance, be found in Étude Op. 25 No.6, bars 7 and 8, where Magaloff consistently played A instead of A#. This is probably due to a problem of memorization.

Omitted inner voice

A special case of systematic deletion is the omission of an inner voice: throughout a sequence of onsets, an inner voice is omitted partially or completely. In most instances the most likely cause is either a memorization problem (the least significant voice was simply forgotten) or the need for technical simplification, depending on the complexity of the passage. For instance, in Étude Op. 25 No.10, bar 16 (Figure 2), Magaloff omitted one of the two inner voices from a sequence in which the two hands move in parallel octaves. In this highly homogeneous context, the omission is very obvious to the audience and clearly not a problem of memorization but a result of the technically demanding nature of the piece.

Note order errors

These errors form the only category that relates to timing: the order in which two (or more) successive notes are played is switched, resulting in two (or more) substitution notes. Instances of this pattern are mainly found in Étude Op. 25 No. 3 and Prelude Op. 28 No. 8. In both pieces, the affected group of notes is a descending pattern in the left hand, consisting of four notes. In the étude, the lower of the two notes at the first onset is played after the third note in the group, resulting in a downward sequence of four notes. In the prelude, the affected group is very similar, with the slight difference that the first two notes are to be played successively instead of simultaneously. Again, the two middle notes are often switched, producing the same downward sequence as in the étude. Figure 2 shows an excerpt from the prelude. As the performance tempo of both pieces is high, the change in note order is hard to notice. This suggests intentional simplification as the reason for the error.

DISCUSSION

This study is part of a series of investigations of a unique resource of onstage performances. Categorizing the errors in them allows an inventory of possible error situations to be built. Studying sequences of errors, the context and patterns in which they occur, and their likely causes can help build a model of errors in piano performances. Given suitable data, it would also be interesting to compare how other pianists cope with technically demanding situations: whether they share techniques to simplify passages by harmonic substitutions and whether there are pieces that all find particularly hard to memorize.

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Use of spline curve to evaluate performance proficiency of a Czerny piano piece

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Our previous study evaluated the level of proficiency in playing the piano for only a scale of one octave. We try to evaluate the proficiency for a piano etude by Czerny, by using some conventional parameters concerning the onset, velocity, and duration, as well as those concerning a new feature, which is the tempo, obtained from the intervals of time between adjacent notes. The deviations from the standards, such as the metronome for the onset time, the velocity average, the constant length (200 or 100 ms) of a duration, and the specified tempo (75 or 150 bpm) are obtained. Then, the tendencies of the current performance are obtained from a spline curve. The representative points of the curve are determined based on "crossing" and "turning." We compared the obtained scores given by the proposed method with a simple or previous method, using the adjusted coefficients of determination between score of proficiency estimated by each method and that given by expert pianists. The scores obtained were 0.45, 0.67, and 0.69, for the simple, previous, and proposed, respectively, when playing under 75 (bpm), indicating that the proposed method can be used to evaluate the performance of piano etudes.

Keywords: piano; tendency curve; spline curve; performance evaluation; components calculating parameters

The development of electronic pianos has recently enabled more people to play the piano. Since it costs so much money and time to take piano lessons, many people teach themselves. Several support systems for self-training have been invented. In previous studies on the support systems for self-training, evaluations on the proficiency of piano performances based on a spline curve representing the tendency of the current performance were studied (e.g. Miura *et al.* 2010). However, the task used in the proficiency evaluation in playing the piano was restricted to a scale of one octave. So, the flexibility of tasks is called into question. We tried to evaluate the proficiency for a piano etude by Czerny in this study by using the method proposed in the previous study as well as by introducing new parameters concerning tempo.

METHOD

Participants

Twenty three pianists with over 15 years of experience participated in this recording experiment. Moreover, four of them participated in the evaluation experiment for the piano proficiency.

Materials

Performance task

This study uses nine bars out of Czerny's *Etude No. 40* as the performance task, as shown in Figure 1. Originally, the tempo of the task was specified as 208 bpm, but we changed it to 75 and 150 bpm.

Evaluation model

This study uses a spline curve as the evaluation model (Morita *et al.* 2009). The spline curve represents the tendency curve of current performance. In addition, in our previous study, the determination method for the representative points of the spline curve was based on the sequence of notes by dividing them into several clusters comprised of several notes, based on the "crossing" and "turning" of the finger when playing. Then, the center in each cluster is regarded as the representative points of each cluster. We used the conventional method here.

Evaluation parameters

Five ways of calculation were used, just as in the previous study, for four features such as the onset time, velocity, and duration covered in the previous study, and the tempo, in which the tempo parameters are newly introduced as representing the spontaneous deviations in tempo when playing. The tempo

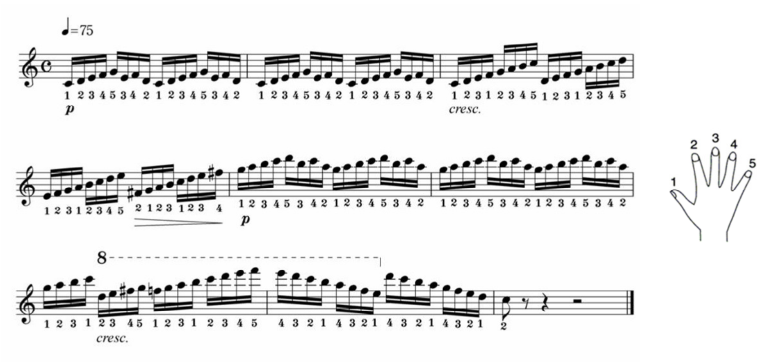

Figure 1. Performance task extracted from Czerny's *Etude No. 40.*

curve is calculated from the interval of time between adjacent notes, shown in Equation 1 as the method for obtaining the tempo b using the time interval for adjacent notes j (ms) with a constant parameter m, which represent the kind of musical note (sixteenth note, in this case).

Equation 1.

$$b = \frac{4 \times 60000}{j \times m}$$

The flow for obtaining the tempo parameter is shown in Figure 2.

Procedure

The effectiveness of the proposed condition is investigated to find a better condition for automatically evaluating the proficiency of a piano performance. The adjusted coefficients of determination between the evaluation scores given by each automatic evaluation and those given by expert pianists were calculated in order to confirm the effectiveness of the proposed method.

Conditions to be compared

Three conditions—"simple," "previous," and "proposed"—are listed in Table 1. The simple method uses six parameters comprised of three features (onset, velocity, and duration) and two statistic amounts (average and standard deviation), the previous method used 15 parameters comprised of three features and five ways of calculation, and the proposed method uses four features (onset, velocity, duration, and tempo) and five ways of calculation, as listed in Table 1. In the previous and proposed methods, the dimensions for the ob-

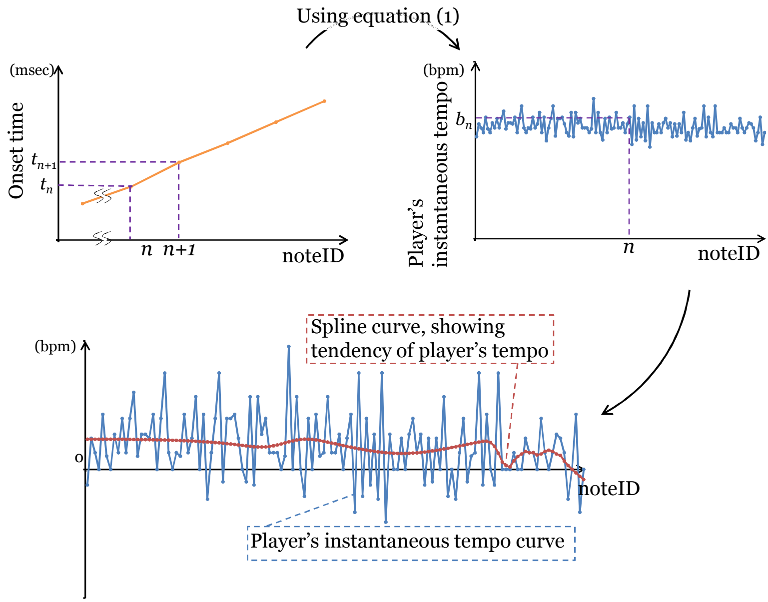

Figure 2. Flow for obtaining tempo curve. (See full color version at www.performance science.org.)

Table 1. Comparison of conditions.

	Simple	*Previous*	*Proposed*
Components for calculating parameters	Onset time Velocity Duration	Onset time Velocity Duration	Onset time Velocity Duration Tempo
No. of parameters	6	15	20

tained parameters are compressed by using the Principle Component Analysis, and the evaluation score is then obtained using the *k*-NN algorithm. Here, originality employs the six principle components whose cumulative contribution ratio is 90%. Figure 3 shows an outline of proposed method.

RESULTS

We used 210 and 196 samples for 75 and 150 bpm, respectively. The results from the adjusted determination coefficients R^2 and correlation coefficients r

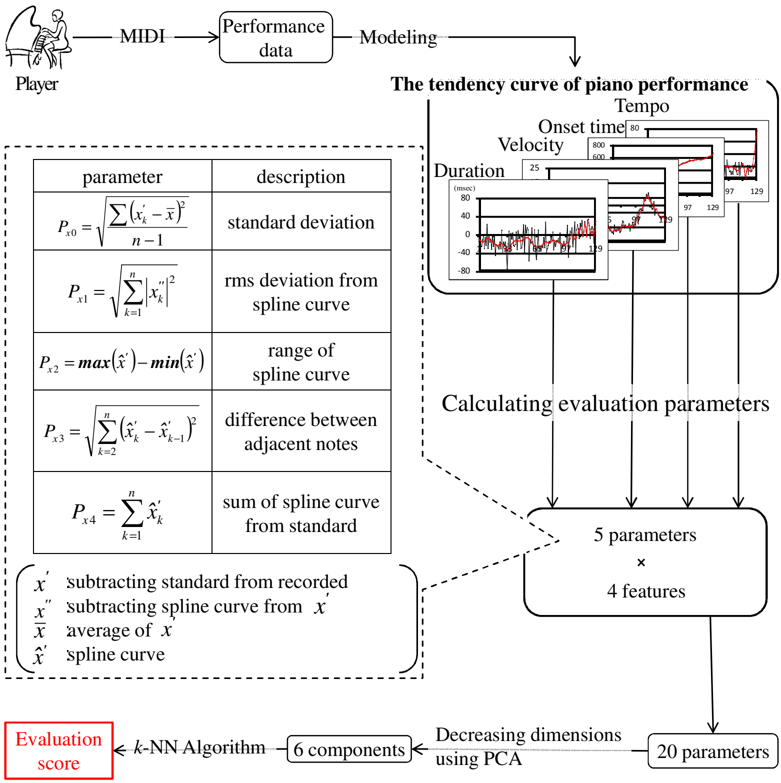

Figure 3. Flow of proposed method for obtaining evaluation score for piano proficiency. (See full color version at www.performancescience.org.)

are listed in Table 2, showing that the proposed method is the best among them in terms of evaluation accuracy.

DISCUSSION

Table 2 lists the adjusted coefficients of determination between the estimated score given by the spline curve or simple method and the evaluated score given by expert pianists in the 75 or 150 bpm performance. As a result, the adjusted determination coefficients of the previous and proposed methods are better than the simple method for the both performances. Therefore, the spline curve model is effective.

Table 2. Adjusted coefficients of determination and correlation coefficients for simple, previous, and proposed methods.

		Simple	*Previous*	*Proposed*
adjusted R^2	75 bpm	0.454	0.671	0.694
	150 bpm	0.523	0.560	0.581
r	75 bpm	0.676	0.820	0.834
	150 bpm	0.725	0.750	0.764

For the usage of the features, the tempo feature provides better results. Since the length of the etude is somewhat long at approximately 30 s at 75 bpm, a deviation in the player's tempo is inevitable, so a tempo deviation is important when evaluating the proficiency of a performance.

Future works are to reconsider the determination method for representative points, to update the conventional way for calculating the parameters, and to consider the phrasing of the performance in order to acquire the player's intention.

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An examination of a MIDI wind controller for use in instrumental research

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The purpose of this investigation was to determine the validity and practicality of using a MIDI wind controller in instrumental performance research. Typical methodology for wind instrument performance research includes at least one expert judge repeatedly listening to randomized performances and scoring them for pitch and rhythmic accuracy. In addition to being very time-intensive, this process is subject to human error. Because MIDI wind controllers collect digital data, the scoring process for this data could become more accurate and faster. Specifically, this study examined correlations between 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. Additional data analysis examined breath control (dynamics) on the wind controller.

Keywords: MIDI; technology; instrument; wind controller; methodology

The advent of the MIDI keyboard in 1983 (MIDI Manufacturer's Association 2010) made available a new tool for studying musical performance. Collyer *et al.* (1997) established the validity of using MIDI keyboards in music performance research. Since then, it has become common practice to use MIDI keyboards in piano research and music-motor learning research (e.g. Finney and Palmer 2003) because they facilitate data collection and analysis for piano-type performance. Another kind of MIDI controller is the wind controller. While MIDI wind controllers have existed for over 20 years, their feasibility as a proxy for acoustic wind instruments has not been studied.

MIDI wind controllers use a saxophone/clarinet style mouthpiece, are about 600 mm long and weigh about 520 g. The key system is Boehm-style and can be set to saxophone or flute fingerings. A true electronic instrument, MIDI wind controllers generate no tone but instead are connected to a sound generating module that enables sound production. The most widely used wind controllers are manufactured by Akai and Yamaha. In addition to purchasing the wind controller, one needs to purchase a sound generating module. For research purposes, these items need to be connected to computer software which records the digital performance data. When using a MIDI wind controller in this way, the researcher can collect data about pitch, duration, and breath pressure (volume). The purpose of this study was to determine how similar performance is on Yamaha WX5 Wind MIDI Controller to performance on a clarinet and alto saxophone. If high correlations can be found between performance on an acoustic instrument and a MIDI wind controller, this tool could greatly expedite the scoring of wind instrument data in research.

METHOD

Participants

Participants (N=10) were university music majors whose major instrument was either clarinet (n=5) or saxophone.

Materials

The Yamaha WX5 Wind MIDI Controller was used in this study. It retails for about US$700. 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, amount of wind pressure, and fingering mode. There are three saxophone fingering modes and a flute fingering mode. The most significant difference in key set up between the WX5 and a flute or saxophone is that there are 4 octave keys operated by the left thumb.

Yamaha recommends the WX5 be connected to the Yamaha VL70-m, a virtual acoustic tone generator, which retails for about US$800. The unit is 220 mm x 212 mm x 46 mm and weighs about 1.3 kg. The advantage of using this tone generator over another tone generator is that it has a line-in to receive the WX5 line-out, and it has a pre-set for the breath pressure setting of the WX5.

The tone generator was connected to a MacBook Pro laptop using a USB MIDI Interface (UM-1G from Cakewalk, retails about US$40). This device transmits the MIDI data to notation or sequencing software. In this study, I used a version of Cubase. It is also possible to use Finale.

Figure 1. Musical piece participants learned.

Procedure

Participants elected to participate in a two-day study of repeated measures design. On day 1, they practiced scales and a short musical piece (see Figure 1) on both their acoustic instrument and the wind controller. Participants had as long as they wanted to prepare the scales and piece to specified metronome targets. When participants deemed they had learned the passage "as well as possible, including pitch, rhythm, and dynamics," they recorded a final performance trial. Approximately 24 hours later, participants returned to make the recordings again. The design was completely counterbalanced.

RESULTS

All acoustic trials were randomly ordered into master files for scoring. The experimenter determined pitch and rhythm accuracy by repeatedly listening to each trial. Each pitch and rhythm was scored as correct or incorrect. The MIDI data generated by the wind controller was collected by Cubase software, which provided graphical representation of the performances, as well as displaying it in standard music notation. The notation output for each performance was also scored on a note-by-note basis as correct or incorrect. Pearson's r was used to examine the relationship between the acoustic performances and the wind controller performances on a note-by-note basis. At the symposium, results will be presented for pitch and rhythmic accuracy for the technical scales and performance piece. Graphical and numerical results of the dynamics will also be presented.

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Thematic session: Learning and teaching II

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Lost in Eden: Guided practice for the musical tourist

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A myriad of factors influence a novice musician's willingness to learn to make music. How dependent is this motivation on effective practicing? What happens when, with the guidance of a music educator, musicians *practice practicing*? This research asks whether *guided practice* at an early age might prove a catalyst in the development of effective practicing which naturally occurs with musical expertise. The study explores whether developing effective learning strategies at an early age might have a significant impact on intrinsic motivation that results from greater success in addressing musical challenges. Over the course of an academic school year, 12 novice musicians participated in guided practice sessions with the researcher. Interviews with the musicians and their parents at the beginning and the end of the duration of the study, as well as video recordings of practice sessions at the musicians' homes, reveal an increase in the repertoire of practice strategies and self-regulated learning. Musicians also indicate greater self-efficacy in addressing musical challenges.

Keywords: practice; meta-cognition; motivation; self-regulation; guided practice

In the context of this study, "practicing" is defined as any activity undertaken for the purpose of developing proficiency at performing a musical task or achieving a musical goal. Practicing does not limit itself to becoming skilled at the technical aspects of learning to make music on an instrument but may concern itself with musical aspects of a piece as well as intra- and inter-personal relationships. The study also considers the relationship between effective practicing and motivation.

The literature relevant to this study explores characteristics of expert—as well as novice—practicing, motivation, and the role music teachers play. The term "deliberate practice" (Ericsson *et al.* 1993) is often used when describing what the experts do. It is effortful and purposeful, goal-oriented, draws appropriately from a repertoire of practice strategies, and is characterized by self-monitoring. Effective practice is characterized by high levels of metacognition (McPherson and Renwick 2001), which include an awareness of an extensive repertoire of strategies, demands of the task, and personal strengths and weaknesses (Barry and Hallam 2002, Hallam 1995). Coupled with this is the appropriate execution of activities and behaviors referred to in the literature as self-regulation (Nielsen 2001). Self-regulation both controls choices made by the musician and monitors outcomes (Pintrich 1999).

By contrast, the novice musician demonstrates few if any of the characteristics of the expert. A small number of strategies is used and these only negligibly. For many young musicians, repetition from the beginning to the end of the piece is the only strategy used (Rohwer and Polk 2006). Their practice is largely without focus or a clear intention and they play pieces through without any self-correction or identification of difficult passages to work on (Pitts, Davidson, and McPherson 2000). There is virtually no self-regulation (Barry and Hallam 2002). Research indicates production deficiency - a gap between what young musicians know, what their teachers tell them about practicing, and what they actually do (Rohwer and Polk 2006). The evolution from novice to effective, expert-type practicing seems to be a natural evolution that develops with musical expertise (Hallam 1997a).

The psychological dimensions of motivation that are most relevant to this study are theories dealing with self-efficacy, self-determination, and task orientations. As noted, self-regulation is an important aspect of effective practicing; the more highly motivated the musician, the more likely he or she is to engage in and develop self-regulation (McPherson and Renwick 2001). Similarly, the greater a musician's sense of self-efficacy, the more engaged cognitively and metacognitively on a particular task (Nielsen 2004). There is also a positive relationship between self-efficacy and self-regulation (Pintrich 1999). It is crucial for the musician to focus on learning or mastery goals and to establish goals that are appropriate and valued (Dweck 1986). The young musician needs to come to value the task itself, not the outcome (Hallam 1995). Three motivational beliefs that promote and sustain self-regulation are self-efficacy, valuing the task, and a mastery or goal orientation (Pintrich 1999).

Little is known about how music educators interact with their students with respect to practicing (Hallam 1998). The research suggests that, overall, practice habits are influenced to a limited extent by teachers' advice (Barry and Hallam 2002). At a typical lesson, teachers are in control and students are passive learners (West and Rostvall 2003). While modeling at lessons can be effective (Sang 1987), there is evidence that too little time is spent modeling practicing (Kostka 1984) and much wasted time verbalizing instructions (Sang 1987).

There is little research about the way musicians learn about practicing (Hallam 1997b). Marilyn Kostka (2004) suggests that:

> teachers should take time during lessons to practice practicing with their students. Most of us are inclined to correct students' errors immediately which is, of course, the most time-efficient way to improve their performance. However, this denies them the important opportunity to define and self-correct their mistakes. Instead, the teacher might carefully observe what students do when confronted with a problem and then give helpful suggestions based on the student's actions. In this manner, the student will be more likely to remember and implement these suggestions when alone (p. 25).

This is very much the essence of guided practice.

The overall aim of the study is to discover whether or not and to what degree a guided practice intervention might catalyze the natural evolution from novice to expert-type practicing, developing autonomy in the musicians as learners. Guided practice sessions seek to orient the musician toward identifying and mastering small tasks, developing a repertoire of practice strategies to do so, and develop their feelings of self-efficacy in addressing musical challenges. Another purpose of this study was to determine, through video recordings of the researcher as participant, what teacher behaviors are effective when conducting guided practice.

METHOD

Participants

The participants in the study were 12 elementary school students ranging in age from 8 to 13 years. The parents of the musicians were also participants in the study as observers of their children's practicing at home. At the commencement of the study, the musicians had anywhere from six months to one year of experience in music education either in concert band or private piano tuition. The researcher is also a participant in the study. Video recording of guided practice sessions were made so the researcher could evaluate which music teacher behaviors are effective in helping the student develop effective practice behaviors.

Procedure

The study took place over the course of one academic year. In September 2010, musicians and parents were interviewed to establish a description of practice habits and attitudes for each student participant. Sessions were video recorded and analyzed by the researcher to determine teacher behaviors that most significantly facilitated the development of effective practicing. Surveys were completed by both parents and musicians after six months—the time of the writing of this paper—to determine what, if anything, had changed regarding practice behaviors and attitudes. At the end of the study, the researcher will again interview both parent and musician participants to determine how practicing has changed.

RESULTS

The musicians' practice habits and attitudes as determined at the beginning of the study revealed profiles that were typical of novice practicing as set out in the literature. Results of the guided practice intervention after six months were determined by a musician and parent survey. Responses to the musician participant survey indicate several conspicuous changes when the students were asked to indicate practice strategies they now use that they did *not* use prior to the study: 92% indicated that, when starting a new piece of music, they look over the entire piece first, find what they deem to be the difficult parts and start there; 83% indicated that, in their practice, they "define a task and focus on that task" and that they will "make the task smaller if necessary" (quoted from the survey); 75% indicated they felt their practicing was better organized than before; 58% noted an increase in persistence, confidence, more focus, a greater sense of accomplishment, and an overall more positive attitude toward their practicing.

A significant observation by the researcher at piano lessons was the spontaneous use of strategies by all of the students when they encountered a difficult section or sought to correct an error.

Parents of eight of the participants responded to the survey. Consistent with the musicians' responses, all of the parents noted their child focusing on the more difficult sections of a piece of music and seeking to master that task. More than the students, the parents commented on the use of specific tools used by their children, especially use of the Kodaly rhythm syllables (*ta, ti-ti*), the metronome, and playing hands separately if a piano student. One mother who, as with all the parents, is present at the lesson, would actively observe the guided practice and indicated that she used to have to remind her son about practice strategies he could use when he encountered a challenge. In her response to the survey, she noted quite emphatically that one significant change she notices is an increased independence in the use of strategies. All the parents noted an increase in persistence as well as a more positive attitude.

With respect to teacher behaviors that facilitate guided practice effectively, viewing the video recordings revealed two dominant themes: first, a willingness on the part of the teacher to ask questions and, second, a great deal of patience in allowing the student to *discover,* with the guidance of the teacher, a response; indeed, to learn. There is also the unqualified requisite of a flexible lesson agenda.

DISCUSSION

I believe this is the first study that examines the relationship between music instruction on practicing and novice musicians. The most significant implications from this study are for applied pedagogy of practicing. For the private music teacher, this may mean a significant paradigm shift with respect to expectations of students at private lessons, lesson agendas and goals, and rapport with students during lessons.

Further implications of this study are the inclusion of pedagogy of practicing in music teacher education and curriculum documents: teaching musicians how to practice effectively needs to be an objective.

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Learning to be a creative performer: Developing mixed methods to understand teachers' and students' approaches and constructs

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This study investigates creativity in musical performance, focusing on aspects of teaching and learning within two London conservatoires. The exploratory phase reported here aims to map beliefs and practices in relation to creativity and originality, and develop appropriate methods while building collaborations with the partner institutions. The mixed-methods design had three strands, each allowing participants to shape the research agenda: (1) focus groups with teaching staff, (2) observations of one-to-one lessons of six teacher-student pairs, followed by video-recall sessions with participants, and (3) semi-structured interviews. Focusing on (1) and (2), the paper discusses some outcomes, challenges, and benefits of this approach. Different aspects of performance creativity are uncovered. Analysis of focus group data revealed two main concepts of creative development: "toolbox" (acquisition of a set of tools) and "butterfly" (emergence of a personal quality from within). Filmed one-to-one lessons and recall sessions showed examples of practice and allowed insight into creative processes as experienced by the teachers and students involved. The study takes first steps toward modeling creativity and its development in the conservatoire context. It is argued that defining adequate models of performance creativity will be made possible only through multiple methods allowing insight into complex phenomena within their social and musical contexts.

Keywords: creativity; originality; education; performance; methods

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The art, science, and simulation of performance

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This article juxtaposes two contrasting professional domains—surgery and music—as a starting point for discussing the concept of *performance* in different settings. The paper examines possible parallels between emergency surgery and jazz improvisation as distinct yet related forms of performance, drawing selectively upon relevant literature. It then develops the concept of *simulation* as a bridge between the closed world of the operating theatre and the wider world of those who cannot access it. Presenting an accurate yet safe "transcription" of this closed world can offer an experimental setting for exploration. The article describes *Distributed Simulation*, a concept developed by the author's research group at Imperial College London. The possibilities of low-cost, portable yet highly realistic simulation extend beyond its obvious value for practicing safety-critical skills and procedures. There is clear potential for vicariously experiencing other worlds such as those of music, drama, and dance, allowing each domain to learn from others.

Keywords: performance; surgery; simulation; expertise; music

Operative surgery is often perceived to be a "scientific" activity. At first glance this may seem self-evident. After all, the framework within which patients are diagnosed and operated upon fits comfortably within a scientific paradigm. Diseases are diagnosed by the systematic gathering of information from history taking and physical examination, supported by increasingly sophisticated laboratory tests and imaging technology and (where necessary) surgical intervention. If diagnosis proves difficult, more tests (it is widely believed) will eventually yield the answer.

The same appears to apply to operative surgery. Decisions about treatment are based on the evidence of controlled trials conducted according to the methods of science. Surgeons are trained to lay aside their emotions and hone their technical skills. The public perception of surgical operations is of structured and controlled events, where high levels of skill combined with an almost superhuman clinical detachment leave no room for the unexpected.

The reality, however, is different. Although rigorous science must underpin clinical practice, medicine is also an art. All experienced clinicians are acutely aware of the complexity and unpredictability of dealing with individual human beings (whether these be patients or colleagues) and the challenges of applying general scientific knowledge to particular instances (Kneebone *et al.* 2006). The operating theatre is no exception.

MAIN CONTRIBUTION

In this article, I argue that operative surgery can be considered as performance and that, although usually framed as a science, the operating theatre has much in common with the performing arts. Even the terminology of surgery has obvious resonances with the drama. Operations are "performed"; surgery takes place within a "theatre"; and everyone has to "play their part" as an operation unfolds.

Of course there are obvious differences as well as similarities. In performance arts such as theatre, dance, and music, performance is designed to take place before an audience. This "public face" of the process is an integral element of its nature. Surgery, however, can be witnessed only by those with privileged access, by legitimate participants in a community of practice (Lave 1991, Wenger 1998). And of course, error or misfortune in surgery can lead to serious damage or even death for the patient. However, although the stakes are different for the *receivers* of a surgical and an artistic performance—patients as opposed to audience members—the levels of expertise and professionalism of the *performers* have much in common.

Nevertheless, the successful performance of a challenging operation by an expert surgical team has much in common with a well-rehearsed play. In music, dance, and drama, extensive practice and rehearsal underpin every production or recital. As Malhotra (1981) puts it, a rehearsal is "the delivery table upon which the world-of-music is born" (p. 116). In the case of surgery, however, most of the learning that culminates in expertise is gained through participation in repeated performance, in the form of actual operations on real patients. Rehearsal (as opposed to practice) is seldom used (Kneebone 2009).

In all these domains, however, the finished performance conceals the hard work and artifice that underpins it. In every case, it is only the performance itself that is on show. The antecedent stages of practice and rehearsal are hidden from those outside the profession. Much that appears spontaneous and fluid is the result of intensive preparation, yet this is seldom acknowledged. And there is surprisingly little consistency about how experts acquire their expertise. It seems that everyone has to learn for themselves how to practice, how to recover from mistakes, and how to ensure that the performance is perceived as successful.

In order to explore the notion of surgery as performance in more detail, I focus on one type of operation—emergency surgery for traumatic injury—and one type of performance art—jazz ensemble improvisation. Some explanation may be helpful for the non-medical reader. Much operative surgery is "elective," where a patient undergoes a planned procedure for a disease or condition that has already been diagnosed. For example, a patient with gallstones may have their gallbladder removed, or someone with cancer may need part of their intestine cut out. Preoperative tests will usually have shown the extent of the problem, allowing the surgical team to plan in detail what needs to be done. Although each patient is unique and unanticipated complications may always arise, the overall sense is of a procedure whose stages are clearly mapped.

Emergency surgery for trauma, on the other hand, has a different character. When a patient is admitted with a stab or gunshot wound, it may be evident that they need emergency exploration but not at all clear what has been damaged. The surgical team cannot know what they will find until they open the patient's body.

Such emergency operations are not uncommon and often take place outside normal working hours with hastily constituted groups. Especially in the current climate of the UK National Health Service, members of the surgical team may never have worked together before. So individual clinicians (surgeons, anesthetists, nurses, and others) are required to form an effective team under conditions of great uncertainty and stress, performing to the best of their ability in the interests of a patient for whose safety they are jointly responsible.

Of course it is expected that each clinician will show mastery of the elements of their individual craft. The surgeon must be able to handle tissues, control bleeding, remove or rejoin organs. The anesthetist must keep the patient both alive and asleep. The theatre nurse must ensure that all equipment is ready as needed, providing the surgeons with the right instruments at the right time. And so on. But all these elements, though necessary, are not in themselves sufficient. It is possible to have highly competent individuals who nonetheless do not work as an effective team.

So the social functioning of performing teams is of great interest and importance. If allowed to become destructive, the stress and unpredictability of emergency surgery can cause fault lines to emerge and the patient's safety to be jeopardized. But that same stress and unpredictability can also result in inspired performances, where experts respond to the unexpected with fluidity and co-ordination to achieve spectacular success. It is this aspect of surgery—this responding effectively to conditions of uncertainty—that resonates with musical improvisation.

This paper therefore considers the parallels between emergency surgery and jazz improvisation. It links the author's personal experience as a surgeon and a teacher with recent literature on musical improvisation. Much of this highlights the human, social nature of jazz performance. Ingrid Monson (1996) points out that "interacting musical roles are simultaneously interacting human personalities, whose particular characters have considerable importance in determining the spontaneity and success of the musical event". She goes on to state that "a prerequisite to successful participation within a jazz group is a repertoire of tunes that may be called by other musicians—and the ability to play them in more than one key" (p. 26). In surgical terms, this equates with team members needing to master a wide range of skills and techniques which can be activated as required in response to a given situation in the operating theatre.

Berliner (1994), in his monumental study of jazz improvisation, also highlights the social aspect of performance. "The operations of improvisation involving more than one person," he says,

> require the instant assimilation of ideas across the band's membership. Musical materials extemporaneously introduced in any of the parts can influence the others, potentially providing renewed inspiration for all. The unpredictable quality of the band's musical negotiations is a fundamental ingredient in every performance, imbuing its creations with uniqueness (p. 497).

This resonates with Sawyer's (2003) point that group performance is more than the sum of its parts and that the complexity of group behavior makes accurate prediction impossible. This property of *emergence*, of not knowing in advance how a particular group of people will function creatively, is clearly evident in trauma surgery. At its best, inspiring performances can coax more out of every member than they knew they could provide. At its worst, dysfunction and failed communication can jeopardize the whole performance.

Solis and Nettl (2009) emphasize that effective improvisation is based on hard work. Writing about music (but giving a description equally applicable to surgery) they say that:

> outsiders or novices to the world of improvised music may perceive improvisation as a phenomenon *on the edge of magic* [my italics]. As the journey into the art and craft of improvised performance continues, the sense of magic dissipates, revealing an experience steeped in the musical nuts and bolts that are so primary to improvisation within a given genre. Jazz musicians have often maintained that musicians must be prepared in advance to gain the freedom to play with spontaneity in public performance (pp. 127-128).

This mysterious, almost magical aspect of surgery is often commented on by newcomers such as medical students and novice nurses. It is only after long exposure that the ways of the operating theatre become familiar.

Eventually, all these elements of technical skill and team work becoming seamlessly integrated. As long ago as 1921, Dalcroze (cited in Solis and Nettl 2009) said:

> Learning to improvise is similar to learning a language. You speak a language fluently when you reach the stage of not having to think about each and every word you enunciate; you can concentrate entirely on the content of the communications. Thus it is with music, that by knowing it one no longer thinks atomistically about individual notes but rather shapes larger phrases, often in improvisatory fashion, according to what it is that one wishes to communicate (p. 135).

So there seems a consensus that the apparent freedom of jazz improvisation is built on a solid foundation of many years of rigorous preparation, both in terms of technique and knowledge. Repeated playing with other musicians trains players to listen, to be aware, and to avoid over-focusing on one's own task to the exclusion of what is going on around. Similar behavior can be seen in the operating theatre, where inexperienced surgeons often become fixed upon a technical task and lose sight of the bigger picture of the operation at large.

Although the literatures of surgery and music are vast, direct comparisons between the two are few. To make that connection, this paper therefore draws on the author's experience in directing a Masters in Education (MEd) in Surgical Education at Imperial College London. This programme is aimed at those wishing to explore the relationship between the biomedical world of surgery and the humanities-based world of education. Exploration of parallels between surgery and other professional domains forms part of the course.

An interactive session in January 2011 with 20 MEd students showcased a professional baroque duo (harpischordist Sophie Yates and violinst Alison Townley) and a professional jazz pianist (Liam Noble). The aim was to explore the differences between scored and improvised musical performance and critically examine parallels with elective and emergency surgery. The students were all qualified doctors, some undergoing specialist surgical training and some already established as consultant (attending) surgeons. The session allowed engagement between surgeons and musicians with the specific aim of exploring commonalities between their two worlds. Through a process of debate and critique, it became apparent that mastery of instruments (whether musical or surgical) and the acquisition of high levels of technique are central to both performers' professional identities.

The musicians set the frame with examples of baroque and jazz performance. Discussion between the musicians and surgeons identified areas of similarity and difference. For example, the operating theatre is a highly complex social and technological environment. Communication is multimodal—much that is communicated is unspoken, being conveyed by stance, gaze, gesture, or silence. During a musical performance too, much is conveyed without being spoken—again through gesture, gaze, and movement (Bezemer *et al.* in press-a, -b, and –c).

What emerged particularly clearly was the crucial importance of the interaction between people who are working together. For example, both surgeons and musicians took it as a given that all participants would have acquired high levels of knowledge and technical skill, whether about anatomy and surgical technique, or harmonic structure and the ability to play their instrument. But in addition to this individual mastery was the need to function effectively with others, under conditions that dramatically differed from those of practice or (in the case of the musicians) rehearsal. The pressures of real life performance brought out characteristics that were often unknown in advance.

The ensemble as a *social* setting is of crucial importance. Here, much that is written about jazz could apply equally to surgery. For example, *active listening*—the continual awareness of what is happening in the wider context of the whole situation, rather than over-focusing on one specific area of activity—distinguishes experts from novices. It seems that the ability to respond to the unexpected is grounded in years of painstaking practice, of gaining technical mastery that allows the execution of tasks to be taken care of automatically. This mastery frees the surgeon or musician to focus on *what* should be done, rather than being bogged down in the details of *how* it should be done.

If the practices of surgery are hidden from view behind the defenses of the operating theatre, how can these practices be brought out for discussion with experts from other domains? Is it possible to construct a bridge between the closed world of surgery and the wider world of other performances?

It is here that simulation offers an attractive solution. By recreating the conditions of surgery within a realistic yet safe environment where no actual patient can come to harm, the *processes* of surgery can be made visible to a wide constituency. At the same time, the *processes* of music can be discussed through comparison.

For example, from a surgeon's point of view the opportunity to *rehearse* an emergency operation, experiencing what it is like to deal with the unexpected (both in terms of injury and the behaviors of a transient team) is invaluable. Although rehearsal is an integral part of most performers' professional lives, I have argued elsewhere that surgeons rarely use it. Instead they move from practice to performance (Kneebone 2010).

Although medical simulation has been used in various forms for centuries, it is only in recent decades that simulation has become widespread in surgical education. Much emphasis is placed on simulation for *practice*, for gaining component technical skills such as tying knots, joining sections of intestine together, or gaining the psychomotor skills of keyhole surgery. More recently, simulation centers have replicated full scale operating theatres, allowing teams to interact with one another and with sophisticated mannequins that mimic a patient's physiological response to drugs and fluids (Gaba *et al.* 2001). Yet, such centers are scarce and prohibitively expensive, both to establish and maintain. Many people who would benefit from their facilities cannot access them. If simulation is to become widely available it needs to be realistic and affordable.

In response to these challenges, our group at Imperial College London has developed the innovative concept of Distributed Simulation (DS) (Kneebone *et al.* 2010). Its aim is not to replicate every detail of an operating theatre or other clinical space, but rather to present only those cues that are necessary to create a sense of engagement and belief. The simulation consists of a lightweight, rapidly inflatable enclosure which can be set up in any available space and which separates the activities inside from the surroundings (see Figure 1).

DS is underpinned by what we have termed "circles of focus," based on the principle that attention is selective. By making what is closest to participant's awareness seem most real, objects in the periphery of vision can be

Figure 1. Distributed Simulation: Surgery in an inflatable operating theatre. (See full color version at www.performancescience.org.)

represented more crudely but still be effective. In the case of the operating surgeon, for example, his or her attention is focused intently on the part of the patient's body being operated on. The field is brightly illuminated by an overhead lamp, and normal social conventions are suspended to allow the surgeon to request and receive appropriate instruments without making eye contact with other members of the team. Objects at the edge of the visual field are registered dimly if at all (Kneebone 2010).

To achieve an effective simulation, highly realistic physical surgical models (made of silicon and created by prosthetics experts from film and television) create a powerful sense of engagement, allowing more peripheral objects (such as the operating lamp and the anesthetic machine) to be represented by more rudimentary models or even by photographic backdrops. Other cues include the beeping of the patient monitor and the physical sensation of being gowned and gloved and working in close proximity to other members of the surgical team. Initial validation studies have shown very high degrees of perceived realism, and a powerful effect upon participants of rapidly losing any sense of artificiality and of becoming fully immersed in a surgical environment. For example, more than half the surgeons participating in one study were unaware that the anesthetic machine was represented by a photograph rather than a real machine (Kassab *et al.* in press).

This realistic yet low-cost approach to recreating clinical environments is opening promising lines of interdisciplinary research. By detaching immersive simulation from the need for dedicated, scarce, and prohibitively expensive static simulation centers, new ways of using simulation can be explored and developed. For example, it may be possible to develop rehearsal environments where musicians can experience at least something of what it feels to step onto a concert platform in front of an audience, using audiovisual techniques to reproduce authentic sounds of audience response and the acoustics of a recital space. It is also becoming feasible to invite experts from domains outside medicine (such as musicians) to take part in simulations of emergency surgery without any danger of harming real patients, exploring unexpected links in a way that would be unthinkable in the primary environment.

I conclude by proposing that the skills demanded by any professional domain constitute a range of elements, though in differing proportions. These may include technical, craft, interpersonal, or situational components. This is equally true for surgery as for the performance arts. No one domain will correspond exactly to any other, but systematic study of these elements will provide a blueprint for an analytical, comparative approach that can bring together insights across disparate domains.

IMPLICATIONS

This comparison of surgery with jazz improvisation highlights how common features of performance can be found in unlikely places. Framing operative surgery as performance and viewing it as a performing art has highlighted new perspectives and provided new insights. I hope this process may illuminate both surgery and music, to the benefit of each.

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Advancing interdisciplinary research in singing: A performance perspective

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A major collaborative research initiative focusing on singing, entitled Advancing Interdisciplinary Research in Singing (AIRS, www.airsplace.ca), is engaging researchers worldwide in studies representing three research themes: how singing develops in every individual, how singing should be taught and used for teaching, and how singing impacts wellbeing. Over 20 studies are ongoing in nine sub-themes (i.e. three for each of the primary themes of development, education, and wellbeing). This article highlights performance aspects in the developmental theme by focusing on a test battery of singing skills that is being administered across ages and cultures by researchers in several parts of the world. The presentation also provides an overview of the performance aspects of the research enterprise as a whole, giving a context for the remaining presentations in this symposium by researchers engaged in or affiliated with the AIRS project. The project itself represents a research model applicable to studies of performance on any musical instrument. Such studies would be useful for determining unique aspects of singing performance versus unique aspects of performance on other musical instruments and for determining aspects common to performance of all musical instruments including the voice. Applications could also extend to other performance arts such as drama and dance.

Keywords: singing; interdisciplinary; development; education; wellbeing

Singing is an example of music performance that is accessible to almost all human beings. Singing requires no musical instrument other than the human voice. Basic skills of singing evolve naturally at the same time as the child learns the basic skills of speaking. What these singing skills are, how they can best be nurtured, and their benefits to wellbeing throughout the lifespan are topics in need of investigation both independently and in conjunction.

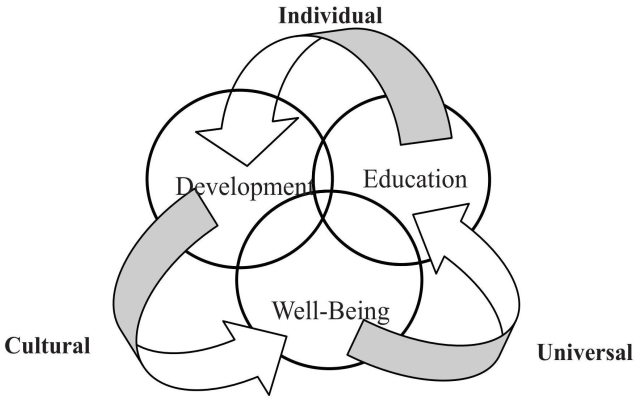

Figure 1. General framework of the AIRS program of research on singing, examining individual, cultural, and universal influences.

A major collaborative research initiative focusing on singing called AIRS (Advancing Interdisciplinary Research in Singing, www.airsplace.ca) is engaging researchers worldwide in studies of how singing develops in every individual, how singing should be taught and used for teaching, and how singing impacts on wellbeing. As depicted in Figure 1, these three interrelated research domains are being examined with respect to influences on singing that are unique to an individual, that are culturally determined, and that are universal. Research that seeks to advance our understanding of singing can draw on expertise from many disciplines: for example, music, psychology, education, folklore, acoustics, anthropology, etc. Given the context of the conference, the present article overviews the AIRS project with special focus on performance.

MAIN CONTRIBUTION

AIRS uses a wide variety of quantitative and qualitative methods to acquire data. In the development theme, a new AIRS test battery for acquiring data on singing has been created (Cohen *et al.* 2009). The test includes two language components (a phoneme pronunciation task and a verbal fluency and story generation task) which serve as book ends for nine singing tasks. These include singing the so-called universal minor-third melody, singing a favorite song, singing up to the highest note possible and down to the lowest note possible (vocal range), singing short musical elements such as *doh re mi re* *doh* and a major triad, *doh mi sol*, singing the familiar *Brother John* song (*Frère Jacques*), singing an unfamiliar song, making up the ending of a song, and composing a song prompted by one of four pictures. The data are recorded using an audio-video camcorder. The rich data become even more valuable when contrasted with data derived from successive test sessions (i.e. longitudinal studies) or from other cultures or ages (i.e. cross-sectional studies). Current work is being conducted in two sites in Canada, in England, and in Estonia and Iceland and will soon begin in several other countries including the USA and Brazil, with China and Kenya to follow. Benefits of music training have already been shown, even when that training is not specifically on singing. One study in PEI has compared native Chinese and native English speaking university students revealing the disadvantage to learning to sing the contour of a melody when lyrics are in a foreign language. The detriment occurs even when the singers produce the syllable *la* and not the lyrics. (Stevenson *et al.* 2011). The challenge created by foreign- as opposed to native-language lyrics in learning to sing a melodic contour implies that learning a melodic contour takes processing capacity that is shared by phonemic encoding. Intercorrelations among multiple measures from each of the performance tests help to reveal the underlying mechanisms affecting performance. For example, Bing-Yi Pan at UPEI has discovered a relation between the ability to sing the ending of a short unfamiliar melody and accurately singing a major triad and a descending major scale.

The test battery represents only one research arm of AIRS. To date, over 20 other studies are ongoing in 9 different sub-themes (three for each of development, education, and wellbeing). Electromyographic technology is being harnessed to study facial motion in singing (Russo *et al.* in press) and body movement during singing is being monitored through motion tracking. Acoustical data of singing is being analyzed using artificial intelligence techniques (Devaney *et al.* in press). At the same time researchers are administering questionnaires, making audio-visual recordings and interviewing singers in many contexts.

Groups working within the same discipline may not necessarily agree on the best approaches or questions to address. The history of musical acoustics reminds us of the controversies surrounding the correct tuning of fixed pitch instruments. The same issues can arise in measuring vocal performance, where the voice is a performance instrument of continuous pitch often in the context of equal-temperament. Within vocal pedagogy, various practitioners and researchers may be passionately attached to different approaches. Potential controversies are the bread and butter of research that often leads to productive critical experiments or demonstrations. The real problem arises in interdisciplinary discourse. A trick here is to find common ground between two domains that will enable persons of different disciplines to see how the same material can play a role in an entirely different context. So for example, a finding from the AIRS test battery which reveals a disadvantage in learning the melody of a song when foreign language lyrics accompany the melody, may have implications for formal vocal training in the school setting, a part of the education theme. It could also have an impact on the method of teaching songs of a foreign culture to children in a study of learning non-native songs as a means of improving attitudes to persons from a different nationality. The latter is a project in the singing and wellbeing theme led by Lily Chen-Hafteck teaching children in Canada, Brazil, China, and Kenya. If further we find that elderly persons similarly are unable to learn a melody when the words are presented in a foreign language, this would impact the study in the wellbeing theme that focuses on the role of singing in intergenerational understanding (Heydon in press).

At the same time, from the education theme, analysis of songs in the natural repertoire of children of certain ages (cf. Campbell 2010) should confirm the findings from the test battery about what intervals or short melodic patterns the children are able to produce at that age, and conversely, capacities demonstrated in the test battery could predict what elements might appear in the songs of children of these ages.

It is one thing to see the potential relation between the findings in two different disciplines and another to establish the interdisciplinary dialogue. For example, developmental psychologists collect data and analyze it statistically. Educators or ethnomusicologists, however, may provide descriptive evidence that is less likely to be submitted to statistical tests. Both groups may provide notation of songs with different considerations regarding tuning. While the developmental psychologist may fail to consider some of the musical aspects of singing (e.g. focus instead on the communicative dimensions of facial expression, the suppression of body motion in accordance with certain stylistic conventions), the educator may not see the value of videotaping examples of pedagogy in the studio or choir context and may feel that this could hardly be enough of a contribution to a project. Naturally, researchers in one area may find it challenging to fully understand the work of researchers in another area. It is challenging enough to keep up with and appreciate the work of peers in one's own research area.

The problem is further exacerbated with researchers from different cultures, even those working within the same field. Standards of excellence may vary across cultures. What is regarded as essential knowledge or protocol by scholars in one culture (e.g. a background in basic epistemological philosophy; the canon for the specialty; journals of significance; use of standard bibliographic referencing) may be unappreciated or regarded as unnecessary by scholars of another culture. The problem is further augmented by language. That is, even if there were complete agreement on standards of excellence and how one goes about research, communication among scholars is challenged by virtue of language differences.

Whereas a large multidimensional set of studies operating simultaneously is no guarantee of added value, a project on singing however has several advantages in this regard. Researchers of singing are often singers and musicians or persons who appreciate music. AIRS collaborators understand that they are members of a choir. Metaphorically speaking, the members sing different parts in harmony; with sufficient practice, they will perform at a high level suitable for the world audience. The AIRS annual meeting is an academic symposium in which, from time to time, everyone sings together literally and metaphorically. It is a matter for empirical research whether singing at a meeting helps to facilitate subsequent dialogue in the short and long term.

Just as fulfilling relationships between individuals may require effort, similarly, relationships across or even within disciplines require nurturing. AIRS works at this by teleconferences established to focus on synergies, by student funding applications that require reference to the impact of the proposed work on more than one theme or sub-theme, by the establishment of a global committee to address how best to take advantage of opportunities afforded by the multinational research team and how to address problems that might arise from multiculturalism and the development of a student network with representation from all research themes of the project. Finally, the common currency of the AIRS Digital Library, still in development, will enable AIRS researchers to meet across disciplines while working on the same materials from different perspectives, and potentially different locales.

IMPLICATIONS

Questions of development, education, and wellbeing are questions that could be addressed to some extent about performance on any musical instrument. In parallel with the AIRS tripartite research theme approach, it would be possible to have a musical-instrument version of the test battery, study what goes on in the band, orchestra, or teaching studio; study the value of learning repertoire from other countries along with the cultures of those countries; explore the development of an intergenerational musical instrument curriculum, and study the health benefits of playing particular instruments.

Such studies may help to determine the unique benefits of singing versus the benefits of playing a particular instrument, as well as what is the common benefit of singing and playing an instrument. Such a mammoth study is a natural follow-up of the AIRS project because it is important to define the boundaries of the benefits of singing. For example, whereas singing allows engagement in music without the purchase of an expensive instrument, there may be some benefits of playing an instrument that cannot be matched by singing. It is necessary to begin that investigation to find out. The design of the AIRS project with its focus on development, education, and wellbeing could also be transposed to other artistic domains such as drama and dance.

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Have we made ourselves clear? Singers and non-singers' perceptions of the intelligibility of sung text

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The intelligibility of sung text is an important component of listeners' enjoyment of vocal music and a central concern for singers and, for example, choral conductors. Expert listeners such as singers and singing teachers may be better than non-singers at perceiving sung text. We replicated and extended an earlier study investigating the intelligibility of semantically and non-semantically meaningful words performed solo and by a small group of trained soloists by carrying out an experiment in which we manipulated listening expertise, type of text, number of singers, and time of hearing. Participants listened twice to four songs with meaningful and "scrambled" lyrics, sung in unison by a choir and solo, and wrote down as many of the words as they could discern. Singers were better at the task than non-singers; more words were recorded on the second hearing and when the words were meaningful. Sung text involves distortions of consonants and vowels to which singers may be more accustomed, so that they find it easier to discern texts even when scrambled. Choirs may be harder to understand than soloists because their phonemes are more variable and less clear. In future research we will use operatically trained soloists and polyphonic choirs.

Keywords: choral; expertise; lyrics; solo; vocal

The intelligibility of sung text is an important component of listeners' enjoyment of vocal music and a central concern for singers and, for example, choral conductors (Fine and Ginsborg 2007a). Factors underlying intelligibility include performer (e.g. number, vocal technique) and listener attributes. It may be easier for one singer to convey the words of a song, and their meaning, than for a group of singers. Vocal technique relates to the culture of Western classical music. "Trained" singers learn to project their voices and use clear diction (solo singers: Adams 1998, Falkner 1994; choral singers: Emmons and Chase 2006). The modification of vowels in the interests of preserving the musical line (Hollien *et al.* 2000) and consonant confusions (Collister and Huron 2008) can affect intelligibility, however, as can the use of vibrato (Sundberg 1994)—all of which might be thought of us distorting the "natural" attributes of the lyrics. The singer, however, can only do so much to ensure intelligibility (Fine and Ginsborg 2007b); the perception of sung text depends to a certain extent on the listener. Those who are themselves experienced singers and singing teachers, and are therefore members of the same culture as the performer, are more likely to be attuned to factors affecting singers' diction, and better than non-singers at resolving the acoustic signal into recognizable words. In a preliminary experiment, listeners with experience of both singing and listening to singing wrote down significantly more of the words of songs—whether sung by a trained soloist or a small group of trained soloists—than listeners without such experience (Fine *et al.* 2009).

We have replicated and extended Fine *et al.*'s (2009) study, first, by replacing the small group of trained soloists with an unaccompanied chamber choir, to test more realistically the difference between the intelligibility of a soloist and a group of choral singers. Second, while we compared once again listeners' ability to discern the words of semantically- and non-semantically-meaningful songs, we constructed the latter using an improved strategy.

METHOD

Participants

Twenty-four singers (7 male, 17 female), aged 19 to 81 years (median=24.5), were recruited from a music college and an amateur choir; 24 non-singers (18 male, 6 female), aged 18 to 62 years (median=20.0), were recruited from students and staff in a university department. The singers reported a mean of 26.8 (SD=23.6) years' experience of singing, 6.9 (SD=6.7) hours' singing, and 5.1 (SD=4.6) hours' active listening to singing in the seven days prior to taking part in the experiment, while equivalents for the non-singers were 2.1 (SD=3.5) hours' singing and 5.1 (SD=10.8) active listening to music generally.

Materials

A comparison was made of the ability of singers and non-singers to discern and write down, on first and second hearings, the words of songs ("meaningful" vs. "scrambled") when sung by a soloist and a choir. Four short, novel, songs were performed *a cappella* by a solo soprano and a choir singing in unison with the correct lyrics in English and with the same lyrics scrambled. All stimuli were recorded in the same room at 48 kHz, 24 bit resolution onto a digital audio workstation, and then encoded as MP3 files at a constant bit rate of 320 kbit/s using a Neumann KM130 omnidirectional condenser microphone placed about 1.3 m from the singer(s). Stimuli were played to participants on a laptop computer using either its internal speakers or external speakers. All participants stated that the stimuli were loud enough.

Procedure

In the first part of the study each participant was required to provide demographic information and then complete a daily singing and listening diary for seven days either in response to daily e-mails or on paper. The second part of the study consisted of the experiment. Each participant was tested individually. The researcher gave the participant a piece of paper and two pens of different colors. Having explained the procedure, the researcher played a sequence of short songs to the participant. Each song was played twice. The participant was encouraged to write down the words using one of the two pens while listening to the recording. The first time the song was played the recording was stopped at the end of each of the four lines of text. The second time it was played through without stopping, and the participant was asked to use the other pen to indicate alterations or additions to the words s/he heard.

Analyses: We used the informational semantic match (ISM) method described by Hustad (2006) for transcribing speakers with dysarthria. The number of syllables (including phonemes) transcribed acceptably was calculated as a percentage of the maximum possible. Credit was given for misheard consonants that were feasible in the context of the preceding or next word (e.g. "and choose" for "and shoes") but not mis-heard vowels unless very close. Word order, morphological, segmentation, and spelling errors were ignored, as were "additional" words not in the target material. Two of the researchers scored a proportion of the data independently, and agreed in 93% of syllables transcribed. Disagreements were resolved following discussion.

Scoring: It was not possible to test all participants in all conditions, so a repeated-measures ANOVA could not be undertaken. Instead, a linear mixed model analysis was carried out using SPSS. The dependent variable was percentage of syllables transcribed acceptably. There were four fixed factors: group (singer vs. non-singer), number of singers (solo vs. choir), words (meaningful vs. scrambled), and attempt (first vs. second). Correlations were

Table 1. Main effects.

		Mean %	$F_{44,132}$
Participants (listeners)	Singers	67.0 (SD=20.9)	
	Non-singers	55.8 (SD=23.8)	9.2**
Performance	First	56.9 (SD=23.2)	
	Second	65.9 (SD=22.1)	36.2***
Text	Meaningful	76.3 (SD=17.7)	
	Scrambled	46.5 (SD=17.4)	398.0***
Performer(s)	Soloist	65.6 (SD=22.0)	
	Choir	57.1 (SD=23.3)	33.1***

Table 2. Bivariate correlations between demographic variables and task performance.

Participants	*Singers*	*Non-singers*	*All*
Age	R=-0.548**	R=-0.437*	R=-0.349*
Years' experience	R=-0.544**	NS	NS
Hours' singing	NS	NS	R=0.328*
Hours' listening	NS	NS	Rho=0.388**

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

obtained between the percentage of syllables transcribed acceptably and the participant's age, experience of singing (in years, generally, and hours during the previous week, specifically), and recent active listening to singing. Exploratory data analysis revealed one set of outlying scores in each group. When these scores were removed temporarily, the significance of the results was not altered, so results, means, and standard deviations (SDs) are reported for all participants.

RESULTS

As shown in Table 1, there were significant main effects of all four variables such that singers found sung text more intelligible than did non-singers. The soloist was more intelligible than the choir. Generally, it was easier to make out the words on second hearing and when the text was meaningful.

As shown in Table 2, younger participants performed better on the task than older; there were also significant positive correlations between hours of singing and hours of listening per week and task performance.

DISCUSSION

As hypothesized, singers found sung text more intelligible than did non-singers, supporting the conclusion that the sharing of a culture in which it is acceptable to distort consonants and vowels, as they are normally produced in the context of speech, can compensate for the "unnaturalness" of such modifications and the use of vibrato. Generally, it was easier to make out the words on second hearing than first and when the words were meaningful than when they were scrambled; audiences would benefit if composers and singers alike took note of this finding.

The results also support the hypothesis that the same lyrics sung by a soloist are likely to be more intelligible than those sung by a choir. If the comprehension of sung text, like speech, relies on the clarity of consonants and vowels, choirs may be harder to understand because they produce more variable and less clear phonemes. It is also possible that intelligibility, in this study, was affected by pitch (Hollien *et al.* 2000, Di Carlo 2007). While the soloist was not operatically-trained, she was a soprano singing in a high register (for her); the choral performances may have been more intelligible because the tenors and basses—although singing in unison—were singing an octave and two octaves below the sopranos. This will be addressed in a future study by comparing the intelligibility of high and low soloists. Also, the extent to which soloists are more intelligible than choirs is likely to depend on ability and training. It may be, for example, that operatically-trained soloists are more intelligible than singers without such training.

Finally, the finding that task performance apparently deteriorated with age and experience may be a function of the relative non-homogeneity of the sample of listeners; while two-thirds of the singers were students, the remainder were the considerably older members of an amateur choral society, while only a small group of non-singers was recruited from members of staff in their 50s and 60s. This too will be addressed in future studies.

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Adults identifying as "non-singers" in childhood: Cultural, social, and pedagogical implications

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Singing is widely evidenced as a learned behavior, proceeding developmentally. Contrarily, the literature reveals a prevalent notion in Western culture that singing ability is governed by inherent, biological variability. This paper discusses the impact of these divergent views in a Newfoundland-based investigation of childhood-attributed adult "non-singers" (NS). It examined how participants' NS identities developed, and how such self-perception affected their lives from personal and socio-cultural perspectives. Phase I of the study comprised case-studies of nine childhood-attributed NS, including empirical measures of individual singing ability. This evidence informed a survey instrument (Phase II) administered to a wider cross-section of the public (neither pre-designated as singers nor NS) for possible wider applicability of Phase I findings. A common experiential profile emerged illuminating participants' NS identity formation. Survey data confirmed case-study findings.

Keywords: "non-singer"; entity; development; pedagogy; access

This paper is about everyday singing (not performance) as a human capacity, and about adults who have believed since childhood that they cannot sing.

Evidence is well-established that humans possess a species-wide facility for singing as a learned musical behavior featuring development across a continuum of increasing singing skill and knowledge (Welch 1986). The singing potential of individuals begins to be realized (nurtured and/or hindered), commencing in infancy, through learning encounters in particular socio-cultural contexts across and beyond childhood (Welch 1986). Singing is not only integral to all human cultures (Merriam 1964) but is expressive of the individuals who comprise them and relate within them. The value and practice of singing are globally divergent. A culture's imperatives shape its expressions, and one of the functions that culture seems to fulfill is the determination of the ability/disability view of singing within it. Merriam (1964) remarked that whatever the cultural belief system about "talent," the power of the prevailing perspective determines who may or may not become "musical" in that society. Two African cultures illustrate opposite views about human musical capacity. The Venda (Blacking 1973) believe in and enable singing development in each member from birth, thus enabling inclusive success by all. But the Ewe (Merriam 1964) neither expect nor support pervasive singing development, nor do their members all develop musically.

These rival stances on singing development as a human phenomenon may be seen as compatible if viewed in the light of Dweck's (1999) self-theories of intelligence. Such divergence results from motivation/achievement which are influenced by incremental or entity views of intelligence/ability. Dweck (1986) demonstrated that self-beliefs are more powerful predictors of future achievement than IQ. Self-beliefs are strongly influenced by folk psychology, which exerts a powerful influence on the formation and perpetuation of cultural assumptions. The function of folk psychology is to represent the prevailing notions of the general population. The cultural need exists to identify/explain the patterns comprising the differences in heterogeneous societies. Dundes (1975) called these patterns folk ideas, or the descriptive constructs of perceived reality, and characterized a folk idea as a belief that structures attitudes—a form of cultural validation. The fact that "non-singers" (NS) are well represented in an international lexicon demonstrates the pervasiveness of the NS concept as a perceived social reality in diverse cultures. Colloquial descriptors of singing "disability" abound (e.g. note deafness, dysmelodia, droners, grunters, monotone and tone deaf; Welch 1986). This intuitive folk view of the nature of human singing as a fixed entity has entered into cultural narratives, reflecting cultural practices (Ayotte *et al* 2002).

The limited research on adult NS reflects the polarity of incremental and entity views. One branch of inquiry is development-oriented, while the other represents the tradition of deficit research. The developmental stream has produced common findings documenting an internationally-shared NS culture (Abril 2007). The NS culture thus revealed is one of social anxiety about and exile from singing, begun in childhood, and continuing across the lifespan. In contrast, the "deficit" line of research has tended to focus either on neurologically-based investigations of musical disability, termed "congenital amusia" (e.g. Ayotte *et al* 2002) or psychological studies of "tone deafness" (e.g. Wise 2009) with the latter research suggesting that these two conceptualizations are not synonymous. There is also some dispute about the use of the term "congenital," given that current research appears to lack any neurologically-based studies of young children.

To understand the phenomenon of the NS adult, an extended study was undertaken in Newfoundland, with (1) self-reported individual cases and (2) application of case-study findings to a wider population.

METHOD

Participants

Case-studies (Phase I) comprised nine participants (6 female, 3 male). The respondent pool for the survey (Phase II, n=197) represented a cross-section of the public, neither pre-designated as singers nor NS.

Materials

Case-study data were collected via semi-structured interviews, participant-written reflective journals, and inter-participant group discourse. Singing competency in each case was assessed with an instrument which design was informed by professional practice and a literature review. Phase II data were gathered via a specially-designed survey instrument comprising quantitative and qualitative elements across eight sections that embraced foci from themes that emerged from the Phase I inquiry.

Procedure

Networking selection was employed to identify participants as NS since childhood, aged mid-30s to mid-50s and native, longstanding residents of Newfoundland (NL). Semi-structured interviews were carried out, participant-written reflective journals collected and researcher-moderated participant group discourse conducted. Interviews and group discourse were audio-recorded via a DAT recorder. All data were transcribed, checked against recordings for accuracy and entered into the analysis software program QSR NVivo 8 to facilitate the derivation of themes and sub-themes. Individual participant singing assessments of Phase I were conducted using a protocol designed to assess a wide continuum of developing singing skills. Assessment stimuli were gender-matched to participants. Identical DAT recorders were used to both deliver stimuli and record sung responses. An external expert panel independently assessed participants' responses. Evaluative data were then entered into a spreadsheet to facilitate analysis. In Phase II, 1000 questionnaires were distributed to two groups of adults in NL and anonymous responses collected. Quantitative data from n=197 respondents were entered into Microsoft Excel and SPSS (v16) to facilitate analysis. Qualitative data were transcribed and entered into the analysis software program QSR NVivo 8 to facilitate the derivation of themes and sub-themes.

RESULTS

An autobiographical, socially-located, and developmental view of singing emerged. Participants' empirically-assessed singing behavior exceeded their self-predicted ratings. Case-study data revealed a profile of shared NS attributes which survey findings confirmed:

- NS believe they are unable to sing, accepting the bi-polar, fixed folk concept that humans either can or cannot sing.
- NS attribution arose chiefly in other-imposed negative, defining school/other ensemble sites, often involving authority figures; less often, it was self-inferred by singing skill comparison with other(s).
- At onset, authority attributors were seen as expert, NS self-belief was accepted without resistance, believed irrevocable and persisted across the lifespan.
- NS childhood singing environments had low exposure to, encouragement of, access to involvement, experience, and instruction in singing.
- Being NS reportedly creates a host of negative emotions (e.g. anxiety, humiliation).
- NS risk management strategies (e.g. self-deprecating humor) are commonly used to pre-empt judgment/embarrassment/shame in social-singing settings.
- Regret at singing deficit/social marginalization typify NS identity.
- NS report nil instruction/intervention offered/available for their singing.

The study yielded a wealth of insightful narrative about being NS across the lifespan. Many NS attributed in school performance settings, reporting they assumed that they had been silenced due to performance pressure on the teacher. The appearance of inclusivity often constrained children to remain within the group while required to "mouth the words." Carla (43 years old, attributed at age 7) is representative:

> But it was a dread that you were going to have to go to music, singing I guess. I really disliked it because it was an ordeal. You had to get in the back row and pretend you were singing while everybody else sang…but you were not allowed to sing and you weren't allowed to turn it down.

> You felt terrible. It was like "you can't sing, so we're not going to bother with you".... It was an absolute nightmare. I'll never forget it. I didn't mind that I couldn't sing, but why I had to pretend I could sing was the part I don't think we liked. All of our school chums knew it. We knew it. It was never "try a bit harder or half dozen of you girls come down a little earlier or stay after class." There was no encouragement, none whatsoever. There was no instruction. They worked with you to sing a song same as anybody. I guess practice makes perfect for those that could sing. But I never sing. You never hear me in the shower, accidentally, ever sing a note. Never in the car. Never even to myself.

DISCUSSION

Upon attribution, non-resistant NS acceptance and irrevocability belief were uniformly reported. Given that the mean age of NS attribution in this study was 9 years (many as young as 7), with most attributed by authority figures (teachers: 66%), the relationship of children to authority attributors is at the heart of their non-resistance and acceptance of irrevocability regarding this new found status as NS.

Two key issues factor in this attributional encounter: trust and power. Children trust authority figures on both interpersonal and epistemic levels (Corriveau and Harris 2009). *Interpersonal trust* is that which the child vests in the authority as a person—to be thoughtful, fair—to keep their promises. *Epistemic trust* means that children believe that the adult has expert knowledge. Such reliance on expert knowledge aligns with the reports in this study of unquestioning belief in participant NS attribution. Children evaluate information as to its accuracy (trustworthiness) in two principal ways: a perceptual-driven mode (trusting their own senses) and a socially-driven mode (deferring to consensus, *possibly even despite perceptual evidence available to them*). Children notice who agrees with whom, and they tend to trust informants who belong to a consensus (Corriveau and Harris 2009). Therefore, because the widespread notion of human as NS is firmly established in the culture as a folk idea—i.e. a generally accepted popular "belief" (Ayotte *et al.* 2002, Wise 2009), the child is likely to encounter a wide social-consensus on this point. The issue of power (i.e., *legitimate power* and *expert power*) also affects a child's attribution as NS by an authority figure (Raven 1965). *Legitimate power* is rooted in the child's obligation to accept the authority figure's influence attempt (i.e. you are an NS) because the child believes that the authority has a legitimate right to do so. *Expert power* emanates from the perception that the authority has the knowledge/expertise to make the NS attribution (Raven 1965). Moreover, 74% of NS survey respondents and 100% of case-study participants reported that they had not been offered any help to improve their singing, which underscored a sense that intervention would have been useless to the child. Those NS surveyed who did report receiving help were not helped by teachers, perhaps suggesting that disinclination to intervene may indicate the possibility of their holding an "entity" view of development or being ill-prepared to help. Given evidence of reported childhood singing difficulty varying from 30% at age 7 to 4% by age 11 (Welch 1986), and 9 years being the mean age of arrested singing development in this study, then a possible lack of pedagogical and/or cultural awareness of singing potential begs further investigation.

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Entrainment to speech and song

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Do we entrain similarly to speech and song? English and French participants were asked to tap along with the same set of sentences, in three conditions that varied in temporal regularity and musicality. The utterances, produced by a single vocalist, were either spoken naturally, spoken regularly (aligning syllables with a metronome), or sung regularly. Participants tapped more regularly to both song and regular speech than to natural speech. One can entrain to natural stimuli that are not musical: participants tapped with similar regularity to regularly spoken and to regularly sung stimuli. However, participants' taps were better aligned with the metronome underlying song than regular speech. Although sensitivity to rhythmic regularities is not unique to music, the current findings support the idea that music, due to its rhythmic structure, is a privileged stimulus to elicit entrainment.

Keywords: entrainment; tapping; speech; song; rhythm

Entrainment is the natural tendency to perceive and to synchronize one's responses with temporal regularities present in external stimuli (Large and Jones 1999). One can entrain to stimuli of various rhythmic complexities, from a steady metronome pulse to complex music exhibiting several metrical levels (Drake *et al.* 2000), to stimuli with no obvious regular beat, such as speech (Wilson and Wilson 2005). Entrainment is generally investigated by using sensorimotor synchronization tasks such as tapping. Tapping variability and synchronization with the underlying beat can be used to infer entrainment strength.

Most documented cases of entrainment are related to temporally regular stimuli (Phillips-Silver *et al.* 2010). Can we entrain to stimuli with no underlying steady beat? Research on entrainment to speech suggests that conversational turn-taking (Wilson and Wilson 2005) can be simulated with an oscillator model that has also been applied to entrainment with music (Large and Palmer 2002). The question of whether speech can be considered a regular stimulus is matter of debate because speech is not isochronous (for a review, see Patel 2008). Listeners should entrain better to regular stimuli, such as singing, than to less regular stimuli, such as speech. Another question is whether melodic information is necessary to elicit entrainment. Snyder and Krumhansl (2001) have shown that removing pitch variations in ragtime piano music does not impair listeners' tapping performance; the removal of pitch information has not been examined with human speech or song. Although one could entrain to both speech and song, music (and thus song) might be the paramount stimulus for eliciting synchronized motor responses. Finally, one can wonder whether rhythmic differences between languages influence entrainment. Stress-timed languages, such as English, are usually perceived as more rhythmically regular than syllable-timed languages, such as French (Cutler 1991). Therefore, one could entrain more to English than to French.

We investigated how people entrain to vocal productions that vary in their musicality, temporal regularity, and language rhythmic class. We asked English and French-speaking participants to tap to English and French utterances produced in three conditions: (1) spoken with a natural (irregular) prosody (henceforth, *natural speech*), (2) spoken with a metronome inducing an underlying beat (*regular speech*)—a condition that could be compared to rap music or poetry slam, and (3) *sung* with a metronome. Because the naturally spoken condition has no clear underlying beat, we expected participants to tap more variably with natural speech than with regular speech and song. In addition, preferential entrainment to music would predict that participants should tap less variably and with fewer asynchronies to song than to regular speech.

METHOD

Participants

Twenty-four monolingual native English speakers (mean age=23.1 years, range 19-40) and 24 monolingual native French speakers (mean age=26.5 years, range 18-46) were recruited from the Montreal area. Participants were not selected for their musical experience. The study complied with the norms of the McGill University Ethics Review Board.

Figure 1. Score and lyrics for one sung stimulus in French with its English counterpart.

Materials

Twelve English and 12 French sentences were recorded in three conditions by a balanced English-French bilingual speaker experienced in singing. All sentences were composed of 13 monosyllabic words. English and French sentences were matched on word frequency, syntactic structure, and rhythmic structure. The three recording conditions were as follows. In the *naturally spoken condition*, the speaker was instructed to speak the sentence with a natural prosody. In the *regularly spoken condition*, the speaker was asked to align every other syllable with a 120 bpm (500 ms interonset interval) metronome click presented through headphones. In the *regularly sung condition*, each sentence was sung *a capella* on a melody of 13 quarter notes (one note per syllable), aligning every other note with a 120 bpm metronome click. Twelve tonal melodies were composed for the sung condition (7 major, 6 minor; see Figure 1). Each sentence was paired with two different melodies in the sung condition. Naturally spoken utterances had an average duration of 3.43 s, regularly spoken utterances 3.83 s, and sung utterances 4.18 s.

Procedure

All auditory stimuli were presented to participants over headphones. Tapping responses were recorded on a silent electronic keyboard as midi data, with a temporal resolution of 1 ms. Participants' spontaneous tapping rate was measured at the beginning of the experiment; they were asked to tap at a regular and comfortable pace with the index finger of their dominant hand, for 30 s. This was followed by the speech, regular speech, and song tapping task, in which participants were instructed to tap along to the beat they perceived in the utterances they heard. On each experimental trial, an utterance (naturally spoken, regularly spoken, or sung) was presented three times. Participants were instructed to listen to the first presentation of the utterance, and to tap along to the stimulus on the second and third repetitions. English- and French-speaking participants were presented with both English and

French stimuli, blocked by language, with the order of language presentation counterbalanced among participants. Within a language block, conditions (natural speech, regular speech, song) were mixed and experimental trials were presented in a pseudo-random order within each language. In the sung condition, the sentence-melody pairing was counterbalanced across participants (each participant heard each sentence paired with only one melody). Between language blocks, participants completed a questionnaire about their linguistic and musical background. At the end of the speech tapping task, the participants completed a second measure of their spontaneous tapping rate. Finally, they were asked to tap along with a sounded metronome (IOI=500 ms, for 30 s) to assess their synchronization accuracy with a simple stimulus. Speech and song tapping data were collected from a total of 144 trials (2 languages x 12 sentences x 3 conditions x 2 repetitions). The participants' language was a between-subjects variable; the stimulus language and the condition were within-subject variables.

RESULTS

There was a main effect of condition on tapping variability in the speech and song tapping task as indexed by the Coefficient of Variation of Inter-Tap Intervals (CV [ITI]; SD/M), $F_{2,92}=45.16$, $p<0.001$. Tukey's post-hoc tests revealed that participants tapped more variably to natural speech (M=0.30, SD=0.15) than to regular speech (M=0.18, SD=0.12) or to song (M=0.12, SD=0.13) (see Figure 2, left panel). Tapping variability was significantly higher for English than for French stimuli, $F_{1,46}=4.21$, $p<0.05$. The same ANOVA run on the Coefficient of Variation of the Inter-Syllabic Intervals (CV [ISI]) of the stimuli similarly revealed a main effect of condition, $F_{2,22}=142.91$, $p<0.001$. Naturally spoken (M=0.46, SD=0.10), regularly spoken (M=0.33, SD=0.08), and sung stimuli (M=0.19, SD=0.05) each differed significantly from each other (see Figure 2, right panel).

Participants' synchronization with the regular stimuli (regular speech and song) was compared by examining the asynchronies of their taps relative to the timing of the nearest metronome click to which the singer had been asked to synchronize her production (not heard by the participants). Participants' taps tended to be anticipatory for both types of stimuli. The asynchronies were smaller to sung stimuli (M=-3.9 ms, SD=33.4) than to regularly spoken stimuli (M=-15.3 ms, SD=36.6), $F_{1,46}=18.1$, $p<0.001$. English and French participants did not differ significantly on any of the control tasks (spontaneous motor tempo and tapping with a metronome), nor did they differ in their performance in the speech and song tapping task.

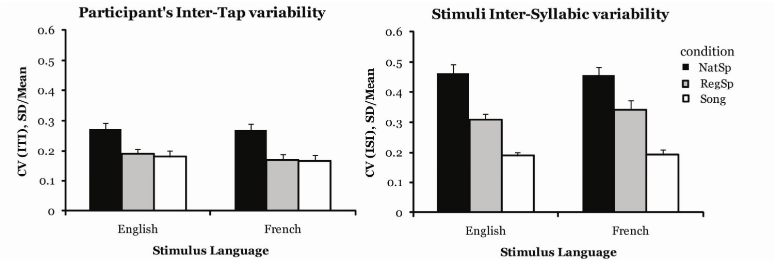

Figure 2. Left panel: Mean Coefficient of Variation (CV) of Inter-Tap Intervals (ITI) by stimulus language and experimental condition (natural speech, regular speech, song). Right panel: Mean Coefficient of Variation (CV) of Inter-Syllabic Intervals (ISI) by stimulus language and experimental condition. Error bars represent the standard error of the mean.

DISCUSSION

English and French participants were asked to tap with vocal utterances that exhibited a gradient of temporal regularity from natural speech (less regular) to song (most regular). The presence of an underlying beat facilitated entrainment in regular speech and song compared with vocal stimuli with no regular pulse (natural speech). Listeners tapped with a similar regularity to regularly spoken and to sung utterances, even though the syllables in the stimuli were spaced more regularly in song than in regular speech. However, tapping asynchronies were smaller for song than for regular speech. Our results suggest that temporal regularity can be extracted from vocal (verbal) utterances that convey a rhythmic pulse but have no melodic variations. Our regularly spoken stimuli were comparable to poetry or rap-music, suggesting that one can entrain to speech if it is regularized in a musical way. This supports the idea that music, due to its rhythmic structure, is a privileged stimulus to elicit entrainment. The present findings generalize across English and French speakers, but participants tapped more variably to English than to French utterances. This seems to contradict the idea that it is easier to entrain to stress-timed than syllable-timed languages; at least when spoken utterances are mixed with sung utterances. Further research should generalize our conclusions to a larger sample of speakers, as well as to less controlled situations and stimuli, such as people tapping or clapping their hands to real-world singing and rap music.

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Perspectives on singing and performance in music therapy

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This article provides an overview of the potential efficacy of vocal performance as an intervention in music therapy within the context of vocal performance and associated health benefits. The authors advocate increased collaboration between music therapists and other professionals in order to develop, implement, and evaluate carefully designed performance-based singing and wellness initiatives in various contexts. Indications and contraindications for the use of performance-based singing interventions are provided. Implications for research, practice, and society are presented.

Keywords: community music therapy; singing; performance-based therapy; health and wellness

"Music therapy is the skillful use of music and musical elements by an accredited music therapist to promote, maintain, and restore mental, physical, emotional, and spiritual health" (Canadian Association for Music Therapy [CAMT] 1994). Currently, the CAMT has about 310 accredited members, and there are six university-based music therapy training programs in Canada. Music therapists provide services in a variety of healthcare, educational, and private practice settings, working with people of all ages and abilities. As a body of knowledge and practice, music therapy is a transdisciplinary hybrid of two main fields, music and therapy; as a treatment modality, it is diverse in application, goal, method, and theoretical orientation (Bruscia 1998). The scope of practice among music therapists can vary widely and is often shaped by the context and culture in which the music therapy occurs.

Performance involves a public display of skill. Although music therapy typically occurs in private settings where groups or individuals engage in music experiences associated with various musical and non-musical therapeutic goals, the current authors believe that music therapists also have a role to play in broader clinical and non-clinical contexts, including those that use music performance for health promotion and wellness. [*Note.* The term "health" is being viewed from a holistic biopsychosocial perspective that encompasses body, mind, spirit, society, culture, and environment, and proposes that these elements interact in complex ways which as a whole affect individuals' overall state of health and wellbeing; Engel 1977, Bruscia 1998.] A growing area of practice, Community Music Therapy (CoMT, Pavlicevic and Ansdell 2004), supports this perspective and the responsibility of music therapists "to help clients access a variety of musical situations, and to accompany them as they move between 'therapy' and wider social contexts of musicing" (Ansdell 2002, p.10). [*Note.* "To music is to take part, in any capacity, in a musical performance, whether by performing, by listening, by rehearsing or practicing, or by providing material for performance (what is called composing), or by dancing"; Small 1998, p.9.] Music therapists have much to offer in performance settings that involve vulnerable persons or special interest groups. In these situations, music therapists can design music experiences accessible to participants of varying abilities (musical and otherwise) and help them manage the potential psychological ramifications of performance (Jampel 2011).

There is a growing literature on the health benefits of singing. [*Note.* As it is beyond the scope of this paper to review all of the research in this area, the authors recommend that readers consult recent systematic reviews by Clift *et al.* (2010) and Gick (in press) for more information.] Chorale rehearsal and/or performance have been linked with dimensions of benefit such as increased wellbeing and relaxation, social benefits, improved breathing and posture, spiritual benefits, emotional benefits, and benefits for the heart and the immune system (Clift and Hancox 2001). Different types of choir groups have been studied, such as seniors (Hillman 2002), men who are homeless (Bailey and Davidson 2003), offenders with mental illnesses (Reed 2002), and female prisoners (Siber 2005) as well as music therapy based individual and group therapeutic vocal performances (Aigen 2004, Ansdell 2005, Jackson 1995, Snow *et al.* 2008, Turry 2005).

This article's main aims are to increase awareness about the health benefits of vocal performance and to promote increased collaboration between music therapists and other professionals in order to develop, implement, and evaluate carefully designed performance-based singing and wellness initiatives in various settings.

MAIN CONTRIBUTION

Although inherent benefits occur in performance-based singing initiatives, facilitating these experiences for vulnerable persons requires knowledge, thought, skill, and care (Young 2009). Singing is a personal form of self-expression that evokes strong feelings (Pavlakou 2009). In groups, it is challenging to meet individual singers' needs, work with the limitations of any illness or disability, while also strengthening group identity (Jampel 2011). It is also a skill to evaluate and recognize someone's readiness to perform (Turry 2005). The following indications and contraindications provide initial guidelines for the responsible use of performance-based vocal interventions in music therapy.

Indications and contraindications for the use of performance-based singing interventions in music therapy

Based on the literature and the authors' experience, performance-based vocal interventions may be *indicated* when:

- Vocal performance is a genuine client interest (O'Grady 2008), and the client is open to collaborating with the therapist (and other group members, if applicable) in order to establish parameters of performance.
- Vocal performance is directly linked to pre-established or emerging therapy goals and will presumably benefit the client(s) in some way.
- A vocal performance could serve as a pivotal healing or reconstructive experience for a client who needs acceptance from others or for a client who has had negative past performance experiences.
- The client displays an inherent ability and passion for vocal performance and potential therapeutic contraindications can be rectified.

Based on the literature and the authors' experience, performance-based vocal interventions may be *contraindicated* when:

- A desire for an aesthetically pleasing or "perfect" musical product (by the client or therapist) obscures client clinical goals (Turry 1998).
- The client is not realistic about his/her vocal potential and/or performance aspirations.
- Even in consultation with the therapist, the client is unable to choose repertoire to his/her own satisfaction or unable to choose music that is appropriate for him/her, perhaps indicative of a broader problem with life regulation (Jampel 2011).

- The client does not have the emotional capacity to cope with a bad performance or negative feedback (real or perceived).
- The venue or forum within which the client wants to perform is not appropriate (i.e. the performance will not satisfy or "fit" the expectations of the audience; Jampel 2011).
- The client is unable to manage negative "internal [critics] voices" (Jampel 2011).
- A client is unable to connect (musically or interpersonally) with other members of a performing music therapy group.
- The client obtains no satisfaction from performance experiences (Jampel 2011).
- The client suffers from an anxiety disorder that inhibits the potential benefits of vocal performance.

IMPLICATIONS

Implications exist for research, music therapy, and interprofessional practice for community and society. Well-designed, collaborative research projects that utilize multiple research methods (i.e. experimental trials, mixed methods, qualitative paradigms) are required. Various aspects of performance need to be more clearly defined such as performance versus rehearsal contexts, public versus private performance, and presentational versus participatory performance activities (Powers 2010). Last, the creation of a database of relevant case studies and descriptions of "singing and wellness" projects would help organize current knowledge and also help to identify specific areas where research is needed. In music therapy practice, performance-based therapy interventions need to be "legitimized" and included on the continuum of standard music therapy practices so there can be better documentation and the development of relevant ethical guidelines. Increasing interprofessional collaborations between music therapists, music educators, chorale conductors, performers, healthcare workers, and other relevant professionals will help develop and establish high quality performance-based and non-performance-based singing and wellness initiatives.

Addressing these implications for research and practice could lead to the development and implementation of sustainable, high-quality singing and wellness initiatives in various contexts and communities. It may even create new kinds of communities, increase participation in singing activities, and broaden public perspectives on the roles of vocal performance in promoting health and wellness.

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Thematic session:
Physicality of performance

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Investigating the physiological demands of musical performance

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An understanding of the physiological demands of music performance can be used to inform musicians' training and help prevent performance-related health problems. While the psychology of performance has been relatively well researched, little is known about the physiological demands of music performance and the relevance of fitness to musicians. This study examined the oxygen uptake during performances of a series of pieces given by skilled pianists. Five undergraduate and postgraduate piano performance students were recruited at Trinity Laban Conservatoire of Music and Dance to give informal performances totaling approximately 20 minutes. Energy expenditure while playing was assessed via measurements of heart rate (HR) and oxygen uptake. Mean oxygen uptake was 8.65 ml.kg.min while certain pieces peaked around 25.00 ml.kg.min. Mean HR was 108.95 beats per minute (bpm) with certain pieces peaking at 173 bpm. Energy expenditure in piano playing appears to be intermittent in nature, with fluctuations in intensity within each piece and differences in intensity between pieces. From this study, it appears that mean oxygen uptake during piano playing is similar to that during brisk walking.

Keywords: energy expenditure; performance; pianists; indirect calorimetry; fitness

While the psychology of music performance has been extensively investigated, less is known concerning the physical demands—in particular, energy requirements. Llobet and Odam (2007) advocate the development of the musical "athlete", but what sort of athlete do musicians need to be? Research has shown rock drumming to be an intense and physically demanding activity, with mean heart rate (HR) values of 155 bpm and peak HR values reaching 179 bpm, well in excess of age predicted maximum. This indicates that rock drumming is a high intensity activity, relying upon both the aerobic and anaerobic energy systems (Smith *et al.* 2008). Differences in heart rates have been identified between music practice and performance, and between different pieces of music, indicating that there is much variance in music playing with regard to energy requirements (Iñesta *et al.* 2008, Mulcahy *et al.* 1990). However, methods adopted by previous researchers to measure energy expenditure should be viewed with some caution. The use of heart rate as a means of predicting energy expenditure has been found to be unreliable during non-steady-state activities such as dance (Redding *et al.* 2004). Additionally, influential factors such as anxiety cast further doubt on the reliability of heart rate data. Indirect calorimetry through the measurement of oxygen consumption has been found to be the most reliable method for determining energy expenditure (McArdle *et al.* 2006).

The current study sought to develop a clearer understanding of the physiological demands of music performance and, in particular, the oxygen uptake during performance by skilled pianists.

METHOD

Participants

Participants were two undergraduate and three postgraduate piano performance students at Trinity Laban Conservatoire of Music and Dance (three male, two female, mean age=23.20 years, SD=3.27). Participation was restricted to pianists because it was important to observe one group of musicians at a time, and also because pianists can perform while wearing a portable gas analyzer mask.

Materials

Each participant was requested to prepare 20-30 minutes of music to a public performance standard. They were asked to choose pieces they perceived to be technically and physically demanding. A total of 13 pieces was recorded. Participants gave an informal solo performance, during which energy expenditure was assessed in two ways: a Polar heart rate monitor and watch (Polar Accurrex, USA) was used to monitor and record heart rate, and a portable telemetric gas analyser (Metamax 3*b*, Germany) measured oxygen uptake (VO_2).

Procedure

Necessary ethical clearance was obtained from the Trinity Laban Research Ethics Committee. Following the collection of informed consent from each participant, equipment for measurement was fitted. After becoming accustomed to playing with the equipment on, participants performed their first piece. The Metamax was then removed to allow the participant to drink water. Following calibration and reattachment, participants performed their second piece.

Data analysis

Ventilatory oxygen uptake (VO_2) data was calculated relative to each participant's body mass and described as milliliters per kg of body mass per min (ml.kg.min). This is to account for the varying body mass between participants, thus allowing for comparative analysis. Heart rate values were analyzed and expressed as beats per min (bpm) as well as calculated as percentages of each participant's age predicted HR maximum. Means and standard deviations as well as peak VO_2 and HR values were calculated for each piece of music.

RESULTS

The mean oxygen uptake for the 13 pieces was 8.65 ±2.55 ml.kg.min, with a range of 4.71-11.82 ml.kg.min. The mean % of HRmax was recorded as 55.43% of HRmax across the 13 pieces (mean 108.95 bpm; Table 1).

The 13 pieces of music differed considerably from each other in terms of duration, mean, and peak oxygen uptake. For example, Liszt's *Dante Sonata* lasted 18 minutes and reached a peak of 25 ml.kg.min, whilst Prokofiev's *Sonata No.7 (II)* lasted 6 minutes and reached a peak of 18 ml.kg.min (Figure 1). Furthermore, certain pieces fluctuated more in intensity than others. The data show a greater variation in intensity within Liszt's *Dante Sonata* than Chopin's *Barcarolle* for example (see Figure 1).

There was also a notable difference in heart rate between pieces. A mean HR of 157.40 bpm was recorded when Participant D performed Ligeti's *L'escalier du diable*, at one point rising to 173.00 bpm. The mean HR recorded while Participant B performed Ravel's *La Valse* was 90.86 bpm, lowering to 74.00 bpm at one point, which is consistent with a resting state.

In Ravel's *La Valse*, VO_2 peaked at 24.00 ml.kg.min, while in Chopin's *Barcorolle* it reached only 14.00 ml.kg.min at its maximum point (both Participant B). Chopin's *Barcorolle* was of overall lower intensity throughout,

Table 1. Duration, mean VO_2, mean HR, and mean %HR max for the performed pieces.

Pianist	*Piece*	*Duration (min)*	*Mean VO_2 (ml.kg.min)*	*Mean HR (bpm)*	*%HR max*
A	Liszt, Dante Sonata	18	8.37	118.59	61.13
A	Prokofiev, Sonata No. 7 (II)	6	6.69	106.61	54.95
A	Prokofiev, Sonata No. 7 (III)	4	9.88	125.15	64.51
B	Ravel, La Valse	12	11.36	90.86	45.89
B	Chopin, Barcarolle	9	8.21	76.56	38.67
C	Martinu, Cello Sonata No. 2 (I)	8	11.50	103.98	52.51
C	Ravel, Violin Sonata (II)	6	11.07	97.49	49.24
C	Ravel, Violin Sonata (III)	4	11.82	102.24	51.63
D	Liszt, Paganini Etude No. 2 in E*b*	7	9.04	137.61	71.30
D	Ligeti, L'escalier du diable	5	9.47	157.40	81.56
E	Debussy, Prelude No. 7	5	5.37	99.71	49.61
E	Chopin, Revolutionary Etude	4	4.92	99.54	49.52
E	Chopin, Ballade No. 4 in f	10	4.71	100.68	50.09
	Mean	7.54	8.65	108.95	55.43
	(±SD)	(4.01)	(2.55)	(21.11)	(11.48)

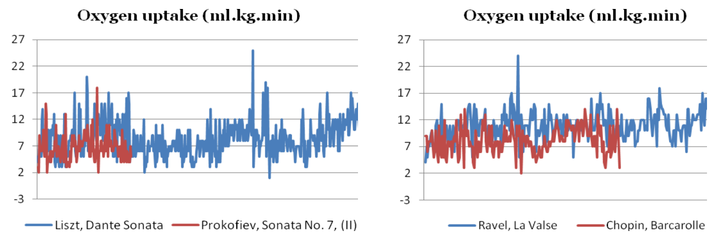

Figure 1. Oxygen uptake during two different pieces performed by Participant A (left panel) and Participant B (right panel). (See full color version at www.performance science.org.)

with a mean VO_2 of 8.21 ml.kg.min, compared with Ravel's *La Valse* which was performed at a mean VO_2 of 11.36 ml.kg.min (Figure 1, right panel).

DISCUSSION

The aim of this study was to investigate the physiological demands of music playing through a descriptive analysis of VO_2 and HR during the performing of 13 piano pieces. The data show that the average VO_2 required to perform the piano pieces was 8.65 ±2.55 ml.kg.min. This is on par with activities such as brisk walking. While the overall mean oxygen uptake is relatively moderate, at certain times there are short high intensity bursts of activity which demand much more oxygen.

The mean HR recorded while Participant D performed Ligeti's *L'escalier du diable* was 157.40 bpm. This is similar to values previously recorded for rock drumming (Smith *et al.* 2008). It could be argued that certain pieces of piano music are performed at similar intensities to rock drumming therefore.

Findings show that there can be much variation between pieces. The mean VO_2 required to perform Chopin's *Ballads No. 4 in f* was 4.71 ml.kg.min, while the mean VO_2 required to perform Ravel's *Violin Sonata (III)* was 11.82 ml.kg.min. However, these two pieces were performed by two different participants. Factors such as the participants' activity-specific skill level could have affected how hard they needed to work to perform. Nevertheless, variation existed between pieces even when performed by the same participant (see Table1).

The data show that piano playing is an intermittent activity whereby intensities fluctuate in a non-steady fashion. This is consistent with findings in both Smith *et al.*'s (2008) rock drumming study and in the dance literature (e.g. Dahlstrom *et al.* 1996, Wyon *et al.* 2004). Implications are that consideration should be given to the training of musicians in terms of their cardiorespiratory fitness; supplementary physical training such as interval training could therefore form a valuable part of a musician's education.

For this initial study, it was decided to observe as many different pieces from different pianists as possible in order to gain a broad understanding of the energy requirements of piano performance. Future research could usefully examine the same piece played by a number of different participants to examine and account for possible differences in skill level. It should also be noted that variation may be caused by differences in participants' metabolisms due to gender, age, or body composition. Additionally, these findings cannot be applied to other instruments. Future research could examine the energy requirements of other instrumentalists and also vocal musicians to determine their physiological needs.

In conclusion, the present study demonstrates that physiological demands of different piano pieces vary and that piano playing is an intermittent activity. Overall, it appears to utilize the level of oxygen uptake needed to walk briskly, but can also peak at levels consistent with dance and rock drumming (Schantz and Astrand 1984, Smith *et al.* 2008).

Acknowledgments

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The day-to-day workload of ballet dancers

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Professional ballet dancers typically face long work days, and many complain of fatigue, particularly as a cause of injury. However, little information exists regarding the daily physiological demands of a dancer. The aims of the present study are to examine daily activity and sleep patterns of professional ballet dancers. Data regarding a single "work day" (09.30-18.30 hours) were collected from 84 ballet dancers over a three-week period to ensure that data were representational of a "typical" day. Seven dancers were from the corps de ballet, 16 were first artists, 12 were soloists, and 16 were principal dancers. Results indicated significant differences between dancer rankings for mean exercise intensity and the percentage of time spent at sedentary intensity (<3 METS), moderate intensity (3-6 METS) ($p<0.005$), and vigorous intensity (6-9 METS) ($p<0.05$). The rest versus work time were also significantly different ($p<0.001$) between rankings. It was concluded that (1) the average daily workload of professional ballet dancers varied significantly according to roles and gender and (2) the scheduled rest breaks were insufficient in length to combat fatigue, or that dancers were not utilizing their breaks to rest properly.

Keywords: ballet; work; recovery; fatigue; injury

The majority of research on the physical demands of dance has focused on the individual demands of class (Cohen *et al.* 1982b, Dahlstrom *et al.* 1996, Rimmer *et al.* 1994, Schantz and Astrand 1984, Wyon *et al.* 2002), rehearsal (Rimmer *et al.* 1994, Wyon *et al.* 2004) and performance (Cohen *et al.* 1982a, Schantz and Astrand 1984, Wyon *et al.* 2004) without looking at the effect of how these interact over a whole day. Monitoring training load is a vital component of athlete/dancer welfare, especially as dancers perceive that the main

Table 1. Participant details.

	Gender	*Age (years)*	*Height (cm)*	*Weight (kg)*	*Smokers*
Corps de ballet	Female (n=7)	25 ± 3.27	165.0 ± 2.67	45.0 ± 6.20	2
	Male (n=31)	20 ± 1.47	182.0 ± 2.00	67.3 ± 5.37	5
First Artist	Female (n=16)	26 ± 4.35	161.6 ± 2.89	47.0 ± 7.21	1
	Male (n=12)	22 ± 1.13	179.0 ± 3.00	70.8 ± 5.87	3
Soloist	Female (n=12)	25 ± 3.51	159.2 ± 5.20	44.3 ± 5.51	1
Principal	Female (n=16)	33 ± 2.99	161.9 ± 1.25	46.3 ± 2.63	0

cause of injury is fatigue/overwork (Brinson and Dick 1996, Laws 2005). The aims of the present study are to examine daily activity and sleep patterns of professional ballet dancers.

METHOD

Participants

Data regarding a single "work day" (from 09:30-18:30) were collected from 84 dancers over a three-week period (to ensure that data were representational of a "typical" day) from one international touring ballet company. Measurements of height and weight, along with the participants' dates of birth and their smoking habits, were recorded (see Table 1).

Procedure

Participants wore an armband containing the "Sensewear" (Bodymedia Inc., Pittsburgh, Pennsylvania, USA) multiple accelerometer (SWA) device on their right upper arm throughout the day. At the end of the dancers' work day the armbands were removed and the data downloaded.

Data collection

The SWA includes a 2-axis accelerometer, a heat-flux sensor, galvanic skin response sensor, and both skin- and near-body ambient-temperature sensors. The device estimates energy expenditure in terms of kilocalories (kcals) and exercise intensity (EI) in metabolic equivalents (METS). Its accuracy for estimating energy expenditure (EE) during physical exertion has been confirmed through several reliability and validity studies. The mean exercise intensity for the day—i.e. the amount of rest (<1.5 METS) versus work time (in minutes)—was documented, as was the amount of the day spent in each intensity band (sedentary=<3 METS, moderate=3-6 METS, vigorous=6-9 METS, and very vigorous=>9 METS) as both the absolute time (in minutes) and time expressed as a percentage of the dancers' working day. The length of periods at rest (<1.5 METS) was also documented in minutes. The greatest single amount of time spent below 1.5 METS for each day was documented as the dancers' greatest "rest break" (GRB), while the mean length of all rest breaks (MRB) throughout each day was also calculated.

Statistical analyses

The pre-analyses Chi-Square and Kolmogorov-Smirnov normality tests were used to detect if variables were normally distributed. Non-parametric Kruskall Wallis test was used for the following variables, which were not normally distributed ($p<0.05$): mean length of rest break (MRB), longest rest break (GRB), work-to-rest ratio, percentage of day at 6-9 METS, and percentage of day at >9 METS. One-way ANOVA was used to analyze the following variables, which were normally distributed: mean exercise intensity for the day, percentage of day at <3 METS, and percentage of day at 3-6 METS. Descriptive statistics were also used to report the results. Statistical significance for all analyses was set at $p<0.05$.

RESULTS

Analysis indicated no gender differences, though this is probably due to lack of male soloists and principals. The percentage of the day that was spent in each intensity band, grouped by dancer ranking within the company showed significant differences ($p<0.05$) between rankings. Significant differences between rankings ($p<0.005$) for the mean exercise intensity were reported, where soloists had a significantly greater workload than did artists and first artists. The mean daily workload between dancer rankings show that soloists worked at a significantly greater intensity over the day than the first artists and corps ($p<0.01$) (Figure 1).

First artists and the corps de ballet dancers worked at a similar mean intensity, while principal dancers worked at a mean intensity that was greater than these two groups, but still less than the soloists. While the mean exercise intensity (all dancers) remained fairly low (<4 METS), the highest intensities dancers reached were 11.2 min-1 ±3.32 for principal dancers, 11.3min-1 ±4.02 for soloists, 9.7 min-1 ±3.16 for first artists, and 10.1 min-1 ±3.83 for corps de ballet dancers. These higher intensities were reached on few occasions during

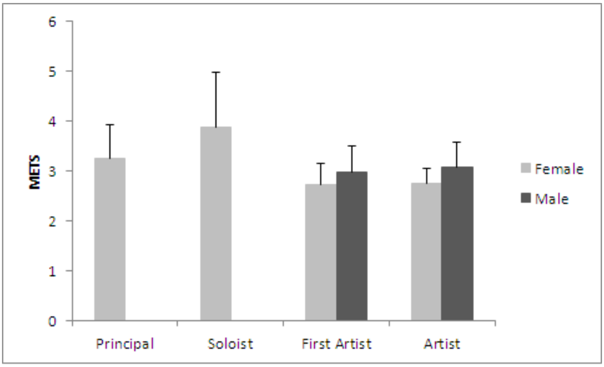

Figure 1. Mean Workload by rank.

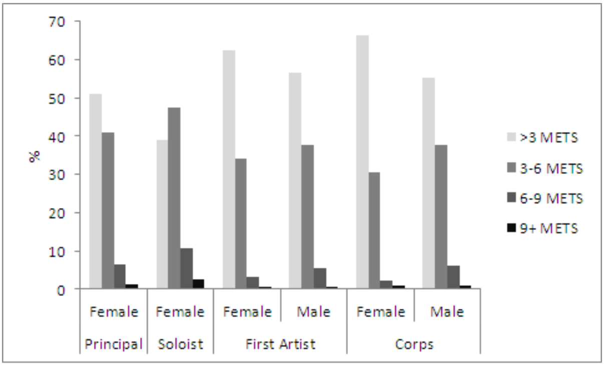

Figure 2. Percentage time spent at different MET categories by rank.

each dancer's day, and were only sustained for a very short period of time; less than 5% of the day in most cases (Figure 2).

Significant differences between rankings for the amount of time at "rest" versus the time above resting intensities were reported ($p<0.001$). This variable can also be expressed as a ratio of work-to-rest over the whole day. It can be observed that the only group of dancers to spend more time resting (<1.5 METS) than working was the corps de ballet. Of the other dancers it can be seen that principal dancers and soloists spent less than half a minute at rest for every minute danced, while first artists spent just over half a minute. The greatest amount of rest time seen throughout the day, at any one time (GRB),

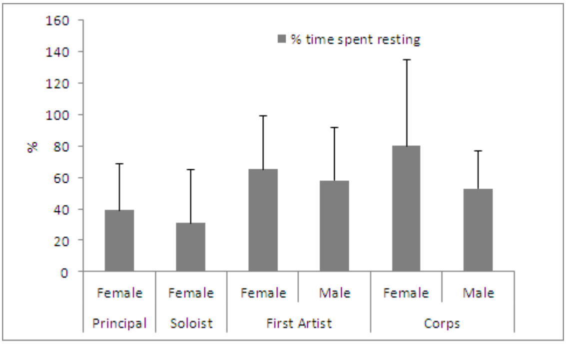

Figure 3. Percentage time spent resting during working day.

were analyzed; results revealed GRB times of 36.0±31.35 minutes. Forty-six out of 51 dancers (90%) had GRB times of fewer than 60 minutes; 17 dancers (33.3%) spent fewer than 20 consecutive minutes at rest at any one time.

Data on sleep time indicated that dancers spent a mean time of 6:45 (hours:minutes) ±1:35 (range=3-9 hours) lying down at night, but only a mean time of 5:20±1:30 (range 2:20 – 8 hours) in a deep sleep mode.

DISCUSSION

The present study has demonstrated the variety in workload for dancers across ranks in a professional ballet company. Though the mean METS are similar for all ranks, it is the soloists that have the hardest work schedule. One dancer had 9 hours 39 minutes of dancing (3+ METS) in one day with 2 hours spent at 6-9 METS, and he expended 5417 kcal. The data also highlight the lack of rest periods during the day that are long enough for eating and subsequent digestion. Deep sleep also varied greatly; research has shown that the hormones related to muscular repair and healing are only released during stage 3 and 4 of sleep (Holl *et al.* 2011). These data could possibly be linked to the high injury rate seen within dancers as the lack of overnight healing would exasperate chronic injuries.

This schedule is the opposite of that employed within the majority of sports where the focus has shifted to quality rather than quantity of training and rest has been recognized as part of the training regime (Bompa 1999, Issurin and Kaverin 1985, Matveev 1965, Wyon 2010).

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Psychophysiological study: Ambulatory measures of the ANS in performing artists

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Professional performing artists routinely manage stressful demands encountered during public performances. Fourteen professional performing artists (6 dancers, 6 opera singers, and 2 conductors) rehearsed and performed in a concert hall setting while wearing the Vivometric LifeShirt, an ambulatory instrument that measures autonomic regulation. Contrary to our hypothesis, that greater parasympathetic changes from baseline to performance would be related to higher perceived states of subjective flow during performance, we found decreased cardiac autonomic balance (CAB) and regulatory capacity (CAR) was related to dispositional and state flow in performing artists. As a group, they endorsed moderate to high dispositional and state flow as measured by two self-report instruments. This case study is the first study to investigate psychophysiological flow states during public performances. A larger sample size is needed to understand the role autonomic regulation plays in subjective flow experiences; however, the findings in this study suggest that decreased autonomic regulatory capacity is not necessarily deleterious to performance flow experiences.

Keywords: ANS; flow; performing artists; anxiety

The aim of this case study was to examine psychophysiological flow states as measured by self-report and ambulatory measurements of the autonomic nervous system in professional performing artists during rehearsal and performance events. We hypothesized that greater parasympathetic (vagal) changes from baseline to performance would be related to higher perceived states of subjective flow during performance.

According to Csikszentmihalyi (1990), flow is considered an optimal experience, one that incorporates a convergence of inter-related elements. Flow includes: (1) balance between an individual's perception of challenge and his or her skill-level, (2) action-awareness which is the ability to become absorbed while maintaining awareness of skill execution, (3) appropriate goal setting, especially when the individual is able to define a goal and adequately prepare to achieve that goal, (4) unambiguous feedback that helps clarify goal achievement, through an ability to receive internal and/or external feedback necessary to modify performance, (5) total concentration on the task at hand through blocking extraneous thoughts and distractions, while maintaining awareness of the present moment, (6) sense of control accompanied by challenge-skill balance, (7) loss of self-consciousness, or the quieting of internal doubts and criticism, (8) time is transformed, especially when the self is no longer subjected to ongoing self-evaluation, (9) autotelic experience, or an intrinsically rewarding experience related to an autotelic personality, and (10) total flow which is the sum of all nine flow scales.

Since flow states are considered to be integrating positive experiences in performing artists (Kirchner *et al.* 2008), we hypothesized that these states would be marked by physiological autonomic regulatory capacity (CAR) and cardiac autonomic balance (CAB) (Berntson *et al.* 2008). The autonomic nervous system (ANS) controls visceral organs and the cardiovascular system. It is regarded primarily as an involuntary regulating process that synergistically interacts with the endocrine and central nervous systems (Furness 2006). Further, the parasympathetic branch of the ANS, and in particular vagal control, is considered essential for psychological and physiological well-being, since it serves to buffer stress and threat responses (Kok and Fredrickson 2010) and increases the capacity for attentional and emotional regulation (Miskovic and Schmidt 2010).

Based on this psychophysiological response, we hypothesized that performing artists who endorsed higher flow states would also experience greater CAR and CAB during performance.

METHOD

Participants

The 14 professional performing artists included two conductors, six opera singers, and six dancers. All participants had a minimum of five years of training and one year of professional performance experience. There were five males (35.7%) and nine females (64.3%) in the sample, with a mean age of 28.86 years (range=20-61 years).

Materials

Physiological measurements

During all testing, a Vivometrics LifeShirt monitoring device was worn to determine cardiac output (TCG method) and heart rate variability. Embedded in the LifeShirt are two inductive plethysmography bands or sensors. Also incorporated into the shirt is a triaxial accelerometer that detects and records movement and body posture. Three disposable self-adhesive electrodes, one above each breast and the third placed on the lower right abdomen, are inserted through the slots in the shirt. The electrodes, strain gauges, and mercury switches are plugged into a central data cable that is attached to a palm pilot computer, which participants wear around their belts. The LifeShirt requires calibration of the respiration cycle to enhance respiratory sinus arrhythmia measures (Wilhelm *et al.* 2003). Vivo Logic is a statistical software package that analyzes autonomic physiological variables.

Dispositional Flow Scale-2 (DFS-2) and Flow State Scale (FSS-2)

The DFS-2 and FSS-2 (Jackson and Eklund 2004) are self-report, 36-item instruments that assess the construct of dispositional and state flow. A five point Likert-type scale (1=never to 5=always) is used, with nine subscale scores measuring mean dimensional concepts of flow and a total mean scale score assessing a global flow construct. The flow scale scores can be divided in low agreement (1-2) which suggests that the person's experience was not substantially "flow-like" in nature, moderate level (3) indicating some endorsement of flow experiences, and high level (4-5) indicating the respondent endorsed frequent flow or always experienced flow in their selected activity. The scales have been used on individuals ranging from 16-82 years. The DFS-2 can be administered at any time to gather dispositional flow experiences regarding a specific activity; whereas state flow experiences are gathered within one hour following the performance of a given activity. There is adequate reliability, construct validity, and internal consistency in the DFS-2 and FSS-2. They are considered to be an excellent measure of the dispositional and state tendencies in flow experiences.

Procedure

In this case study design, the subjects were all professional performing artists who participated in a larger study conducted at California State University, Northridge's Exercise and Psychophysiology Laboratory in the Department of Kinesiology. After completing an informed consent, they were fitted into the

Vivometrics LifeShirt. After calibration, the artists first rested in a supine position for seven minutes, participated in a rehearsal for an upcoming public performance, and then ended the session with a post baseline rest period. Within a week, the same procedure was followed; however, they were studied during a public performance (costumes or tuxedo were worn over the LifeShirt). Each performing artist completed self-report tests to measure dispositional-state flow. The participant's ANS responses, collected in the portable computer attached to the LifeShirt, were processed through the Vivologic software system. Variables included the pre-ejection period (PEP), which is the time between depolarization of the ventricles and the actual contraction of the left ventricle. It is a method of measuring SNS activity; PEP decreases when there is increased activity from the SNS, which is associated with an increase in heart rate (Berntson *et al.* 2008). The respiratory sinus arrhythmia (RSA) is the peak-valley difference in R-R intervals and is a naturally occurring variation in heart rate (HR) that occurs during a breathing cycle, mediated by vagal nerve activity, and thus considered a PNS activity at rest (Berntson *et al.* 1997). Using spectral frequency analysis, the R-R interval data was converted into normalized high frequency (HF*n*) (0.15-0.40 Hz) domain in order to assess vagal HF-HRV. Stroke Volume (SV), breaths per minute (Br/min) and a measure for apneas/anxiety (PERCS) were also calculated. All autonomic variables were normalized to their square root values and then converted to z-scores for further analysis. The cardiac autonomic balance (CAB) and the cardiac regulatory capacity (CAR) were derived: CAB=HF*z*–(-PEP*z*) and CAR=HF*z*+(-PEP*z*) (Berntson *et al.* 2008). These derived autonomic response scores were determined for the baseline, dress, performance, and post-base rest periods. The data were entered into SPSS 18. Correlational and independent sample t-test analyses were conducted.

RESULTS

The 14 performing artists endorsed moderate to high subjective dispositional flow, ranging from frequent to always on the total flow and nine flow subscales. During the performance, their state flow responses ranged from agree to strongly agree on all flow scales. The correlation analysis indicated significant relations between CAB performance and PEP (r=0.71, p=0.004), HFn (r=0.71, p=0.004), SV (r=0.65, p=0.013), HR (r=-0.68, p=0.007), state flow scale for clear goals (r=0.62, p=0.019), and at post-base rest, state flow scale for challenge at the task at hand (r=-0.92, p=0.008). Significant relations were found between CAR performance and PEP (r=0.71, p=0.004), HFn (r=0.71, p=0.004), SV (r=0.66, p=0.013), HR (r=-0.68, p=0.007). At post-base rest, CAR was related to dispositional flow scale for transformation of time ($r=-0.99$, $p<0.001$), and dispositional autotelic flow ($r=-0.82$, $p=0.047$).

In the independent sample t-test, when the sample was split by the mean score (mean=4.0) into high and low dispositional total flow, only SV was significantly greater in individuals with high dispositional flow than in those with lower levels of dispositional flow during performance ($p=0.030$). Whereas, when the group was split based on mean total state flow, a decreased performance baseline CAB score was present in those who had high state flow ($p=0.032$). Also, an increased post-baseline rest breaths-per-minute was significantly different in those with higher levels of state flow ($p=0.004$).

The autonomic indicator for anxiety (PERCS) was evident in four of the performing artists at baseline, six individuals during dress rehearsal, six during performance, and four during post-base rest. One of these performers had a panic attack just prior to entering the stage.

DISCUSSION

Like the findings of de Manzano *et al.* (2010), our study demonstrated that the high flow group had decreased autonomic balance (CAB). Wellbeing may be experienced by increased cardiac contractility as evidenced by increased SV in the high flow state group. The self-report flow measures demonstrated that performing artists found the experience to contain moderate to high flow. Perhaps the negative correlations between both CAR and CAB and the flow elements (clear goals, transformation of time, challenges at the task at hand, and autotelic personality) amplify the subjective perception of greater flow states, especially when decreased autonomic regulation occurs in the familiar environment of a concert hall. Like the military sample studied by Morgan *et al.* (2007), the performing artists may be able to tolerate greater sympathetic activation with less autonomic balance and regulation because they are buffered from the negative effects of anxiety due to a different neurochemistry that operates effectively under conditions of high stress. Limitations of this case study include small sample size. Future studies should explore other neurochemical variables that may be related to optimal performance especially since they may mediate the decreased CAR and CAB responses found in this study.

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Thematic session:
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Preparing for the unpredictable: Identifying successful performance strategies in human-machine improvisation

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We examine the human creative process involved in performing with Mimi (Multimodal Interaction in Musical Improvisation), a system designed for human-machine music improvisation on a keyboard or other MIDI instrument. Mimi makes use of a factor oracle data structure to generate new musical material based on seed material from a human performer. Used in conjunction with a MIDI interface that gives the performer operational control over Mimi and a visualization scheme that gives the performer advance notice of Mimi's actions, this system presents opportunities and challenges for the improvising musician that differ from other improvisational contexts in significant ways. This study identifies and examines some strategies for successful performance with the system, including managing interpolations, transitions, and formal design, with implications for pedagogy and for future development of human-machine improvisation systems.

Keywords: improvisation; multimodal interaction; musical structure; improvisation strategies; human-machine interaction

In this paper, we explore some strategies employed in performances with Mimi (Multimodal Interaction in Musical Improvisation), a human-machine improvisation system that uses a visualization scheme to give performers advance notice of Mimi's actions (François *et al.* 2007, François 2009, François *et al.* in press-a).

The Mimi system is designed by François and collaborators for human-machine improvisation on a keyboard or other MIDI instrument. Mimi can take musical material provided by a musician, encode it as a factor oracle (Allauzen *et al.* 1999)—an efficient data structure first used by Assayag and Dubnov (2004) in music improvisation—and recombine the material as improvisations on the learned input. In the OMax systems by Assayag and collaborators, in addition to the improvising musician, a second performer at the computer manipulates the audio generated by the factor oracle. With Mimi, the improvising musician has full operational control of the system and can affect Mimi's learning state, improvisation state, memory, recombination rate, and playback volume through a MIDI controller. A piano roll-style visual display gives the user information on the current state of the improvisation engine, a ten-second heads-up for the music the machine will soon play, and ten seconds' review of music the user recently played together with Mimi. Figures 1-3 show screenshots from Mimi. The lower panel shows the music in Mimi's memory, with a cursor indicating the portions of music used in the recombined material; the upper panel shows a scrolling timeline of the notes to be played and recently played (notes sound when they cross the centerline). Mimi has been deployed in performances, and employed in an installation for high-level structural improvisation using four instances of Mimi (François *et al.* in press-b).

We have discovered in our research that Mimi's interactive visualizations play an important role in assisting the improvising musician in the act of planning and orchestrating a performance. WoMax (Lévy 2009), an offshoot of OMax, offers an alternative visualization scheme that displays the links created by the factor oracle. Relatively few studies have examined the human experience of performing with human-machine improvisation engines. A study by Addesi and Pachet (2005) examines the ways children interact with the Continuator (Pachet 2003), another human-machine improvisation system. Related to improvisation planning, Dubnov and Assayag (2005) proposed a method of quantifying novelty and varying the sequence and flow in OMax. Studies of performers' experiences with human-machine improvisation systems may be useful to researchers interested in better modeling of human improvisation, to music pedagogues interested in formalizing improvisation strategies, and to performers interested in pursuing new modalities for improvisation. This study examines the human creative process and some of the improvisation strategies involved in performing with Mimi.

MAIN CONTRIBUTION

Improvisations performed with human-machine systems like Mimi present their own distinct set of challenges and benefits for the human performer apart from the issues that typically arise in improvisation between human performers. In the following sections, we outline some strategies that can be used to help guide a performer in both preparing for, and playing with, a system like Mimi. These strategies were discovered over the course of several months by the first author practicing and performing with the system. Examples are taken from live performances at the People Inside Electronics concert at Boston Court Performing Arts Center in Pasadena, California, USA, on 5 June 2010, and the Ussachevsky Memorial Festival concert at Pomona College on 4 February 2011 (videos of these performances and others are viewable online at www.youtube.com/mucoaco).

Interpolations

Mimi's visualization scheme, which gives advance notice of Mimi's actions, affords the performer unique musical opportunities not ordinarily available in the course of improvisation. Improvising musicians are not normally privy to the exact details of the immediate plans of other improvisers, but with Mimi, the improviser is also able to plan a precise reaction to musical material *before* it sounds, adding a compositional element to the interactions. Thus, the performer's actions can become intertwined with Mimi's in an intimate and almost seamless way.

The performer may choose to interpolate material that leads up to a musical event, departs from an event, or links two events. Figure 1 shows one example of a musical phrase, generated by Mimi, which is then elaborated on with interpolations improvised by a human performer both before and during the phrase. The final result is a synthesis of two or more musical ideas that nonetheless can be perceived as a single phrase.

As a side effect of its data structure, Mimi may occasionally recombine two segments of material that seem disjunct in terms of range or dynamics. In cases like these the performer can "smooth out" this boundary through the interpolation of connecting material. Figure 2 shows one instance of such a boundary, where the performer plays a series of ascending chords to lead up to what would have otherwise been an abrupt chord onset.

Transitions

Transitions between different musical sections or ideas present particular challenges for the performer improvising with Mimi, since the performer has no direct control over what Mimi chooses to play, and Mimi does not respond directly to the performer as a human improviser would. For example, a human improviser would be likely to respond immediately to a change in har-

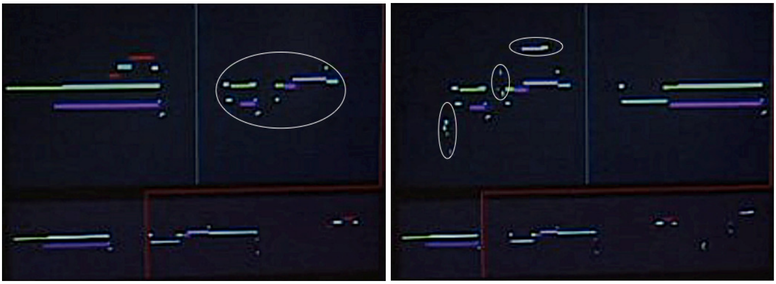

Figure 1. A musical phrase generated by Mimi before it is played (left, circled) and after it is played (right), with interpolated material by a human performer (circled).

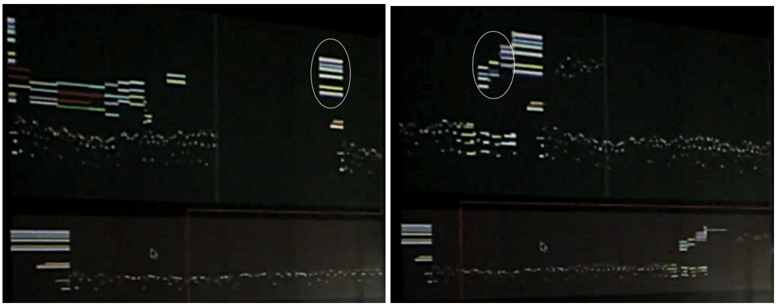

Figure 2. An abrupt chord entrance by Mimi before it is played (left, circled), and after it is played (right), with connecting chords by a human performer (circled).

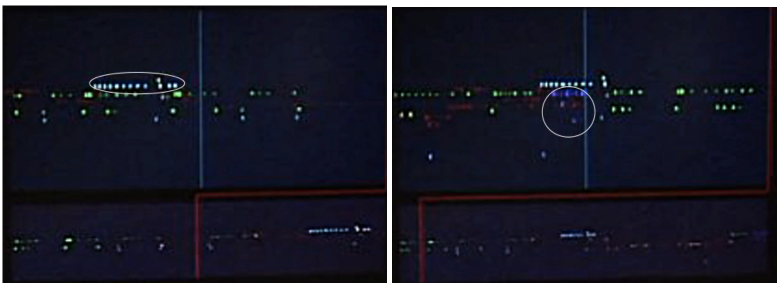

Figure 3. A new pitch introduced by the human performer (left, circled) and then reintroduced by Mimi (right), with a new harmonization by the human performer (circled). (See full color versions at www.performancescience.org.)

mony or texture, while Mimi cannot do so (though Mimi may learn from that material and perform that change at some point in the future). Therefore, the performer who wishes to incorporate musical transitions into an improvisation must use more indirect methods.

It is possible to create gradual harmonic transitions through the use of common tones or common chords. For example, the performer can at any time introduce new tones that complement the existing texture. As Mimi incorporates these new tones into its data structure, over time it may move to introduce these new tones into its musical tapestry, and the performer may move to a different sonority that incorporates those tones. By stringing several transitions of this sort together, long-term harmonic progressions can be created, if the performer so wishes. Figure 3 demonstrates one example of a common-tone transition.

Mimi's controls also give the performer the option of clearing Mimi's memory of all musical material. This is a more drastic transition strategy, but it is effective in creating large structural boundaries in an ongoing improvisation. Other issues relating to formal design of improvisations with Mimi are discussed in greater depth elsewhere (Schankler *et al.* 2011).

IMPLICATIONS

Mimi's visualization scheme can serve as a support for planning, exploring, and studying improvisation strategies. The strategies developed for successful performance with Mimi may be applicable to other systems, or to performance with other human improvisers. The visuals may also help listeners intuit the kinds of online problem solving that improvisers engage in: contrast, interpolation, and transitions. Thus, systems like Mimi may be able to play a powerful role in improvisational pedagogy, not only for the performing musician, but also for the active listener. There is a strong indication that Mimi shapes the habits of performers, but further study is needed to determine what those effects are, and if they are consistent across a large group of performers.

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Expressive performance in music: Mapping acoustic cues onto facial expressions

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The acoustic attributes conveyed in music are often ambiguous, and people vary in their sensitivity to such attributes. For this reason, expert musicians supplement performances with non-acoustic cues that support communication, including gestures and facial expressions. For musicians, facial expressions are often interpreted as emotional communication, but they reflect many other properties of music. Facial expressions provide information about phonetic information, pitch and interval size, tonality, closure, dissonance, and emotional states. How can continuous changes in facial expressions simultaneously reflect multiple dimensions of the auditory signal? In this article, I will introduce a model of music communication that explains why performers map acoustic information onto facial expressions and how these mappings influence the perceptions and experiences of music listeners.

Keywords: movement; music; emotion; perception; synchronization

Research on music performance typically focuses on the production of sound and resultant acoustic information. In a series of investigations, we have shown that music performers supplement acoustic signals of music with richly informative facial expressions and body movements. These movements not only provide phonetic information (Quinto *et al.* 2010), but they provide signals of emotion, dissonance, pitch structure, and phrasing. They also extend the time-period within which communication occurs: meaningful expressions are observed prior to and after the production of sound (Livingstone *et al.* 2009). Pre-production facial expressions may *prime* forthcoming acoustic signals for listeners, facilitating accurate perception and encoding. Post-production facial expressions may reinforce representations of structural and emotional signals. By extending the temporal window of communication, facial expressions and body movements provide an umbrella that surrounds the acoustic dimension of music, supporting and enriching auditory signals and creating a multimodal experience of music. Because rapidly changing acoustic signals are often ambiguous or difficult to decode, especially for musically untrained listeners, visual signals also function as a safety net for breakdowns in the transmission of acoustic information.

MAIN CONTRIBUTION

Recent research has revealed that the facial expressions and body movements of musicians are remarkably important for music experience. Thompson *et al.* (2008) investigated the significance of facial expressions for communicating emotion in music. Participants were presented with audio-visual presentations of two types of sung intervals: an ascending major third and an ascending minor third. Ascending major third intervals connote a positive emotion whereas minor thirds connote a negative emotion. In the congruent condition, audio-visual recordings of sung intervals were presented to participants in original form. In the incongruent condition, the video showing facial expressions accompanying the major third were re-synchronised with audio of the sung minor third, and vice versa. A group of participants judged the emotional valence of congruent and incongruent intervals. Sung major thirds were judged as more positive emotionally than sung minor thirds, as expected. However, judgments were also influenced by facial expressions. Participants judged both intervals as more positive when accompanied by facial expressions used to produce a major interval than a minor interval. The effect remained when participants were told to ignore visual information or when participants were given a challenging secondary task that involved attending to rapid sequences of numbers. These findings suggest that visual signals are integrated with auditory signals automatically in a way that does not vary with available attentional resources.

Facial expressions of emotion may be particularly informative because they extend beyond the temporal window within which acoustic signals of emotion are available. Livingstone *et al.* (2009) used motion capture or electromyography (EMG) to record the facial movements of singers. Singers were presented with audiovisual recordings of sung phrases performed with happy, sad, or neutral emotional expressions. They then imitated the recordings. Analysis of facial movements revealed reliable signals of emotion that occurred before, during, and after the production of sound. Perceivers of music, in turn, could reliably decode these visual signals of emotion (Thompson *et al.* 2009).

Facial expressions also allow listeners to assess consonance and dissonance in music. Thompson *et al.* (2005) selected twenty excerpts from audio-visually recorded performances of B. B. King playing blues guitar. In ten selections (visual condition 1), King's facial expressions and body movements conveyed musical dissonance: signals included wincing of the eyes, shaking of the upper body, and a rolling of the head. In the remaining ten selections, King's expressions were neutral (visual condition 2). Two groups of participants (n=26) were presented with the 20 excerpts and judged the level of dissonance in each. One group judged dissonance in audio-only presentations and the other judged dissonance in audio-visual presentations. Dissonance was defined as a discordant *sound* that suggested a need for resolution. For audio-only presentations, there was no significant difference between the two visual conditions in mean ratings of dissonance. That is, for the musically untrained participants in this study, the guitar sounds themselves did not predict the dissonant facial expressions made by B. B. King. For audio-visual presentations, there was a large significant difference in dissonance ratings between the two visual conditions: when guitar sounds were coupled with dissonant facial expressions and body movements, they were judged as acoustically dissonant. That is, visual signals arising from facial expressions and body movements guided acoustic judgments.

Facial expressions also carry information about musical structure. Thompson and Russo (2007) found that facial expressions reflect the size of sung melodic intervals. Participants observed silent videos of musicians singing 13 melodic intervals and judged the size of each interval the singer was imagined to be singing. Participants could discriminate intervals based on visual information alone. Facial and head movements were correlated with the size of sung intervals. More recently, Thompson *et al.* (2010) presented participants with silent video recordings of sung melodic intervals spanning 0, 6, 7, or 12 semitones. Again, interval sizes were discriminated based on visual information alone. Even when the auditory signal was made available, facial expressions still affected judgments of interval size, suggesting that visual signals are integrated with auditory information to form an overall sense of interval size. The effects of facial expressions remained when a challenging secondary task was introduced to consume attentional resources. The latter finding suggests that audio-visual *integration* of interval size information occurs independently of attention.

Facial expressions also reflect phrase structure. Ceaser *et al.* (2009) investigated whether musical performers use facial expressions to communicate a sense that a musical phrase has come to an end. Musicians hummed *Silent Night* with two endings. One version ended on the first note of the scale (doh) and conveyed a sense of closure. The other version ended on the fifth note of the scale and conveyed a lack of closure, as though the melodic phrase was unfinished. Fifteen participants were presented with video-only recordings of the hummed sequences and judged whether the (imagined) melody was closed (came to a satisfactory end) or unclosed (seemed unfinished). Accuracy was reliably above chance, indicating that participants were able to read expressions of musical closure from the facial expressions of the musicians.

IMPLICATIONS

What can explain this remarkable capacity of facial and body movement to convey multiple qualities of music, and what are the implications for understanding music cognition? Over the past decade, a body of theory and evidence has emerged concerning the cognitive-motor implications of music. This development suggests a *common-coding* framework for understanding the role of facial expressions and body movements in music perception (Prinz 1990). Specifically, it has been suggested that music has the capacity to engage cognitive-motor processes that function in human *synchronization* (Overy and Molnar-Szakacs 2009). Motor processes involved in synchronization, in turn, may be integrated with the perception of structural and emotional attributes of music. Music affords explicit synchronization in time (clapping, tapping) and pitch (singing along). However, implicit forms of synchronization may also occur in response to musical input (Overy and Molnar-Szakacs 2009). All synchronization involves motor processes, but such processes need not entail explicit or observable movements.

The facial expressions and body movements of performing musicians are explicit manifestations of the motor commands that are activated during the production of musical sounds. The qualities of those movements may reflect the degree of muscular change required in producing a musical event, and the degree of mental effort involved. Events that are unstable and poorly represented in memory require greater effort and motor commands may be less specified. Thus, singing a highly unstable pitch may lead to greater irrelevant muscular activity and apparent effort in the face than singing a highly stable pitch. The timing and duration of motor actions may also reflect the stability of mental representations of music. Action timings may be more precise for stable musical events than for unstable musical events.

Music perceivers readily decode facial movements, linking different movements to different musical events. According to Thompson and Quinto (in press), decoding is also facilitated by implicit synchronization during music listening. For example, an ascending interval may activate motor commands associated with the vocalization of that interval; these commands may then contribute to the recognition and classification of the interval.

The involvement of synchronization in music perception means that all musical events can have an emotional quality. The synchronization-feedback model proposed by Thompson and Quinto (in press) posits two processes that assist with goal-directed behavior. One is a behavior-guiding feedback process that registers errors and acts to correct the error. The second is a feedback loop that monitors discrepancy-reduction over time (i.e. monitoring the first process). The concurrent operation of both feedback systems, one controlling position and the other velocity, leads to rapid and effective synchronization to music.

Feedback from each system is experienced as emotion. Feedback from the behavior-guiding process leads to tension and prediction responses, discussed by Huron (2006). In the tension response, arousal is elicited as a target of synchronization is approached. In the prediction response, positive or negative feedback arises depending on whether synchronization with the target event is correctly aligned. Positive feedback rewards and reinforces alignment; negative feedback motivates increased effort in synchronization.

The second *monitoring* feedback process is maintained by emotional valence. When there is an increase in synchronization accuracy over time, positive feedback results. Otherwise, negative feedback results. Thus, moment-to-moment *arousal* and *reward* generated by the (first) behavior-guiding feedback process are combined with experiences of emotional *valence* generated by the (second) monitoring feedback process.

Together, the two synchronization-feedback processes continuously imbue music with emotional character, though other links between music and emotion have also been identified. Facial expressions and body movement are explicit instances of motor commands that occur not only in performers, but also in listeners. Such movements reflect musical structure, emotion, and a common bond between performers and listeners.

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Choreographic approaches to music composition for a new musical interface: The eMic

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Gesture in performance is widely acknowledged in the literature as an important element in making a performance expressive and meaningful. The body has been shown to play an important role in the production and perception of vocal performance in particular. This paper is interested in the role of gesture in creative works that seek to extend vocal performance via technology. A creative work for vocal performer, laptop computer, and a human-computer interface called the eMic (Extended Microphone Stand Interface controller) is presented as a case study to explore the relationships between movement, voice production, and musical expression. The eMic is an interface for live vocal performance that allows the singers' gestures and interactions with a sensor based microphone stand to be captured and mapped to musical parameters. The creative work discussed in this article presents a new compositional approach for the eMic by working with movement as a starting point for the composition and thus using choreographed gesture as the basis for musical structures. By foregrounding the body and movement in the creative process, the aim is to create a more visually engaging performance where the performer is able to use more effectively the body to express their musical objectives.

Keywords: eMic; gestural; voice; performance; technology

The eMic is a gestural controller for live vocal performance and electronic processing that has been in development since 2003 (Hewitt and Stevenson 2003, Hewitt 2003). The eMic is designed as a means to extend the voice in performance via electronic processing technologies. It aims to address the desire for the vocalist using amplification to increase the level of control over their own sound in the sound system and to harness the audio processing technologies once confined to the recording studio. It aims to do this in a way that is not only musically responsive to the performer, but also visually engaging for the audience. The design is discussed in Hewitt and Stevenson (2003) but in summary consists of a modified microphone stand that captures the physical gestures of the vocalist via an array of sensing devices including pressure sensors, distance sensors, tilt sensors, ribbon sensors, and a joystick microphone mount. The data captured from gestures is sent to a computer, running audio-processing software, which is used to transform the live audio signal from the microphone and/or other musical materials.

The design of the eMic draws upon the stylized and stereotypical gestures used by popular vocal performers (Hewitt and Stevenson 2003). By drawing on the existing gestural interactions that singers make with their microphone stands, the design aims to minimize the need for the vocal performer to retrain to use the device and is also a means for drawing on the performance codes of popular music performance. The extent to which these intentions are understood from an audience perspective in the works so far composed varies according to the gestural data to sound mapping relationships and how closely these relate to the familiar gesture/sound relationships found in the popular music tradition.

The eMic represents a merging of the designer's practice as a laptop artist with her experience as a pop singer, bringing the embodied, expressive and contextual aspects of the pop vocalist together with the wide-ranging musical possibilities offered by audio processing software.

The designer has created and performed numerous works for the eMic since its 2003 debut. The compositional process for these works has typically commenced at the computer, building processing patches and assigning parameters to the eMic sensors. In order to play the composition, the body needs to adapt to "playing" the instrument. This approach treats the eMic more like a traditional "instrument" that requires the human body to develop a command over it. The recent collaborative work *Idol*, discussed in this paper, offers an alternative approach to composing for the eMic where movement is the starting point for the generation of musical materials (Hewitt 2010a, 2010b). At the core of the eMic concept is a desire to integrate the body into the process of creating works for performances with voice and technology; each work with the eMic is a new experiment with this idea.

Jacques Dalcroze (writing in 1931) points to body movement as being crucial to the process of unifying the musical elements and focusing on musical expression. He says that human motion is the instrument by which human beings translate inner emotions into music (cited in Choksy *et al.* 1986, p.31).

The approach taken to creating *Idol* could be seen to be in alignment with the views of Dalcroze.

A number of studies have attempted to understand the relationship of bodily gesture in the production and perception of vocal performance. (Davidson 2001, Dibben 2010). Understanding the function and meaning of gesture in vocal performance is critical to the development of more meaningful mapping relationships with the eMic. Dibben (2010) has drawn upon the field of research around the types of gesture used in vocal performance in order to create a system to categorize the types of gestures used in vocal performance. This research will be used to help gain some insight into the mapping relationships used in *Idol*.

MAIN CONTRIBUTION

Compositional process

The process for generating the work *Idol* commenced with the choreographer experimenting with gestures and movement relative to the eMic interface. Initial ideas produced movement gestures that mimicked recognizable microphone gestures and uses. The choreographer further explored the human-computer interface as follows: (1) as a theatrical device, an object, and a prop; (2) as a dance partner, personifying the stand, treating the stand is if it were another human; and (3) as a traditional musical instrument operating as an extension to the body. The choreographic end result comprised an embodied abstraction of the various elements described above.

Choreographing for the eMic also posed some notable challenges and limitations, as follows: (1) the movement needed to remain in close proximity to the eMic to ensure the vocalist could sing into the microphone and operate the sensors; (2) the cables and leads associated with the eMic provided physical obstacles; (3) the activation of the sensors predominantly required elevated arm gestures in the coronal and sagittal planes; (4) creating movement that could produce musically effective results when coupled to the data mapping and signal processing networks designed by the composer; (5) the performer was not a professional dancer.

The choreographer developed a choreography for the work which the eMic performer was subsequently required to learn. The learned choreography was videoed and the data coming from the sensors was simultaneously recorded. The data and the video were then used as a basis for the compositional process, providing both a visual reference point and a data set representing the movement. The composer was also able to draw on an understanding of the choreography as the performer/participant in that phase.

Table 1. Movement types for mapped sections of *Idol*.

Gesture	*Frequency/17*	*%*
Depictive gestures: ideographs that track the speaker's thought process or musical flow	17/17	100
Manipulation of the body and immediate physical environment (includes "adaptor")	1/17	6
Physical movements necessary for sound production or manipulation	17/17	100
Display/dance	17/17	100

Note. This is not an analysis of the complete work, just the sections where there are mappings of movement to sound via the eMic.

Mapping choices: Correlating movement and sound

In order to understand how movement is used in the context of the musical work, an analysis has been undertaken of the sections of *Idol* where there is a mapping of gesture to sound via the eMic. The classificatory scheme adopted is from Dibben (2010), which was itself an adaptation of the scheme used by Rimé *et al.* (1991), Davidson (2001), and Clayton (2005). Where the categories were not applicable they have been excluded from the table.

There were 17 identified mappings analyzed according to movement types (see Table 1). The findings are as follows: (1) the gestures typically related to multiple categories; (2) all the gestures analyzed were involved in "playing" the eMic so all were necessary for sound production, to control the computer processing and at times the voice as well; (3) all of the movements associated with "playing" the eMic are arguably depictive gestures in that they track the musical flow and typically follow the morphology of the sound; (4) all the movements are arguably display movements in that they are choreographed and rehearsed, devised by the choreographer for their visual appeal. The fact that the choreography is based on the stylized movements found in popular music is also interesting in that the performer is thereby consciously making movements that are related to the expressive conventions of a particular musical genre. This approach to musical expression is described in Clarke (1993) as mimetic and has been identified as an important component in musical expression. Imitation offers a practical experience of music, which is directly related to the bodily involvement of the performer. Clarke says, "the apparent choreographical extravagance of expressive performance may actually be quite a practical way to control the finer details of performance by exploiting the natural tendencies and resistances of the body as a physical system" (p. 216).

Playing two instruments at once

Where there is simultaneous vocalization and "playing" of the eMic, the performance design must negotiate the demands of both of these "instruments." A complicating factor for this performance scenario is that the eMic may also be controlling processing of the live voice. The muscular programming of the voice is mediated by aural and other bodily perceptions and there is a very tightly connected feedback system between vocal production and perception. Interfering with this via heavy processing of the voice can impede the ability of a vocalist to produce the desired sound.

There are a number of strategies adopted in *Idol* to deal with these issues. Example (1): at 2 mins 49 s the performer is seen to tilt the stand and sing a high, sustained note. The tilting gesture triggers the opening of a processor that creates a spectral drone effect on the voice. The gesture that is made allows for simultaneous vocalization and activation of the eMic sensor to occur, while the processing is an extension of what the voice is already doing and so feels quite natural for the performer. Example (2): at 2 mins 7 s the performer is seen moving the joystick and squeezing the pressure sensor on the mic clip as she sings "ahhs" and breathes into the microphone. The squeezing of the mic clip sensor is opening a filter that has the parameters changed by the movement of the joystick. The gesture again allows both vocalization and manipulation of the eMic to occur simultaneously, the processing does not interfere with vocal production and the gesture follows the morphology of the resulting sound.

From the perspective of the performer, the most satisfying sections of the performance were those where the function of the gesture allowed simultaneous activation of the eMic and vocalization but was also an expressive gesture that followed the morphology of the sound. Designing mapping strategies for the eMic may also benefit from further research into acoustic performances that involve simultaneous playing and singing.

IMPLICATIONS

This case study demonstrates the importance of the integration of the body into the music making process as a means to develop expressive performance in the context of extended vocal performance using human-computer interface technology. Developing mapping strategies that combine functional and expressive gestures, has been shown to enhance the expressive performance experience for the vocalist, particularly where the voice and HCI interface are simultaneously performed elements of the performance.

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Thematic session:
Performers' health I

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Can infrared thermography be a diagnostic tool for myofascial pain in wind and string instrument players

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Wind and string instrument players are exposed to repetitive hand and arm movement, with static postures and painful and tiring positions for many hours. Behavioral and psychological factors can be positively related to musculoskeletal disorders with the presence of myofascial pain, which is characterized by localized, hypersensitive spots in palpable taut bands of muscle fibers (myofascial trigger points). This article evaluates the effectiveness of infrared thermography in distinguishing asymmetries in temperatures of anatomical structures of the cranio-cervical-mandibular complex (CCMC) in musicians with myofascial pain and examines correlations with clinical complaints.

Keywords: myofascial pain; cranio-cervical-mandibular complex thermography; wind and string players

Musicians have to deal with physical constraints due to a great amount of practice. Research has shown that the musculoskeletal system is the most frequently involved area of impairment (Morse *et al.* 2000, Rosset-Llobet *et al.* 2000). For instance, the incidence of focal dystonia may be as high as one in 200 professional musicians (Altenmüller 2000, Schuele *et al.* 2005). Pain affects a large number of musicians. It was possible to observe this in a study that involved 57 orchestras worldwide which indicated that 56% of the musicians involved suffered pain during the previous year, and 19% reported strong pains that negatively affected the quality of their performance and forced them to stop playing (James 2000).

To become elite performers, musicians must discipline themselves and practice for many years, using repetitive movements and adopting certain postures, which can promote muscles tension and fatigue. Regarding the cranio-cervical-mandibular complex (CCMC), wind and string instrumentalists have parafunctional habits during their performance. Taking into account that the masticatory muscles of the CCMC make part of a complex neuromuscular system that coordinates different tasks, with primary functions such as swallowing, or mastication and speech, we can understand that playing a violin—for example, with the chin and left angle of the mandible supporting the instrument against the chest and shoulder—originates a lateral rotation and flexion of the CCMC, with muscle hyperactivity, during a daily practice of four hours. This can lead to persistent pain or dysfunction. The musician in this situation is adopting a lateral position of the mandible, with an unbalanced pressure at the temporomandibular joints (TMJ) and with different loads and forces of the muscles of the CCMC during musical performance (Clemente *et al.* 2008). This can actually lead musicians to have temporomandibular disorders (TMD), where they can experience pain around the TMJ, in the masticatory muscles, and contiguous structures, like the shoulder or neck area.

There are studies that have shown that referred pain from the trapezius, which spreads to the head, can simulate the clinical symptoms of a TMD perceived by the patient (Svensson *et al.* 2003). Another example is the injection of hypertonic saline into the masseter muscle of healthy subjects that causes a localized and referred pain, similar to pain distribution seen in TMD patients (Svensson *et al.* 2001). This can occur if a person suffers from myofascial pain (MP), which is characterized by pain in muscle groups, associated with the presence of trigger points (TP), which are sensitive spots in a taut band of skeletal muscle that is painful on compression, being the most commonly affected regions the neck, upper back, shoulder, and lumbar region. The authors of this work intend to demonstrate that musicians due to the physical activity, which their work obliges, with the maintenance of constant muscular loads and the adopting of certain postures, can explain the existence of MP in certain parts of the CCMC, which needs an accurate diagnosis, once there are clinical signs and symptoms affecting the head and neck region, such as headache, earache, orofacial muscle pain, and shoulder stiffness that can mimic other clinical situations. The implementation of an incorrect treatment can be detrimental for the musician's career, so an innovation in our study is the use of a diagnostic tool, such as the thermographic camera associated to the physical examination of the wind and string instrument players.

METHOD

Participants

Five musicians, three wind and two string players, with a primary diagnosis of MP were included in this study. The subjects were diagnosed in the Faculty of Dentistry of the University of Porto, where informed consent was given prior to their inclusion. The musicians played the following instruments, saxophone, flute, bagpipe, violin, and double bass, and presented spontaneous pain that involved the CCMC, with tension-type headache, shoulder stiffness, and orofacial pain. None of our participants presented previous cervical or head trauma that would be a criterion for exclusion.

Materials

A diagnostic imaging test to the CCMC of the musicians was obtained with an infrared thermograpic Flir® camera A 325.

Procedure

Thermal images were obtained before the clinical examination, at a rest position, so the head and neck muscle palpation would not interfere with a potential rise on the temperature of the muscles. To understand the influence of the different instruments in the muscular activity of the CCMC, thermograms were made of the musician while playing for further interpretation. Each instrument player underwent a clinical head and neck muscle palpation, on both sides of the head, for the exploration of myofascial TP. This method involved the palpation of the following sites: temporalis, masseter, sternocleidomatoid, and trapezius muscles. The criterion for diagnosis was the presence of a palpable taut band in a skeletal muscle, presence of a hyperirritable spot within the taut band, local twitch response promoted by the snapping palpation of the taut band, and finally presence of referred pain after palpation of the TP. At this moment the musicians were asked: "If I press this muscle, do you feel any discomfort or pain locally, and in another area? If yes, please indicate the location of the referred pain." The musicians were then asked to distribute the pain pattern at a drawing of the CCMC.

RESULTS

The distribution of TP on the CCMC of the musicians was as follows. The violinist presented TP in the left trapezius and left sternocleidomastoid muscle with referred pain to the left shoulder for a persistent time, and she felt ten-

Table 1. Temperature values of the musicians' infrared thermograms.

	Trapezius muscle's temperature (°C)		
Instruments	*Left*	*Right*	*ΔT left/right (°C)*
Violin	37.7	36.1	1.6
Double bass	34.7	35.4	0.7
Transverse flute	35.4	36.2	0.8
Saxophone	35.2	36.3	1.1
Bagpipe	33.3	32.3	1.0

sion headache on the left side. The double bassist had TP on the right trapezius with referred pain to the mandible angle on the right side. The wind instrumentalists had a referred pain area affecting the right temple, shoulder, and neck in the case of the saxophone player with a TP on the right trapezius muscle, as well as the flute player whom referred pain on the right side of the neck. The bagpipe player presented a TP on the left trapezius with MP in the orofacial region, tenderness on the left side of the neck, but mainly she referred pain "behind the ear," sometimes extending to the left TMJ.

The thermograms allowed for analysis of the CCMC of each musician, mapping the desired region of the face, neck, shoulders, and back, with the concrete measurement of absolute temperature and differences between right and left sides (the JT value) of any anatomic zone of the CCMC (see Table 1). The principle distinguishing factor between normal and abnormal conditions is the difference between left and right sides (JT). One of the latest recommended thermographic evaluations, regarding the JT, considers an "abnormal" thermal pattern when JT is greater than or equal to ±0.36°C (Gratt *et al.* 1996). In our study, it was possible to observe that musicians who suffered from MP showed a different thermal pattern characterized by an asymmetry and an increase of temperature in the affected region (see Figures 1-5).

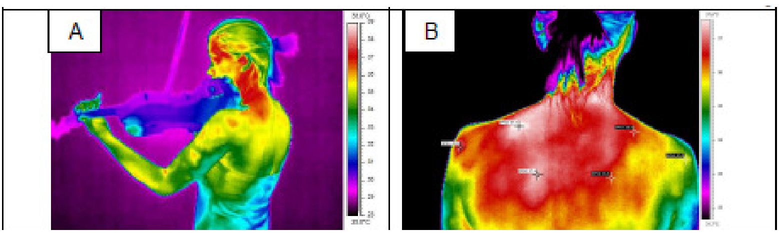

Figure 1. (A) Violinist. (B) Theromogram revealed the highest ΔT.

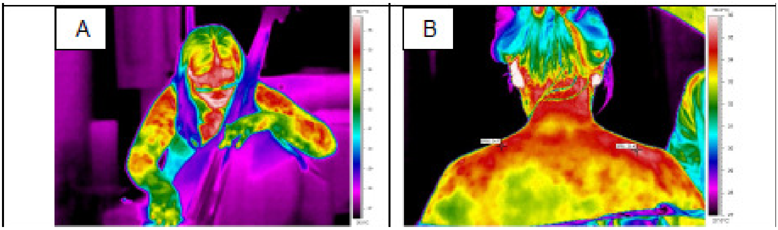

Figure 2. (A) Double bassist. (B) Asymmetric theromographic pattern revealing MP.

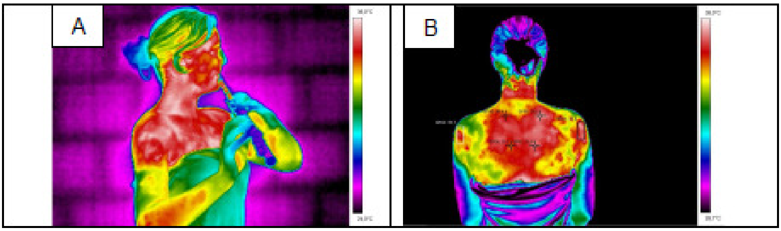

Figure 3. (A) Flutist. (B) Upper dorsal MP on right side of neck and shoulders.

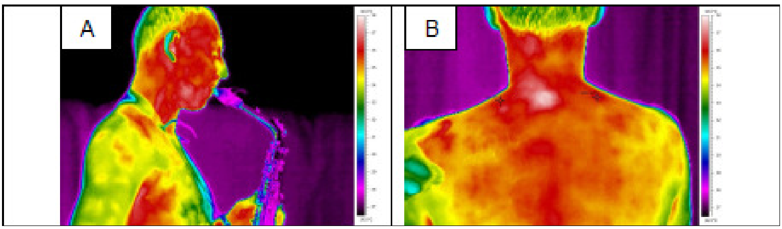

Figure 4. (A) Saxaphonist. (B) Increased temperature in trapezius symptomatic right side.

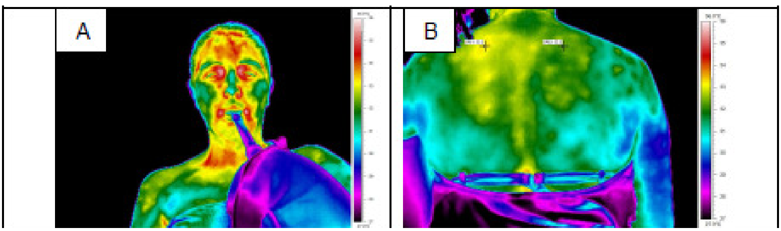

Figure 5. (A) Bagpipe player. (B) Significantly increased temperature on left trapezius. (See full color versions at www.performancescience.org.)

DISCUSSION

Biomedical engineering can "brighten the image" of performing arts medicine. This will able the study and diagnoses of neuromuscular alterations present in musicians, in order to prevent and treat musculoskeletal injuries.

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The assessment of trapezius muscle symptoms of piano players by the use of infrared thermography

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The aim of this study is to understand the correlation of trapezius muscle symptoms in piano players during their performance. The association of piano practice and the general health of a pianist, especially concerning the musculoskeletal system, and head posture has been studied in relation to orofacial anatomic zones and is presumed to have an influence on the biomechanical behavior of the cranio-cervico-mandibular complex (CCMC). Previous research has found that the act of playing piano involves a complex neuromuscular activity with hyperactivity of the masticatory muscles and the postural muscle trapezius. Thermal image assessment was made to the pianist's CCMC while the piano player was playing his/her piece.

Keywords: thermography; pianists; cranio-cervical-mandibular complex

The relationship of the postural muscles, like the trapezius and the symptoms affecting the neck of piano players, can be related to their practice by studying their head and cervical posture. An eventual altered head and cervical posture will produce specific symptoms from the cervical spine, such as tenderness of the neck and shoulder muscles. This can actually develop myofascial pain, which can be activated by chronic overload of muscles, especially in pianists, who make repetitive movements that demand precision. The trapezius is probably the muscle that most often experiences myofascial trigger points (highly sensitive muscle areas painful to palpation and produce referred pain) and is frequently overlooked as a source of temporal and cervicogenic headaches (Simons *et al.* 1999). These temporal headaches are often misdiagnosed with temporomandibular disorders (TMD) that include several clinical problems and involve the masticatory musculature and/or the temporomandibular joint (TMJ) and associated structures. It is, therefore, important to assess the symptoms of the trapezius muscle in piano players and recognize objective signs, perhaps even before they become symptomatic. The proposal of our research is in fact to evaluate the trapezius muscles of pianists by the use of an infrared thermography that measures the body's infrared radiation. The thermal images will give information on the physiopathology of pain in the CCMC of pianists during their performance. Thermal images with a difference of 0.36ºC or greater, left versus right side, are indicative of potentially clinically significant pathology, once it is possible to correlate with the anatomical distribution of pain (Gratt *et al.* 1996).

METHOD

Participants

The experiment was conducted with 7 pianists (3 female and 4 male), ranging from 18 to 27 years old, with classical piano training.

Materials

The thermography was conducted using the camera Flir® A 325. Thermal image assessment was made with a software analysis system (ThermaCAM Researcher Professional) where thermograms were being carried out for further interpretation (Figure 1).

Procedure

The pianists from the Superior School of Music, Porto, were recruited and gave informed consent. The pianists entered the piano classroom for a 15-minute period of acclimatization before capturing the thermal images, and they were given a questionnaire as a screening process for any kind of discomfort or pain regarding the CCMC. The thermal camera was mounted on a tripod and the thermograms were obtained at a dorsal view, anterior view, and lateral left and right view. The musicians also had thermograms made at the rest position before they started playing piano. Regarding the main complaints of the musicians that participated in our study, dorsal and lateral thermograms were made while playing piano in order to infer information on their symptoms in the postural muscles (Figure 1), as a response to a variety of stimuli, during the mechanical task of playing piano. Special attention was

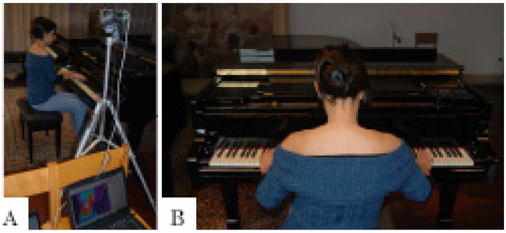

Figure 1. (A) Infrared termography with camera Flir® A 325. (B) Pianist performance.

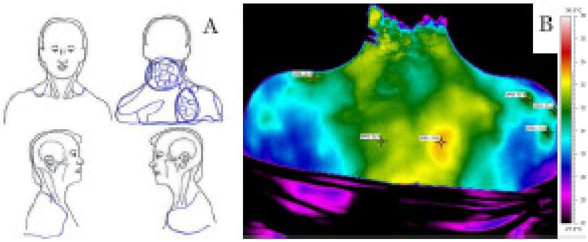

Figure 2. (A) Drawing of a pianist with trapezius muscle related pain. (B) Corresponding thermogram showing increased temperature on symptomatic upper dorsal right side. (See full color versions at www.performancescience.org.)

taken regarding the pianists clothes; the male participants played without their shirts while female participants were asked to play with a sleeveless shirt and their hair tied up. At the end, final thermograms were made to compare quantitative changes of the body temperature, corresponding to certain anatomic structures of the orofacial region.

RESULTS

Infrared thermography was demonstrated to be a reliable diagnostic tool in the study of these pianists. An asymmetric thermal pattern was found regarding the trapezius muscle, which was detected with a higher temperature in the sites where pianists had reported neck and shoulder pain. The five case reports in which the thermograms were made showed coinciding results with the presence of symptomatology of pain (Figure 2), even when the pianists had absence of complaints (Figure 3). A participant reported that "pain in the cervical region on the left side, after one hour of practice," which drew attention to ergonomics during piano performance (Figure 4).

The implementation of well being programs and micro-breaks can eventually reduce the neck and cervical pain on the right side of the pianist in Fig-

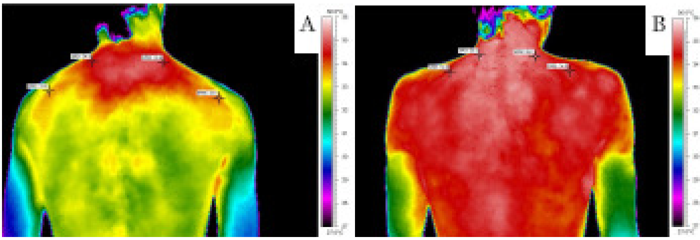

Figure 3. Thermograms of two pianists without pain. Note symmetric thermal patterns.

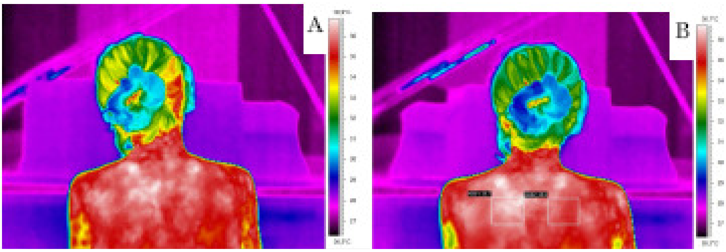

Figure 4. (A) Pianist during musical performance reading her piece. (B) The thermogram shows increased temperature on the symptomatic trapezius left side. (See full color versions at www.performancescience.org.)

ure 5. The perpetuation of pain is common in people who demonstrate symptoms of psychological distress, so it is important to associate and investigate the presence of parafunctional habits, like a pianist who clenches his/her teeth while playing. Oral parafunction was present in this pianist, since it was possible to observe that the initial temperature of the orbicular oris was of 32.4°C right side and 33.3°C left side, and after playing a classical piece, the temperature rose 1.8°C and 1.2°C, respectively (Figure 6). Understanding these factors when studying cervical and orofacial pain is of vital importance since it is consistent with a biopsychosocial model. Piano players, apart from physical requirements with muscle tension, can have stress with changes of emotions regarding the application of a job, where perfection is the limit. Social, cognitive, and behavioral factors can be present in a pianist who studies at a high level international school of arts, with work strain and hours of continuous practice (Figure 7).

It is possible to compare the thermal images of a pianist with reported muscular trapezius discomfort with the asymptomatic side. The implementation of exercise programs with the intention of improving craniocervical mus-

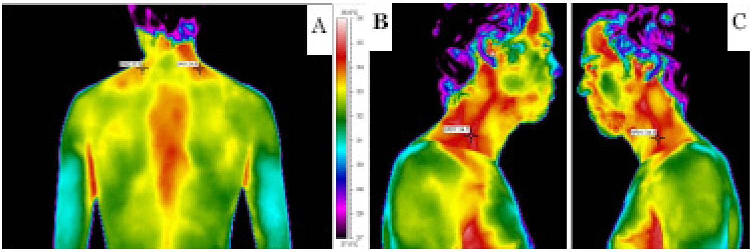

Figure 5. (A) Dorsal view highest temperature on symptomatic trapezius right (34.0ºC) compared with trapezius left (33.5ºC). (B) Thermal pattern shows that the right sterno-cleidomastoid muscle presents higher temperature which is coincident with the piano player's pain symptoms. (C) Left view.

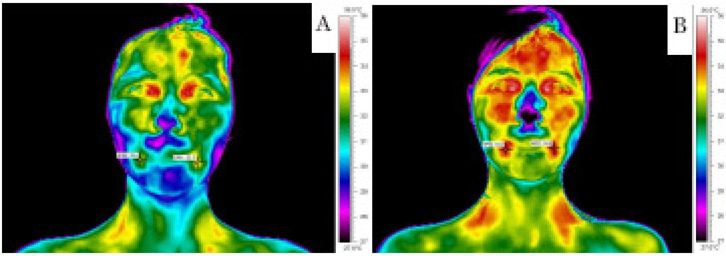

Figure 6. (A) Orofacial thermogram of pianist at rest position. (B) Pianist after playing shows higher temperature values of the orbicular oris muscle, masticatory muscles, and the sternocleidomastoid muscle.

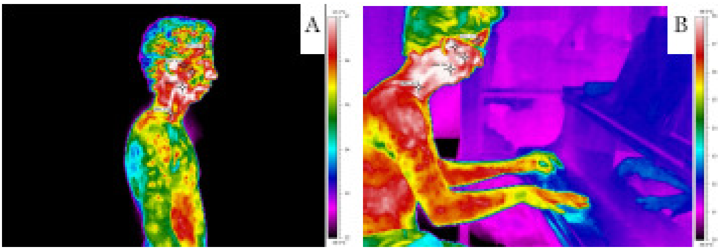

Figure 7. (A) Right lateral view at rest position with masseter muscle (37.2ºC), sterno-cleidomastoid muscle (37.2ºC), temporalis anterior muscle (35.9ºC). (B) Right lateral view during performance with masseter muscle (38.4ºC), sternocleidomastoid muscle (38.2ºC), temporalis anterior muscle (37.7ºC). (See full color versions at www.performancescience.org.)

cular equilibrium and a correct focus on warm-up techniques should be considered as important factors regarding the general health of a pianist.

DISCUSSION

Thermography can be effective in diagnosing muscular pain, providing a relatively inexpensive and non-invasive imaging diagnostic tool. Future studies should be made with a larger sample, where thermography can be an aid in warm-up techniques, by monitoring the body surface temperature of pianists through time.

Acknowledgments

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Head and scapular posture in flutists: A pilot controlled study

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Instrumental practice which requires asymmetrical postures might, in the long term, potentiate musculoskeletal disorders and lead to pain. This, in turn, may have a negative impact on musical performance quality. Thus, the assessment of postural deviations among musicians is of the outmost importance in instrumental pedagogy. This study aims to compare the head and scapular posture of flutists with different levels of expertise and a control group of singers. Results suggest that flutists have a significantly more forward head posture than singers. No significant differences were found for any other head or scapular posture measurement. Contrary to what was hypothesized, years of instrumental practice did not contribute to a more asymmetrical posture.

Keywords: head posture; scapular posture; instrumental practice; flutists; singers

Playing an instrument requires hours of daily practice, repetitive movements, and asymmetrical positions of the body and high levels of mental concentration (Wynn Parry 2004). As a result, the instrumentalists' body often suffers adaptations. Some of these are positive, such as neuroplasticity, larger volume of grey matter and further development of visual and auditory cortex (Gaser and Schlaug 2003). However, others may impact negatively on the performer, such as the development of body asymmetries due to asymmetrical postures required to play certain instruments (Brandfonbrener 2000).

Flutists need to hold the instrument horizontally at the level of the right shoulder. This posture tends to rotate the waist and misalign the shoulders moving the left shoulder into adduction and flexion and the right shoulder into abduction and extension (Frank and Mühlen 2007). In addition, the head is side-flexed to the right and rotated to the left (Dommerholt 2000).

These asymmetrical postures require an increase in muscle activity of different muscle groups, force the flutist to depend on phasic shoulder muscles rather than postural tonic muscles and may lead to pain and fatigue (Dommerholt 2000). As developing expertise to play an instrument requires many hours of daily practice during several years, instruments who require asymmetrical postures may increase the risk of musculoskeletal injuries (Edling and Wiklund 2009). Thus, asymmetric body posture to play the flute may constitute one of the challenges that a flutist needs to overcome, as this may become more prominent with years of instrumental practice, leading to the development of playing-related pain.

This study aims to investigate (1) whether asymmetries in the upper body of flutists exist, (2) if they exist, whether they are more evident than for musicians who do not require asymmetric body postures (e.g. singers), and (3) whether head and scapular postures change with years of flute practice.

METHOD

Participants

Participants included flutists with different levels of expertise and an age- and expertise-matched group of singers. Flutists were divided into 2 groups: those with less than 10 years of instrumental practice (group 1; n=7) and those with more than 10 years of instrumental practice (group 2; n=10). As singing normally does not require asymmetric body postures, singers were chosen as controls (group 3; n=9).

Materials

The variables assessed in this study were head and scapular posture. Head posture was assessed through the measurement of angles between anatomical landmarks using a universal goniometer. A goniometer is made of two mobile arms fixed at a central point named the axis. A bubble level was used to maintain one of the goniometer's arm aligned with the horizontal line of reference. The posture of both the right and left scapulas was measured using measuring tape.

Procedure

Ethical approval to carry out this study was given by the Ethics Committee of the Hospital Infant D. Pedro, Aveiro.

Participants were recruited among flutists and singers from the Department of Communication and Art at the University of Aveiro. All participants received information sheets explaining the study and provided written consent. Data was collected once for each participant and included measures of head and scapular posture.

Head posture was characterized by measuring three anatomic head angles: (1) the angle formed by the line connecting C7 to the tragus of the ear and the horizontal (this measures head position relative to the trunk, when the gaze is in horizontal or in a natural head posture; decreasing values indicate a more forward head posture), (2) the angle formed by the line connecting the tragus of the ear to the canthus of the eye and the horizontal (this allows measures of the position of the upper cervical spine, with increasing values being indicative of a more extended head), and (3) the angle formed by the line connecting the inferior margins of both ears and the horizontal, which provides information relative to side flexion. These angles were chosen because they had been used in previous studies to enable reliable comparisons (ICC≥0.71) (Silva *et al.* 2009). All measurements were repeated three times.

To assess the posture of the right and left scapulas, a similar protocol to Sobush *et al.* (1996) was followed—i.e. the participant remained in a relaxed position and four distances were measured: (1) the perpendicular distance between the superior angle of the scapula and the vertebral column, (2) the perpendicular distance between the inferior angle of the scapula and the vertebral column, (3) the perpendicular distance between the medial aspect of the root of the scapula and the vertebral column, and (4) the height difference between both scapulas. Before measuring these distances the anatomical points of reference in the scapula and a vertical line identifying the column were marked.

The statistical analysis was carried out using SPSS for Windows version 18 and Microsoft Excel 2007.

RESULTS

There were 6 female and 1 male flutists in group 1 and 7 female and 3 male flutists in group 2. This distribution reflects the fewer male flutists at the University of Aveiro. Thus, the control group was matched with groups 1 and 2 not only for age and level of expertise, but also for sex distribution. To maintain this balance, 7 female and 2 two male singers were selected for the control group.

The average ages of participants for each group were 19 years (range=17-21) for group 1; 29 years (range=23-55) for group 2; and 26 years (range=18-46) for group 3.

Table 1. Mean (±SD) differences between measurements for the left and right scapula (in cm).

	Superior angle	*Root of the spine*	*Inferior angle*	*Elevation*
Group 1	1.50 (±1.04)	1.07 (±0.52)	0.70 (±0.50)	1.35 (±1.35)
Group 2	1.40 (±1.29)	0.59 (±0.70)	0.67 (±0.54)	0.80 (±0.57)
Group 3	0.73 (±0.43)	0.79 (±0.47)	0.67 (±0.70)	1.23 (±0.73)

Table 2. Mean (±SD) angular values for head posture measurements (in degrees).

	Forward head posture	*Head extension*	*Head side-flexion*
Group 1	46.87 (±3.27)	20.30 (±4.09)	3.27 (±1.30)
Group 2	54.87 (±5.16)	22.98 (±5.38)	2.77 (±2.38)
Group 3	51.04 (±4.93)	19.06 (±5.14)	1.13 (±1.29)

Results suggested that asymmetries between right and left scapula in flutists tended to be higher when compared with singers (see Table 1); however, these differences were not statistically significant ($p>0.05$). Similarly, flutists seemed to have a more forward, extended, and side-flexed head than singers (see Table 2); however, this difference was statistically significant only for forward head posture ($p=0.04$), indicating a more forward head posture in flutists. Opposite to what was hypothesized, years of practice did not seem to contribute to poorer scapular or head postures ($p>0.05$).

DISCUSSION

Flutists showed a tendency for a more asymmetric scapular posture and a more forward head posture when compared with singers. Results thus support previous observations that one of the most common postural habits in musicians is a forward head posture (Dommerholt 2004). This, in the long term, might contribute to further problems, such as the development of pain, occlusal disturbances and poor breathing efficiency (Dommerholt 2004). Thus, it would be important to assess further this matter and investigate the extent to which different instrumentalists are affected by these postural deviations.

Our results suggest that years of flute practice do not seem to contribute to poorer postures. It is possible that over the years flutists learn practice strategies aiming to compensate for body asymmetries and postural deviations. However, these results need to be further investigated in future studies with bigger sample sizes. Currently, we are developing this study to assess pain intensity related to these postures, as well as to investigate whether flutists develop coping strategies which potentially reduce the negative impacts of body postures assumed during instrumental practice.

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Thematic session:
Movement and embodied knowledge I

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"What am I doing?" Adolescent males and their stories in dance

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The majority of studies on male dancers/students are either from a physical education perspective or from the perspective of established male dancers. Overall, there is an absence of in-depth scholarly study between post-primary school-age boys and pre-professional level dancers (age 13 to 18 years). This study attempts to bridge the gap. The researcher took an ethnographical approach by following more than 50 young boys with little or no dance experience for more than a year. Through numerous interviews, classroom observations, and performances, the researcher reveals the different stages that these young males experience while taking dance. The researcher also randomly selected a few artifacts that the adolescent male dance students created for their D*ancer in Me* assignment as a way to understand how and why they chose to take dance and continued to further participate in dance although they did not enjoy it at the initial stage. This article unveils adolescent male dance students' stories—their thoughts, their successes, and how they have overcome all the challenges. The active involvement in dance as shown by these high school male students is an example of how dance can become accessible and attainable to male adolescents.

Keywords: dance; education; gender; males; embodiment

Despite the positive and encouraging research studies showing clear advantages for males to be in dance when it comes to job opportunity and promotion (Benoit 2000, Berger 2003, Burt 1998, Grillo 1995, Rose 2006), most boys deliberately choose not to dance. A recent study shows that the ratio of girls versus boys who choose dance as an extracurricular activity is 31 to 1.7 (Cameron and Bartel 2008, p. 37). American researcher Benoit (2000) went even further by suggesting that in most cases, male dance students represent less than one percent of all dance classes (p. 1).

In general, adolescent male dance students are usually the forgotten group among popular culture and the academic field. However, in many cases, the adolescent period is considered to be the stage from which professional dancers take form. Some reputable male dancers including José Limón, Paul Taylor, and Alvin Ailey, who were considered as modern dance pioneers and choreographers in the USA, started dancing in their late adolescent years and all became hugely successful figures in American modern dance (Ailey and Bailey 1995, Reich 2005, Taylor 1987).

In prevalent culture, dance seems to have become a more acceptable and enjoyable activity among males as *So You Think You Can Dance* and *Dancing with the Stars* dominate the entertainment world by showcasing both men and women competing in solos, duets, or in group dance forms. Nonetheless, by looking more closely, it is not difficult to see that most of the contestants, if not all, are in their prime time as dancers, age 18-25 years. Many are either professional dancers or mature students attending performing arts colleges or universities, but how did they get there? Not much is known about these dancers in their development into professionals. Overall, the absence of in-depth inquiry between post-primary school-age boys and pre-professional level dancers (age 13 to 18 years) creates a void, which when researched may unveil the keys to unlock the door for more adolescent males to enter dance.

The aim of this study was to locate those few adolescent males who were taking dance and to unveil the realities of being male dance students by focusing on their dance experience in the high school years. With a better understanding of young males in dance, I sincerely hope that we, as educators, will be able to promote dance among male adolescents in and out of schools and to find strategies to keep them in dance.

METHOD

Participants

Twelve students were randomly chosen, among 55 adolescent male dance students, for this research. Both mix-gender and all-boys dance classes were used for observing and videoing purposes. Meanwhile in-depth interviews were carried out with research participants during the study.

Materials

I generated a set of questions to gain a deeper understanding of the students' dance experience in high school. These questions included: What is it like to be an adolescent male dance student in today's school? How do male adolescents see themselves before taking dance, while dancing, and after having taken dance? What works in this particular teaching and learning environment in which boys are minorities compared with girls? What role do teachers, principals, and parents play? What are the standards and expectations in teaching dance to boys? I conducted interviews and surveys and documented students' changes of attitude toward dance over time. A *Dancer and Me* assignment was included to further depict adolescent male dance students' understanding of dance. Selected assignments were also collected and analyzed to comprehend the understanding of male adolescents toward dance. Students' works were seen as artifacts to understand how they applied their physical embodiment (dance) into their analytical, reflective, and critical thinking in theoretical ways (mind). I also videoed both the all-boys dance class and the mixed gender dance classes. Relevant literature and curriculum materials were used to ensure that this research was pedagogical and the findings beneficial.

Procedure

The research process was an inductive, grounded, and exploratory format. I spent a year observing boys in dance classes, rehearsals, and performances. Three interviews were conducted on separate occasions using a semi-structured interview guide. These interviews provided male dance students with an opportunity to express and to tell their stories in dance. The first interviews took place before classroom observations began. This is the time when new students (Grade 9) begin dance and older students resume dance training. More interview questions were raised when the first semester was drawing to an end. The last interviews were conducted in June after they had just completed their year-end dance performance and were working toward their culminating activity. Each interview lasted approximately 15 minutes, and all took place on school premises during after-school hours or at the convenience of those being interviewed.

During the research period, the dance classes were videoed to capture the flow of a class, performance, and interaction between students and dance teachers. It also facilitated and made this research come alive.

RESULTS

Through numerous interviews, dance class observations (both all-boys dance and mix-gendered dance classes), and rehearsal and performance reviews, I not only understood why these boys took dance but I also noticed a trend—

their level of acceptance of dance seem to fall into three stages: denial (partial acceptance), acceptance (full and self), and excel (beyond acceptance).

Stage one: Denial (partial acceptance)

Adolescent male dance students at this stage received mixed responses from friends and expressed partial acceptance of dance. Their friends, some of whom were taking dance or had taken dance in the past, showed some support or acceptance toward their involvement in dance. Among their non-dance friends, there were misunderstandings and bias. When they talked about their dance experience to friends outside school, they received remarks such as "Don't you have physical education?" Here is an account of a dance student about a somewhat stereotypical comment on dance, which might represent the majority of people's view on boys in dance:

> …my old friends from my former school (catholic school) respond very differently. They think that only girls should dance. They accept skating because they can relate it to hockey, which is a man thing. They would say to me like: "Wow, dance, that's weird."

The visual interpretation of the first dance experience in Figure 1 also captures this first stage of denial or partial acceptance of dance that most young male dancers experienced.

Stage two: Acceptance

At this stage, adolescent male dance students justify their taking dance as enjoyment, having witnessed and experienced positive outcomes both physically and mentally. Having benefited from taking dance, they simply want to experience again what they enjoy the most both on stage and in studio. They were confident in dance, not necessarily because they were good dancers, but they valued what they did in class and they enjoyed the time while dancing. These students thrived in a comfortable environment in which they were supported and accepted and dance seemed to be a norm to them and those around them. The perception of being a male dance student developed:

> …none of my friends [boys] has done anything like that [dance] before. They think it is really neat to know how to dance. They know that not many boys are in dance and I am one of the few. They are happy that they have a male dancer friend.

Figure 1. What am I doing? A grade 10 student's artwork on his first dance experience.

Stage three: Excel/beyond acceptance

At this stage, students saw themselves as dancers or pre-professional candidates in dance. They worked hard in dance classes and some even took extra training outside the school. They moved beyond accepting dance to loving the physical challenge and artistic approach in and through dance. Students at this stage usually consisted of senior students, who considered themselves as role models to junior students. They were well-supported by their family and friends for taking dance. They were eager to share their positive experience in dance with others, inspiring other male students to sign up and take dance in high school:

> …everyone [at this high school] around me thinks it is a cool idea to take dance. They are really supportive and saw me as big brothers in dance. …one of my friends did not take dance at the beginning but saw the amount of work I put into dance. He switched to dance and since then, have enjoyed it quite a bit. There is no downside if everyone does it [dance]. But if only one person does it, he can be singled out.

DISCUSSION

While examining the academic world and popular culture, it is not difficult to see that dance still remains as a less explored domain for the majority of male adolescents. In addition to the present knowledge of why they do not dance and why they should dance, we, dance educators and theorists, need to become more informed about those adolescents who do choose to dance and to understand better their stories—their thoughts, their successes, and how they have overcome all the challenges. I see this study as going beyond seeking adolescent males' views on dance to looking at their views on the dance curriculum and the subsequent implications for reform in dance pedagogy. In this way, we learn about the educational values held by these adolescent males, which provide practical and reliable indicators for dance class instruction, curriculum theorizing, and teacher development. Through this study, we can begin to better understand adolescent male dancers—their needs, fears, attitudes, and their expectations. With further studies and more discussion on adolescent male dance students, we hope to encourage more adolescent males to participate in dance and to stay in dance.

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Re-inventing the body image: A pilot project in a boys' secondary school

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In this pilot study we looked to gather evidence on whether providing children with simple routines which enable them to become aware of the major muscles of posture can affect how they incorporate ideas about posture into their daily lives including any music practice. Our conclusions indicate this simple tuition offered in a school environment can be the precursor of a useful tool for the future. Our results could form the base for a more comprehensive longitudinal study on how and what type of physiological awareness courses can offer help and improvement in postural mal-habits for children, teenagers, and adults during every day life but also during performing.

Keywords: posture; body schema; body image; children; ISSTIP

Uniquely among species the human being can gain demonstrable access to the pre-noetic. Is this a boon? Or is the ability to meddle with nature a Pandora's Box? Its role in evolutionary advancement is yet to become evident. Its *dis*advantages are all around us: jutting heads, stooped shoulders, pelvic tilts, poor feet placements, not to mention the pains that often come with these.

The body never really loses its "design sense" as Pete Egoscue (1992) calls it, but all too frequently that sense, the "body schema" (Gallagher 2005), gets obscured by data from another source: our body image. Simple afferent awareness of which muscle groups contribute to a healthy posture may help tip the balance in the schema's favor. Schema and image are not so clear cut in most of the psychological literature. How we think a motion is carried out as opposed to how it is *actually* carried out usually diverge. This dissonance is not just the cause of much illness; it also restricts the artfulness of how we "do"—especially how we apply ourselves in musical performance.

There is only one similar study in the literature. This was carried out by Jack Vinten Fenton (1973) and reported in his book *Choice of Habit*. His first project involved individual work in a primary school with six children as well as physical education classwork by withdrawing small groups. Unfortunately the reporting only takes up five pages of his book; though there are some excellent photographs. Fenton underlines the quasi-contagious acquisition of posture:

> That much posture is acquired by *deliberate and subconscious imitation* was clearly evident in the group and class teaching at Woodhatch for even children who received little or no tuition showed an improvement in postural habits, which could only have been acquired by some sort of imitation (pp. 63-64).

In the second part of his study (taking up only 4 pages), he introduced Alexander Technique to over 200 mixed secondary pupils (aged 12-13 years) over the period of an entire term. To facilitate this, he also recruited a specialist Alexander teacher for two complete days per week. One teacher commented "it seems to me that the major advantage of the project is that it made children *aware* of posture. Previously for them it did not exist" (p. 70). A very apposite observation for the present paper.

METHOD

Participants

One hundred and fifty boys, aged 11-12 years, comprising nearly the entire first year of a boys' secondary school in seven classes of between 20 and 30 took part in the study.

Materials

Sessions took place in a large cleared space (drama room) using a PC with projector and exercise mats. The posture routines were adapted from *Posture in the Growing Child* (Hampshire Education Committee 1956), *Good Posture in the Little Child* (United States Children's Bureau 1933) and *8 Steps to a Pain-Free Back* (Gokhale 2008). Two short paper questionnaires were handed to subjects along with a one-page homework sheet and a one-page information sheet for parents.

Procedure

Each class had two 50-minute sessions over two weeks instead of their usual drama session. The experimenter was introduced at the beginning of the first session as a teacher who was to guide them through some work related to drama techniques for the next two sessions. The procedure developed over 11 consecutive tasks.

Task one: Each initial session started with the experimenter requesting pupils to stand, without fidgeting and with arms at the side. While pupils were standing, the experimenter explained they were to stand for three minutes and during that time they were to notice anywhere they felt discomfort (school children often complain if asked to stand for even the shortest of periods).

Task two: After three minutes, students were asked to sit and complete a short anonymous questionnaire. There followed a short slide presentation on the anatomy of the pelvis illustrating how its alignment affects good posture especially in its role of maintaining a healthy lumbar curve (Rodman 2011a). This was augmented by a pass around of a life size anatomical model with shortened femora. For tasks three and four, two pupils were chosen at random to demonstrate the pair work.

Task three: In groups of two using an exercise mat, one pupil lay supine with knees bent heels touching buttocks and was instructed to "push his belly button into the mat." The attendant pupil felt with his hand that there was no space between the mat and lumbar curve. If there was they were instructed to inform their partner of this until the lumbar spine was flat on the mat. The supine student then gently unbent at the knee to lower one leg onto the mat keeping the back flat, meanwhile concentrating on how the movement affected the muscle sensation just below the navel. They repeated this with each leg until a confident awareness of where the lower abdominal muscle lay and also how the sensation of it increases as the leg was lowered. Partners then swapped roles.

Task four: Again in pairs, one pupil stood back against a wall with buttocks, shoulder blades, and head touching, the heels one or two inches away. His partner noted the gap between the lumbar spine and wall with his hand. The pupil against the wall was then instructed to "push his belly button into the wall." Once done, his partner checked there was no longer a gap between wall and lumbar spine. If there was still a gap he informed his partner until the back was flat against the wall. The pupil was then instructed to take one step away from the wall while "holding on" to the tension brought on by the back flattening. He was informed he should now be stood up with the sensation he was just about to sit down (posterior tilt) and was reminded this is the awareness of his pelvis "harnessed" by the iliofemoral ligament to the femoral heads. The session ended with slides of subjects correcting poor pelvic tilts and distribution of the Parent Information Sheet.

Task five: Task five began the second 50-minute session. Here pupils were shown a number of slides. A simple single shoulder roll routine (Gokhale 2008) was taught to the group.

Task six: With shoulders held in position, students were instructed to protract followed by retract their necks several times (Rodman 2011b). This was described as "doing the chicken neck." They were then instructed to hold the position where the chin tucks in (neck extension).

Task seven: Still in position from task five and six, pupils were instructed to release any tension in their chest. This was described as "a small belly flops over your belt/trouser waistline."

Task eight: Task eight put the two sessions' learning together. Introduced as a six point posture plan: feet, knees, pelvis, shoulders, head/neck, and chest.

Task nine: As a final fun "fill," the class arranged the chairs in two rows, ten feet apart, the students performed a catwalk to a sound track.

Task ten: Homework sheets were handed out to be completed in a week's time and handed to their drama teacher.

Task eleven: Some weeks later pupils were requested to take five to ten minutes of tutor registration time to complete an anonymous final questionnaire.

RESULTS

The first questionnaire (see Figure 1, left and center panels) was answered immediately after three minutes of standing with arms at the side. Rather than a future reference, its real aim was to get pupils to start thinking about a subject they would probably have never considered before. It is noticeable in Figure 1 (right panel) that the lower down the body, the more discomfort felt.

Figure 2 (left panel) shows how well pupils had taken on board the posture work. How wise had they become to posture matters? The final anonymous questionnaire (see Figure 2, center and right panels) was handed out to all participants on the final week of term. Some had had their session at the beginning of the term (approximately 3 months before). Some had only finished. It is interesting to note that 66% wanted no further lesson, yet only 13% could not see themselves using their new knowledge. The 66% "not at all" make up the entire cohort of these.

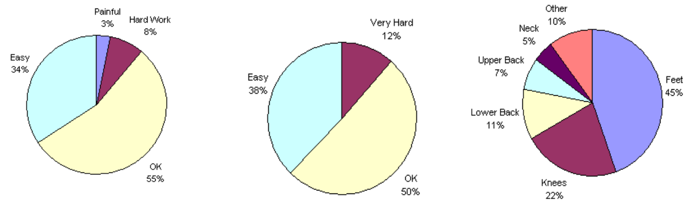

Figure 1. Left panel: What did standing up feel like? Center panel: How hard was it to stand still? Right panel: What got the most tired?

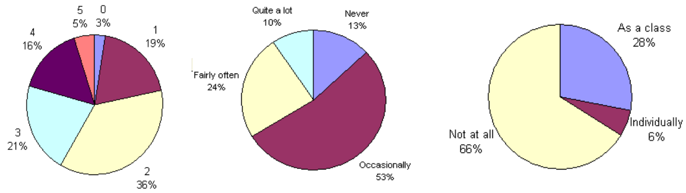

Figure 2. Left panel: Posture points (max. 6) mentioned in homework. Center panel: Can you see yourself using any of your posture knowledge in the future? Right panel: Would you be interested in more sessions? (See full color versions at www.performance science.org.)

There was an excellent response to question 1 of the final questionnaire. Many pupils identified one or more of the posture points as important in standing (i.e. knees unlocked). There were a few comments, both positive and negative.

DISCUSSION

This project set out to establish whether working through simple posture routines in two 50-minute sessions could affect children's awareness of posture. The data from the homework and final questionnaire show clearly that some information had been inculcated. I would surmise one reason this was achieved so quickly was its instant relevance to the pupils' lives: themselves, pupils find their favorite subject. It was beyond the scope of this project to rectify in anyway unhealthy use of the body, though for those whose interest was piqued, this may have happened.

As an instrumental teacher, it is very obvious how the knowledge these pupils have gained will aid me to deliver healthy performance practice. When playing/learning an instrument, posture—how we hold the instrument—is always uppermost in our awareness. Pupils bringing this knowledge with them will be quite advantaged. I would like to think the pupils, if reminded by their teacher, can and will use their knowledge in all manner of activities in school from writing/reading in English, dance/athletics in physical education, or tool use in design and technology.

That the pilot has affected the pupils' perception of posture and given them some knowledge of value is without question. It is envisaged that refresher activities for one lesson per year up to age 14 would consolidate this knowledge and lead to healthier body use. A further longitudinal study is required to ascertain whether or not a program of such brevity could, in the long run, be effective in securing good postural habits amongst this cohort.

Acknowledgments

I would like to thank Hara Trouli, Chair of ISSTP, for her direction, assistance, and guidance; my union, NASWT, and my school, Ernest Bevin, for generously part-funding this project; and the school's teachers for their generous cooperation. Finally, I would like to thank the pupils of Ernest Bevin Sports College for their mature and always lively and interesting contribution.

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Dances of Cape Verde: Tempo, preferences, and entrainment

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Dance is a complex activity, and it gets more difficult when you have to dance with someone. The dancer must be in time with music and in time with the other or others. The entrainment concept has an important role in this case. Why do we prefer to dance with a specific dancer over another? In this study, we sought to find out who dancers prefer to dance with and the reasons for that choice. The studied variables were experience, morphological characteristics, and spontaneous motor tempo. The results indicate the importance of dance experience in preferences, a lack of influence of anthropometric characteristics in these choices, and a tendency to choose partners with a higher spontaneous motor tempo.

Keywords: dance; entrainment; preferences; spontaneous motor tempo; walking

The ability to entrain is observable in many occasions of human life, for example to adjust a speech rhythm in a conversation or to "keep pace" while walking with someone. In dance activities this capacity is crucial. Dance can be considered a complex motor activity as it involves dynamic processes of synchronization to sound stimuli and adaptation of the motor behavior of a dancer. The dancer must be in time with music and in time with the other (couple dancing) or others (group dancing). In dance history, there are some couples that appeared to have a perfect synchronization of movement—for example, Rudolf Nureyev and Margot Fonteyn.

From the point of view of dance training, this is an extremely important capacity for success. In sport-dance (ballroom competition, for example), one of the reasons for success seems to be the right choice of the pair. There is a long literature on the tradition of entrainment and synchronization of movements (Clayton *et al.* 2004, Styns *et al.* 2007) with light or sound stimuli but using tasks such as tapping (Repp 2005) or clapping. Dancing involves more complex motor tasks and introduces new methodological problems.

Nevertheless, this capacity is little studied in dance, and maybe because of this, it is not incorporated into traditional dance training programs. Côté-Laurence (2000) suggested that understanding the processing of rhythmic elements and the control of synchronization may facilitate ballet training.

In my opinion, there are the two types of issues responsible for the lack of studies on dance entrainment: *conceptual* as it exists in the literature and in practice some confusion about what motor rhythm is and its relationship with the musical rhythm, and *methodological* that relates to the difficulty to quantify the variables related to human movement in general and in dance in particular.

In this study, I applied a new methodology that takes into account the characteristics of the dance movement to study specific dance tasks (ecological approach). The problem was to identify the motor rhythm of each dancer and then know whether this feature (preferred tempo) is influential in choosing a partner to interact with in the different dances. As a starting point, I wanted to know if morphological characteristics (length of lower limb, for example) had some influence in the choices, in addition to experience in dance and performance tempo.

METHOD

Participants

The sample consisted of 14 (7 female, 7 male) professionals of traditional dances from the islands of Cape Verde, which performed five shows a week in one of the hotels on the Sal Island. The average age was 24.85±4.07, with a minimum of 20 and a maximum of 31 years. The average weight was 61.88± 6.05 kg, and the weight ranged from 49.4-71.9 kg. The average height was 168.51±5.86 cm, with a minimum of 158.6 and a maximum of 178.4 cm. For the Body Mass Index (BMI), the average value was 21.77±1.55 with 19.2 and 24.5 for minimum and maximum values, respectively. The average years of experience in dance was 5.35± 3.95. Half of the group had over (15, 11, 8, 8, 5, 5, 5) and the other under (4, 4, 3, 3, 2, 1, 1) five years of experience. The older dancers had worked in the institution for seven years, and the youngest had been integrated into the group since then. The traditional couple dances are part of their daily lives and interactions between different members of the team are common.

Materials

For this study, I used a metronome and a camera. Anthropometric measurements were made using the following instruments: a weighing scale (SECA), an anthropometric tape (Rosscraft), a skinfolder caliper, and a segmometer.

Procedure

Collections were held in the conference room of the hotel. Anthropometric measurements and body composition followed the protocol of ISAK (International Society for the Advancement of Kinanthropometry). In the first part of the study, participants were asked to dance each of the four dances of Cape Verde (*Koladera*, *Funaná*, *Mazurka*, and *Kolá Sanjon*) in front of a camera without any sound or visual stimulus. These recordings were used to characterize the real spontaneous motor tempo (rSMT) (see Eerola *et al.* 2006).

I then played several tempos on the metronome and each participant chose the value that was the most comfortable for him/her in the various dances. This part of the study was also recorded on video and was used to characterize the perceptive spontaneous motor tempo (pSMT). These first collections were realized individually with only the subject and the researcher in the room.

In a second phase, with the whole group in the room, everyone was asked to dance each of the four dances with everyone else. This task was repeated on three different days. Interviews were conducted on a different day to find out with whom the dancers preferred to dance.

The most comfortable or preferred walking tempo was also asked and measured. Each dancer took the digital metronome while they were walking home and adjusted the metronome to the rhythm of his/her walk.

Three observers identified the tempo used by each dancer by watching the collected images and adjusting the metronome to it. One minute of each dance was recorded so that the dancers had time to stabilize the structure of the performed steps (*self-entrainment*, see Clayton *et al.* 2004). It was found that 45 seconds was enough to obtain a stabilized structure of the supports that allow expression in beats per minute (bpm). I repeated the observations on three different days (intra-observer agreement), and these data were confirmed by two different observers (inter-observer agreement).

RESULTS

Regarding preferences, I found that no one ever chose the same pair for the four dances. Three subjects chose two different people, nine chose three, and

Table 1. Real spontaneous motor tempo (rSMT), without metronome, and tempo preferred for walking.

	Koladera	*Funaná*	*Mazurka*	*Kolá Sanjon*	*Mean*	*SD*	*Walking*
F1	120	133	120	105	119.50	11.44	110
F2	115	135	120	115	121.25	9.46	111
F3	120	135	118	120	123.25	7.89	113
F4	128	140	120	128	129.00	8.24	120
F5	125	145	120	128	129.50	10.85	110
F6	120	138	115	115	122.00	10.92	104
F7	123	135	115	115	122.00	9.45	115
M1	107	130	110	120	116.75	10.43	110
M2	128	145	120	125	129.50	10.84	115
M3	115	127	118	117	119,25	5.31	110
M 4	112	143	115	120	122.50	14.05	110
M5	118	135	115	115	120.75	9.60	113
M6	115	130	115	112	118.00	8.12	117
M7	110	125	112	105	113.00	8.52	101
Mean	118.07	135.43	116.64	117.14	-	-	111.36
SD	6.28	6.28	3.27	7.13	-	-	4.88
CD	121	155	122	127	-	-	-

Note. F=female dancer, M=male dancer, CD=performance music (bpm).

two chose four different people; this means a different partner for each dance. The mutual choices were only 10 out of 28 possible (35%) with the following distribution: 4 in *Kolá Sanjon*, 3 in *Koladera*, 2 in *Mazurka*, and 2 in the *Funaná*.

There was a clear tendency for the choices of individuals with a rSMT superior to theirs, with 62.50% of choices, while 30.36% chose subjects with less rSMT, and 7.14% chose subjects with the same rSMT.

Comparing the rSMT (real) with the pSMT (perceived), in the overwhelming majority of the cases there was a tendency to dance with the metronome higher than the motor time performed without any stimulus. This difference is even greater when comparing these two values (rSMT and pSMT) with the music tempo (bpm) used during the performances, as can be seen in Table 1.

No significant correlations were found between anthropometric variables, body composition and partner choices. The height, BMI, the somatotype (ecto-, meso-, or endomorph), or the length of the lower limb did not appear to be associated with the choices of the pair.

The results show great evidence that the choices of the dancers are mainly guided by experience: 47 in 56 of the choices, or 83.93%, are from the group with more experience, which means more than 5 years of professional experience.

Note that the male dancer and the female dancer with more choices (three each) in the faster dance (*Funaná*) have higher values of rSTM. On the other hand, in the slower dance (*Mazurka*) the chosen dancers have the lowest values of rSTM. The same applies for the female dancer chosen in *Koladera*, but not for the male dancer (too fast for a slow dance). At *Kóla Sanjon* dance, as four reciprocities in seven were found, the distribution of preferences is more balanced, and this logic cannot apply.

With regard to walking, chosen as the reference standard tempo of each person, the values found for the dances are slightly higher if we take into account the average rSMT. The *Funaná* lies clearly above (it is close to running pace), while the other three dances are slightly above the favorite walking tempo of each dancer. The *Morna*, another Cape Verde dance that was not used in this study because it is not danced in the performance, is clearly below the tempo of walking, with an average of about rSMT 32.50±3.25 bpm.

DISCUSSION

It seems to be evident that the influence of sound stimuli, whether of a metronome or music, increases motor tempo. Moelants (2003) finds that in music for dance, a higher tempo than in natural tempo, "this can be related to the need for a certain 'excitement' in dance music, more than in 'listening music'" (p. 652). The data found in this study confirm that the own motor tempo "accelerates" in the presence of a metronome and even more with the presence of music during the performance.

About the adaptation to the other, there was a preference for dancers that were naturally faster, in the sense of having an rSMT superior to theirs. This choice can be considered intelligent because during the performance they will have to dance to a faster time than their natural, spontaneous time.

More studies are needed to confirm the tendency that the faster dancers are chosen preferably for the faster dances (as was found in *Funaná* either for the first male dancer or the first female dancer for the ranking of the most chosen) and that the slower dancers are the most chosen for slower dances (as was found in the *Mazurka*, the same as above).

In summary, there was a tendency to select partners with more experience and a tendency to prefer those with higher levels of rSTM, and who were therefore faster.

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Thematic session:
The science of singing

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Cochlear implant singing study

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Voice and speech characteristics in deaf children vary considerably from children with normal hearing. Cochlear implant (CI) devices help improve some but not all voice quality parameters 6 to 12 months post-implantation. There remains poor long-term frequency but normal amplitude. This study explores whether vocal training in the form of singing lessons could improve speech production many years post-CI activation. Each participant, aged 13-18 years, received 10 weekly, 30-min. singing lessons at the Hospital for Sick Children. Lessons were conducted by graduates of the voice pedagogy program at the University of Toronto using a curriculum designed to initiate increased vocal effectiveness through pitch matching exercises, alignment and vocal tract shaping, breath management, and articulation of text through song learning. Singing and listening homework was directed by a practice CD produced for the study, and a practice log. Hearing aid users served as the control group. This paper details the design of the study and voice lesson curriculum, the results on the voice use of the teenagers, and indications for further collaborations between voice training (singing) and hearing impaired and cochlear-implanted students.

Keywords: singing; cochlear implant; pedagogy; hearing; speech production

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Intonation in solo vocal performance: A study of semitone and whole tone tuning in undergraduate and professional sopranos

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This article presents a study of intonation in performances of Schubert's "Ave Maria," both *a cappella* and with accompaniment, by six undergraduate and six professional singers. The analysis focuses on the tuning of melodic semitones and whole tones and explores the impact of training and musical context on intonation, as well as whether intonation is significantly affected by the presence of accompaniment. The data from the recordings was analyzed automatically using a MIDI-audio alignment algorithm to annotate the note onsets and offsets and a fundamental frequency estimation algorithm to extract pitch-related information. Overall the singers tended more toward equal temperament except for the non-professional group's semitones, which were closer to Pythagorean tuning.

Keywords: singing; intonation; musical experience; analyzing recordings; musical context

Intonation studies from recorded performances date back to the first half of the twentieth century. Carl Seashore and his colleagues at the University of Iowa did much of this work in the 1920s and 1930s (Seashore 1936). They predominantly focused on whether the intonation practices of the singers they studied conformed to particular tuning systems—for example, Pythagorean tuning, Just Intonation, or Equal Temperament. Only a small number of their studies looked at the context in which the intervals occurred—for instance, whether they were ascending or descending (Schoen 1922). Overall, they found that singers do not tend to sing in any prescribed system and that there is variability between trained singers in their intonation practices. More recent work, including the studies by Sundberg and colleagues (Sundberg 1992, Prame 1997), has confirmed many of the findings of the Iowa studies.

The aim of this study is to explore the impact of training and musical context on the tuning of melodic semitones and whole tones in solo singing, as well as whether intonation, as described by interval size, is significantly effected by the presence of accompaniment.

METHOD

Participants

We ran an experiment with six undergraduate vocal majors from McGill University and six professional sopranos from the Montreal area. The undergraduate participants had completed an average of 2.0 years (SD=0.6) of full-time course work in a Bachelor of Music degree program. They had a mean age of 20.2 years (SD=2.1), and an average of 14.7 years (SD=3.6) of sustained musical activity, with an average of 6 years (SD=2.9) of private voice lessons, and had engaged in daily practice for an average of 5.2 years (SD=3.2). At the time of the experiment, they had a daily practice time average of 1.1 hours (SD=0.7). The ages of the professional group ranged from 28 to 58, with a mean of 35.7 years (SD=11.5). They had an average of 26.0 years (SD=8.7) of sustained musical activity, with an average of 10.3 years (SD=6.0) of private voice lessons, and had engaged in daily practice for an average of 5.2 years (SD=3.2). Their average daily practice time at the time of the experiment was 1.5 hours (SD=0.5).

Materials

Each subject performed Schubert's "Ave Maria" three times *a cappella* and three times with recorded accompaniment. The accompaniment was played back to the singers through closed headphones that were worn over one ear. The semitones and whole tones between notes with a duration of a sixteenth note or greater were examined. Notes shorter than this were eliminated because of their pitch instability. For both types of intervals, the difference between the ascending and descending intervals was evaluated. The semitone analysis also compared the intervals between the leading tone and the tonic to the other semitones in the piece (Figure 1). This allowed for the assessment of a commonly held belief, rooted in Pythagorean tuning theory, that ascending leading tones are sung sharp. The whole tone analysis looked at whether the movement toward or away from stable notes influences the intonation tendencies (Figure 2). The data analysis also considered intonational consistencies both within each performer's *a cappella* and accompanied renditions and across performers.

Figure 1. Schubert's "Ave Maria" with analyzed semitone categories marked.

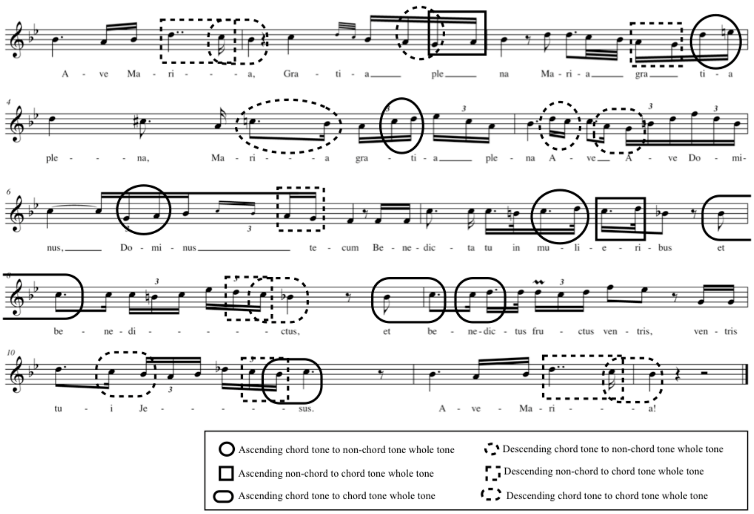

Figure 2. Schubert's "Ave Maria" with analyzed whole tone categories marked.

Procedure

The recordings were analyzed using an automated method for annotating note onsets and offsets by aligning a MIDI version of the "Ave Maria" with the recordings (Devaney *et al.* 2009). Once note onsets and offsets were determined, frame-wise fundamental frequency estimates were made using the YIN algorithm (de Cheveigné and Kawahara 2002). A single perceived pitch was assigned to each note by taking a weighted mean of the fundamental frequency estimates (Gockel *et al.* 2001) and interval size was calculated as the distance between these estimates.

RESULTS

Table 1 shows the means and standard deviations (SD) for all of the ascending and descending semitones and whole tones. The mean semitone size values across all of the singers in both groups tended to be closer to the 100 cent equal tempered semitone and 90 cent Pythagorean semitone than the 112 cent Just Intonation semitone. The whole tone size values across all of the singers for the various conditions centered around both the 200 cent equal tempered whole tone and the 204 cent Pythagorean and Just Intonation whole tones. Tables 2 and 3 show the sizes for the different conditions for the semitones and whole tones, respectively. Linear regression analysis showed the conditions for which there were significance differences. Though the R^2 values were low for the regressions (non-professional singers' semitones: $R^2=0.19$, $p<0.0001$; professional semitones singers': $R^2=0.09$, $p<0.0001$; non-professional singers' whole tones: $R^2=0.08$, $p<0.0001$; professional singers' whole tones: $R^2=0.06$, $p<0.0001$), they were significant and showed some clear trends for the presence of accompaniment, intervallic direction, and the various semitone and whole tone conditions.

Only the non-professional group showed a significant effect for accompaniment, and only for the size of the semitones, which were on average 3 cents smaller in their *a cappella* performances. The professional group showed a significant effect for direction on semitone interval size, with their ascending intervals on average 8 cents larger. The non-professional group showed an effect for whole tone interval size, with their descending whole tones on average 5 cents larger. For the different semitone categories, the non-professional leading tones were on average 10 cents smaller than their non-leading tones. The professional group's non A-B*b*/B*b*-A semitones were on average 7 cents larger than the A-B*b*/B*b*-A semitones. For the whole tone categories, the non-professional group's whole tones ending on a chord tone were on average 5 cents smaller than those ending on a non-chord tone. There was no effect for the professional group's whole tone interval sizes.

Table 1. Summary of the mean interval size and standard deviation (SD) for the two subject groups across all semitones (ST) and whole tones (WT) used in this experiment.

	Non-professional singers		*Professional singers*	
Conditions	*A cappella*	*Accompanied*	*A cappella*	*Accompanied*
(# of instances)	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
ST, up (144)	90 (20)	95 (16)	99 (18)	99 (17)
ST, down (162)	87 (18)	89 (18)	93 (18)	94 (16)
WT, up (198)	198 (23)	195 (22)	200 (21)	203 (21)
WT, down (234)	201 (19)	201 (19)	203 (19)	203 (18)

Table 2. Mean (and SD) of the semitones (ST) sizes (in cents) for each of the tested conditions: A-B*b* leading tone (LT) intervals, A-B*b* non-leading tone (LT) intervals, B-A*b* intervals, other ascending semitones, and other descending semitones.

	Non-professional singers		*Professional singers*	
ST conditions	*A cappella*	*Accompanied*	*A cappella*	*Accompanied*
(# of instances)	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
A-B*b*, LT (36)	79 (16)	91 (13)	95 (17)	93 (14)
A-B*b*, non-LT (72)	95 (20)	100 (13)	99 (17)	99 (17)
B*b*-A intervals (72)	83 (19)	86 (16)	88 (13)	90 (14)
Other ST, up (36)	89 (22)	91 (21)	103 (20)	104 (18)
Other ST, down (90)	90 (18)	91 (19)	97 (19)	97 (18)

Table 3. Mean (and SD) of the whole tone (WT) sizes (in cents) for each of the tested whole tone conditions considered: chord tone-chord tone (CT-CT) up and down, chord tone-non-chord tone (CT-NCT) up and down, non-chord tone-chord tone (NCT-CT) up and down, and non-chord tone-no-chord tone (NCT-NCT) down.

	Non-professional singers		*Professional singers*	
WT conditions	*A cappella*	*Accompanied*	*A cappella*	*Accompanied*
(# of instances)	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
CT-NCT, up (72)	208 (25)	203 (24)	203 (23)	209 (28)
CT-NCT, down (54)	198 (19)	195 (20)	203 (16)	200 (18)
NCT-CT, up (36)	188 (16)	188 (16)	201 (20)	200 (15)
NCT-CT, down (108)	199 (19)	202 (16)	201 (20)	202 (18)
CT-CT, up (72)	193 (19)	191 (21)	196 (19)	198 (14)
CT-CT, down (90)	204 (18)	203 (21)	205 (19)	207 (17)

DISCUSSION

There are several possible interpretations for the differences between the non-professional and professional groups. The significant effect for accompaniment in the non-professional's semitones suggests that the singers become more consistent between *a cappella* and accompanied versions when they acquire more training/experience. The absence of an effect in interval size for the professional group's leading tones suggests that either singers acquire greater stability in their production of leading tones with training or that the singers with less training tend to exaggerate them. This, however, contrasts with the findings for the professional group's whole tone tuning.

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Heart versus head: The implications of register sensation in the female characters of Mozart's *Le nozze di Figaro*

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This research applies the skill of sensory perception in the teaching and performance of Mozart's female characters of *Le nozze di Figaro*. Through the physical sensation a singer experiences when phonating in the extreme head or chest registers, Mozart may be indicating intellectual and/or emotional superiority in these characters. This study is not intended to supplant conventional research about these characters, but to enhance the singer's preparation of these roles and to explore the mind-body connection that Mozart must have understood on an intuitive level.

Keywords: Mozart; Figaro; register; characterization; aria

The use of sensory perception in coordination with the anatomical reality of sound production allows a singer to both physically and intellectually understand the sounds that he or she is making. This research is founded in the belief that attentive and educated sensory perception is absolutely necessary to produce technically sound and artistically powerful, or "authentic," singing (Smith 2007). Through the use of extreme head or chest register sensation, Mozart may be indicating both intellectual and/or emotional superiority in the female characters of *Le nozze di Figaro*. By studying what the women are asked to sing outside of the "normal" F_4 to F_5 range, one can determine each character's emotional or intellectual awareness and sensitivity, resulting in a clearer dramatic understanding and more balanced vocal production.

METHOD

A hypothesis developed out of teaching students to sing Mozart roles such as Fiordiligi, Donna Elvira, Countess Almaviva, and Susanna. When asked in what part of their bodies students processed intellectual thought, they invariably indicated a place in the upper region of the brain. When asked where they experienced intense emotion, they again invariably indicated a place on the body at least as low as the heart, and often lower.

When students were asked to imagine that the very highest parts of their brain were active and available when singing the highest pitches of these roles, and that their hearts and lower bodies were active and available when singing the lowest notes required, incredibly demanding leaps (some of an octave or more) were negotiated with ease of registration without having to over-analyze the adjustment and balancing of vocal registers. There was never an attempt to restrict or block any parts of the body that were not called into a state of extreme alertness, but the sensations typically experienced when female singers reported singing in "pure head voice" or "pure chest voice" seemed to consistently result from the singers' change in heightened awareness of either the elevated intellectual prowess or depth of emotional connection.

Assuming that C_4 is the pitch commonly called "middle" C, and C_5 the pitch one octave higher (and thus, C_3, one octave lower), and assuming that F_4-F_5 is the "neutral" or "normal" singing range for the female voice (believed by many vocal pedagogues to be the mix of chest and head registers), this research involved the counting of individual pitches that fall in the extremes of the vocal range (above and below F_4-F_5) in selected music of each principal female character. All of the female characters—Susanna, Countess Almaviva, Marcellina, and Barbarina—sing predominantly in the "normal" range, which suggests that excursions to the extremes of the vocal range provide clues to the emotional and dramatic abilities of the characters.

The data were compared to the dramatic progression of the character through the opera, and how the performer and audience may perceive the character in her journey.

RESULTS

In Figaro and Susanna's opening duet "Cinque, dieci...," Susanna sings only three G_5 at the conclusion of the duet so as not to obviously appear the intellectual superior of her fiancé. Only when she tells Figaro in the following recitative that the Count wishes to exert his feudal right does she descend to E_4, displaying for the first time an emotional discomfort with the Count's plan.

Marcellina and Susanna spar in the Act I duet "Via resti servita." Upon first glance, the vocal ranges of the two characters appear almost identical. Susanna, however, is the only one of the two women to manage an A_5. She

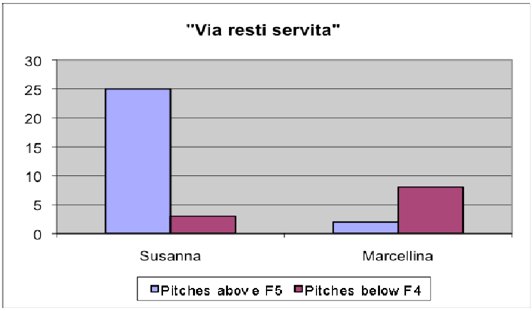

Figure 1. Susanna and Marcellina, Act I, "Via resti servita."

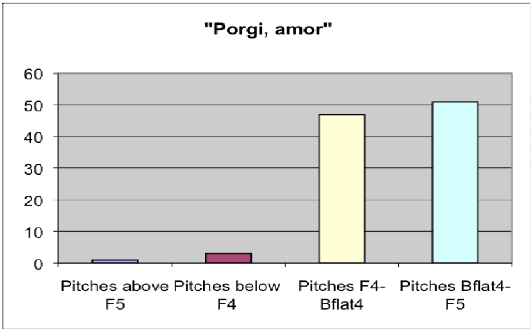

Figure 2. Countess, Act II, "Porgi, amor." (See full color versions at www.performance science.org.)

also sings 11 G_5 and 13 $F\#_5$, while Marcellina manages only one G_5 and one $F\#_5$ (see Figure 1). Marcellina appears to be slightly more emotional in this duet since she manages a greater number of "low" pitches: six E_4 and two $D\#_4$, in contrast to Susanna's three E_4.

The character of Countess Almaviva is introduced in the opening of Act II with her aria "Porgi, amor," where she sings only two pitches of G_5 before the highest pitch of the aria, Ab_5 (see Figure 2). Leading up to the vocal climax of the aria, she never sings below Bb_4. Following her iteration of the only solution to the problem of her unfaithful husband—her own death ("O mi lasci almen morir")—she sings twice as many pitches below Bb_4, managing twice to descend to Eb_4 and once to D_4. She can no longer remain intellectually engaged in the solving of her dilemma and allows herself to fall into the emotional depths of her chest register.

"Susanna, or via sortite!" is interesting because Susanna takes awhile to "warm up" her thoughts. She begins in the neutral middle range of the voice and does not really start accessing her intellectual abilities until it becomes clear that if something is not done, there will be an "un-scandal." She sings two C_6 (the highest pitches of the opera), plus an additional 46 pitches above F_5 in this trio. During the same dramatic action, Countess Almaviva manages only three G_5 but sings in the emotional low range three E_4, one D_4, and even a C_4, her lowest pitch of the opera thus far. The Countess seems very emotionally distraught at the situation; Susanna is more fully engaged in problem solving.

It is interesting that in the Act III duet "Crudel! perché finora," Susanna uses only $F\#_5$ as her "most thoughtful" note. Perhaps she knows that if she sings higher, the suspicious Count will be threatened by her mental acumen. She also never descends to an emotional level below F_4, maintaining her poise in the middle and upper registers.

"Dove sono" is remarkable for Mozart's reluctance to allow Countess Almaviva to escape from the prison of neutrality throughout the majority of the aria. Her two climactic A_5 pitches display her courageous attempt to resolve her relationship problems with the Count by thinking as hard as she can.

The duet "Sull'aria" seems to be perfectly balanced between the Countess and Susanna in terms of range, but the Countess only once sings G_5, and Susanna manages not only five G_5, but a $B\flat_5$ as well. The Countess may be dictating the letter, but Susanna's brain is working even faster.

Barbarina's "L'ho perduta, me meschina" opens Act IV and reveals an enigmatic young woman. The entire cavatina is contained within the F_4-F_5 neutral range, implying that she is either the most balanced of the female characters or that she is incapable of clever thought or profound feeling (see Figure 3).

Marcellina, in the Act IV aria "Il capro e la capretta," clearly demonstrates that, when necessary, she can think with great acuity. Not only does she never descend below the neutral vocal range in this cunning aria, she sails all the way up to two $B\flat_5$. Here, she demonstrates that she is indeed very clever.

Susanna's lovely "Deh vieni, non tardar" ascends only once to A_5 (see Figure 4). In this aria, she also sings the lowest pitch sung by any female in the opera (A_3) and spends considerable time—29 pitches—below the neutral boundary of F_4, indicating the depth of feeling present in this moment.

In the finale of Act IV, Mozart asks Susanna to sing perhaps the most difficult vocal acrobatics of the entire work at "Impara, o perfido! A fare sedut. tor." The octave transpositions seem to indicate that Susanna is trying very

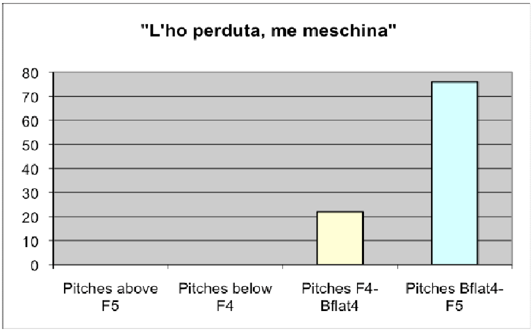

Figure 3. Barbarina, Act IV, "L'ho perduto me meschina."

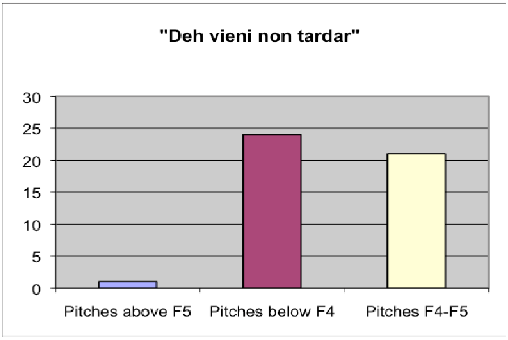

Figure 4. Susanna, Act IV, "Deh vieni, non tardar." (See full color versions at www.performancescience.org.)

hard to be wise in teaching Figaro his lesson, but she is clearly emotionally moved as well. When the Countess finally sings "Più docile il sono, e dico di si," she sings only from G_4 to E_5, the most balanced vocal range in the netural zone. She and Susanna share the melodic line from that point to the end of the opera, demonstrating that emotional upheaval and scheming have come to an end.

DISCUSSION

It is clear that Mozart does use range and register to demonstrate intellectual superiority and depth of emotion in his female characters. Susanna—who, though lower in station, is believed to be more intellectually sound than the

Countess—sings high pitches far more often than the Countess, but also sings lower than her soprano counterpart, making her also emotionally superior. Similarly, Barbarina does not sing a wide range of pitches, limited only to just an octave (F_4 to F_5), demonstrating that she is not terribly smart, nor is she emotionally mature.

Mozart's use of pitch range can influence the performer's perception of the intellectual and emotional state of the female characters in *Le nozze di Figaro*, and provides insight into each character's development as the opera progresses. Numeric data supports this hypothesis, and it is hoped that this theory and the supporting evidence will serve as another way for singers and teachers to understand the female characters that Mozart writes with such depth and understanding.

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Thematic session: Performers' health II

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Sensorimotor alterations in violinists/violists with neck pain

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The aim of this research project was to determine the extent to which neck pain is present in violin/viola players and to investigate if fine motor control and dexterity are influenced by dysfunctions as such. This is important to know as impairments in dexterity are expected to have an impact on motor control in violin/viola playing and contribute to a decrease in performance excellence.

Keywords: violin/viola players; neck pain; sensorimotor impairments; CCFT; EMG

Playing-related musculoskeletal disorders (PRMD) are a common problem in musicians. Growing evidence demonstrates that up to 80% of musicians experience pain within their musculoskeletal system during musical performance (Blum 1995, Fishbein *et al.* 1988, Fry 1986a, 1986b, Ledermann and Calabrese 1986, Molsberger *et al.* 1990). Neck pain is a frequent complaint of violin and viola players. Between 20-28% of violin/viola players reported suffering from neck pain in studies investigating PRMD (Fishbein *et al.* 1988, Ackerman and Adams 2003).

Neck pain is known to be associated with various changes in motor control. Impairment of deep cervical flexors is a common feature in neck pain and contributes to altered muscle activation patterns during various functional tasks of the head and shoulder region (Falla 2004a, 2004b). Additionally, there is evidence of sensory changes and sensorimotor alterations with pain (Sheather-Reid 1998, Scott *et al.* 2005, Bisset *et al.* 2009). Nevertheless, there is no research data at present to determine if these phenomena are present in musicians as well.

METHOD

Within this study, 22 violin/viola players with neck pain, 21 without, and 21 healthy non-musician as a normal control group were required to complete the Neck Disability Index (NDI), the General Health Questionnaire (GHQ), the Patient Specific Functioning Scale (PSFS), and questions about their violin/viola playing.

Sensory testing included pressure algometry over the neck and over the M. tibialis anterior and thermal pain thresholds (cold and heat) over the neck. Sensorimotor hand function was tested with the Human Performance Resources hand module BEP I recording reaction times, tapping velocity, and performance accuracy.

Muscle activity was investigated with surface-electromyography of the upper, middle, and lower trapezius muscle and the sternocleidomastoid muscle (SCM) during the craniocervical neck flexion test (CCFT), a functional tapping test, and a violin/viola playing task.

RESULTS

Based on their NDI scores, the symptomatic violin/viola player group was divided into a low-NDI and a high-NDI group. There were no statistically discernible differences between the musician groups in terms of years playing the instrument and average playing time.

The mean NDI and GHQ values differed significantly among groups ($p<0.001$). No statistically relevant difference was shown for pain intensity values (visual analogue scale) between low and high NDI player groups. A significant difference was shown for participation in sports ($p=0.004$). Concerning the PSFS, nearly all musicians in the symptomatic group reported at least one impaired instrument-playing related activity.

Analysis of sensory data showed significant differences for both cold and heat thresholds between asymptomatic and symptomatic musicians ($p<0.05$). Pressure pain values and motor performance tests with BEP I were not significantly different between player groups and controls. In the CCFT, significantly higher EMG activity was found at several levels of the test ($p<0.05$). Additionally, symptomatic violinists had more often asymmetric SCM patterns. The EMG results of the functional tasks demonstrated trends for higher

EMG values in musicians with high NDI values, but the differences were not significant.

DISCUSSION

Violin/viola playing-related neck pain changes thermal thresholds for heat and cold. This is in accordance with existing studies investigating sensory features in neck pain patients. Function of neck muscles in the CCFT as well as EMG activity in functional tasks were partly altered. Results were not as distinctive as in corresponding studies with non-musician neck pain participants, which may be explained by the higher NDI levels of those subjects. It also has to be taken into account that the musicians investigated complained about task-specific neck pain, which was not present during normal daily life activities. Sensorimotor deficits in an experimental setting assessing reaction speeds, tapping velocity, and performance accuracy of a dexterity task were not present in musicians with playing-related neck pain.

Possibly, sensorimotor deficits of musicians are too subtle and task specific to be picked up with the tests used for sensorimotor assessment in the present study. Therefore, future studies and tests have to be tailored assessing musician's fine motor skills during musical performance

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Good playing practice when drumming: Influence of tempo on timing and preparatory movements for healthy and dystonic players

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Four professional percussionists were recorded when playing single strokes at different tempi (50, 120, 300 beats per minute [bpm]) and dynamic levels (*p*, *mf*, *f*). All players were right handed, but two of the players had their left arm affected by focal dystonia. Audio, contact time, as well as players' arm, hand, and stick movements were recorded. The analysis indicated that the healthy players use the long inter-stroke intervals available at slow tempi to prepare the strokes. Strokes at 50 bpm were, in general, initiated from a greater height and played louder than strokes at fast tempi. As expected, variability was highest for the left arm at 300 bpm.

Keywords: drumming; timing; preparatory movement; motor control; focal dystonia

In order to control timing and sound characteristics of individual notes, musicians typically use preparatory, or anticipatory, movements. In drumming, a player can ensure sufficient striking force by creating a "runway" during which the stick increases its velocity before impact. Strokes to be played at higher dynamic levels can be initiated from a greater height, producing louder sound level at low physical cost (Dahl 2004). However, the player needs to initiate the upward movement of the hand and stick well before the actual downstroke in order for the stroke to arrive on time. With increasing tempo there is less time available for such preparatory movements, suggesting that playing loud and fast may be more of a challenge.

The aim of this work is to investigate how players' movement patterns and timing performance are affected by more extreme combinations of tempi and dynamic levels.

METHOD

Participants

Four professional, classically trained percussionists (19-24 years playing experience) participated in the study. All players were male and reported their right hand as being the preferred in playing. Two of the players had their left arm affected by focal dystonia.

Materials

A motion capture system (Selcom Selspot) sampled the position of infrared LED markers attached to the drumstick and the players' shoulder, elbow, wrist, and index finger knuckle (MPC joint) at 400 Hz. The contact between stick and drumhead was measured electrically, using copper foil at the tip of the drumstick and a thin layer of graphite sprayed at the striking area (a 5 cm diameter circle). All acoustical measures and a trigger from the motion capture system were simultaneously sampled at 16 bits, 160kHz (National Instrument PCI-6143). The signals were then lowpass filtered at a cutoff frequency of 22 kHz and downsampled to 44.1 kHz for analysis.

Procedure

When the markers had been attached, the player adjusted a drum stool to a comfortable level and was given time to try out playing. Recordings started when the player reported that none of the cables obstructed the playing. For each arm, combinations of three dynamic levels (*p*, *mf*, and *f*) and tempi (50, 120, and 300 beats per minute [bpm]) were recorded. The order was randomized, and to avoid fatigue the trials were separated into three blocks, interleaved with another task (see Dahl and Altenmüller 2008).

Analysis

The analysis focused on (1) variability in timing (inter-onset intervals [IOI]), (2) general movement organization, and (3) vertical position and acceleration of the drumstick marker (the vertical acceleration being the most important to transfer energy at impact).

For the overall timing performance, the number of unintended events (e.g. extra bounces or missing strokes) was identified. These errors were then removed and the Coefficient of Variance (standard deviation [SD]/meanIOI) across each trial was calculated.

For the movement data, the 3D movement trajectories from the six markers were checked and outliers and data gaps repaired. After some sparse filtering, the points of impact were determined from the vertical velocity of the stick marker, using an algorithm virtually identical to that used by Dahl (2004). The points of impacts were then used as landmarks when transforming the time series to functional data (Ramsay and Silverman 2005).

The transformation followed the procedure used by Goebl and Palmer (2008). Order 6 b-splines were fit to the second derivative of the position data, with a knot placed every sixth data point. Smoothing of the data was made using a roughness penalty on the fourth derivative ($\lambda=10^{-19}$). By adding extra knots at each hit, it was possible to achieve sufficient smoothing of the second derivative (acceleration) without loss of detail. Lastly, time series were sampled at a new sample frequency of 2100 Hz from the functional data, generating new time series for the vertical displacement, velocity, and acceleration. For each trial, peak acceleration at impact for ten strokes were extracted for analysis.

RESULTS

The analysis showed differences between healthy and dystonic players and also between arms used, an expected result. For the right (preferred) arm and the intermediate tempo (120 bpm) the variability in timing was small for both healthy and dystonic players. At the fast tempo, however, both groups of players displayed errors and increased variability in timing. A pronounced deterioration in movement patterns and lack of timing control in the affected (left) arm was evident for the dystonic players.

When extra bounces after strokes (frequently occurring for one patient at 300 bpm) had been removed, the timing variability was comparable between healthy and dystonic players, ranging between 0.015 and 0.065 at 300 bpm. A repeated measures ANOVA of the Coefficient of Variance for main intervals showed no difference between the two groups ($p=0.726$).

At slow tempi and medium tempo, the movement organization appeared similar for healthy and dystonic players. The top panel in Figure 1 shows how the wrist leads the preparatory movement before the stick. This preparatory "lead" was seen to decrease at medium tempo and become almost anti-phase at 300 bpm. The bottom panel in Figure 1 shows how the MPC marker still

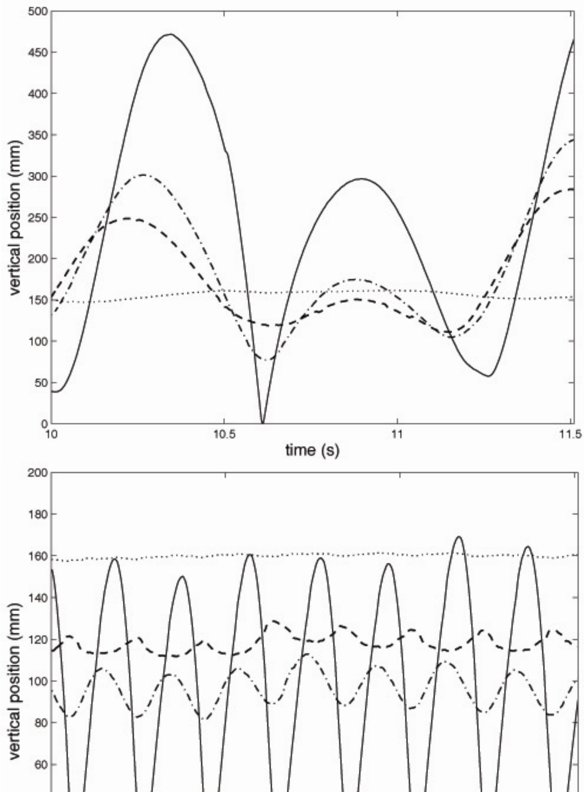

Figure 1. Vertical displacement vs. time for a healthy player at 50 bpm (top panel) and 300 bpm (bottom panel). The lines show the vertical displacements of markers at the elbow (dotted), wrist (dashed), MPC joint (dot-dashed), and stick (full line). Note the difference in magnitude for the vertical position at the two tempi.

leads briefly before the stick, whereas the wrist marker reaches its peak amplitude directly before the hit.

All players initiated strokes at 50 bpm from a greater height compared with faster tempi, but the healthy players produced higher peak acceleration. The two panels in Figure 2 show the peak acceleration at *mf* and different

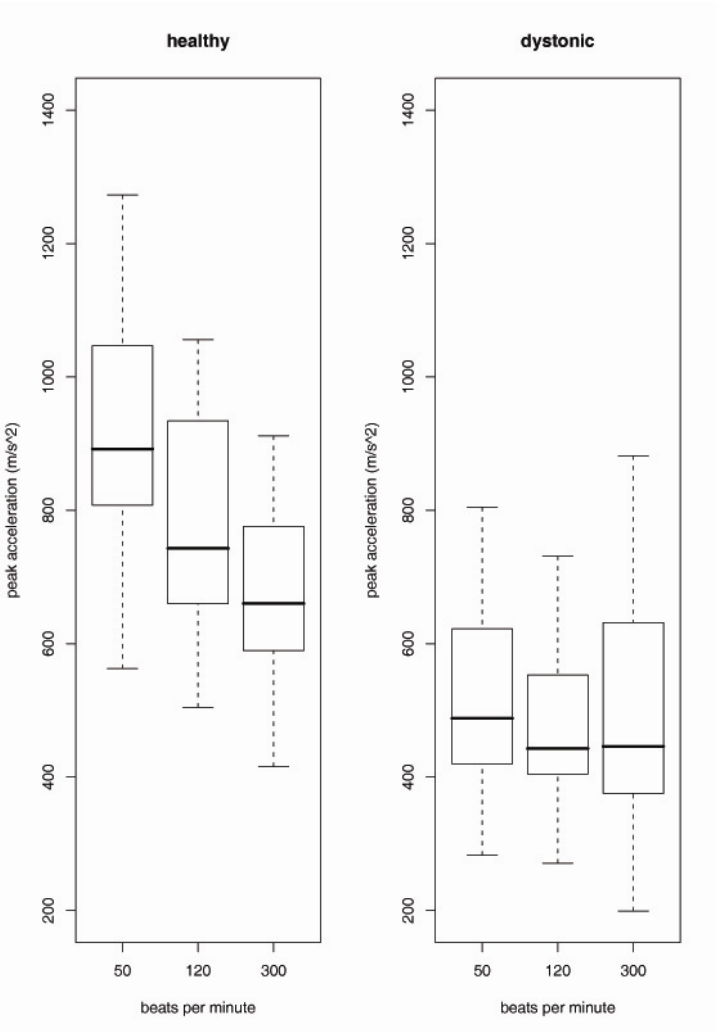

Figure 2. Peak acceleration for *mf* strokes at three different tempi as played by healthy (left panel) and dystonic (right panel) players, using both arms. The boxplots show the first and third quartile around the median (black line) with values within 1.5 times the interquartile range indicated by whiskers.

tempi for the healthy and dystonic players. In general, the two healthy players displayed more of a range in acceleration values. In particular, the healthy players produced higher peak acceleration at 50 bpm compared with strokes at higher tempi but at the same dynamic level (*mf*). This might indicate that these players chose to use the additional time between strokes to increase their dynamic range.

DISCUSSION

The differences in performance between healthy percussionists and those suffering from focal dystonia are evident for the (affected) left arm. When unintended extra hits were removed, however, the timing variability (as measured by the Coefficient of Variance) was not significantly different between the two groups of players. The healthy players appeared to use the additional time between strokes at slower tempi to increase their dynamic range somewhat more than the dystonic players. Although the results cannot be generalized at this stage, this type of research could provide valuable insights in how players' movement strategies change in response to more demanding playing conditions. Such knowledge would have important implications for music teaching and education.

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Getting into the zone: Trait emotional intelligence predicts flow experience in piano performance

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The experience of flow may be one possible explanation for performers' motivation to take on intense musical practice on a daily basis. Being "in flow" or "in the zone" is defined as an extremely focused state of consciousness that occurs during intense engagement in an activity. In general, flow has been linked to peak performances and feelings of intense pleasure and happiness. In this study, flow theory and emotion are discussed in relation to personality and individual differences in musicians. We assessed flow experience in piano performance and emotional intelligence in a group of 76 piano performance students at university level using standardized tests. Multiple regression analysis revealed that flow experience can be predicted by emotional intelligence. Other background variables (gender, age, duration of musical training, and amount of practice) were not predictive. In order to predict high achievement in piano performance, a five-predictor logistic model was used to fit the data, indicating that the odds to win a prize in a piano competition increased significantly with the amount of practice, as found in earlier reports. Importantly, a positive relationship between flow and peak performance could not be supported, suggesting that superior performance in any activity is a multifaceted phenomenon that is conceptually complex and difficult to model.

Keywords: flow; piano performance; peak performance; trait emotional intelligence; flow scale

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Thematic session: Movement and embodied knowledge II

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Is it their bodies that let them down? Dancing past 35 years old

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Age and not being able to cope physically with the demands of performing have often been cited as the reason why dancers retire from dance. The average age of retirement still remains in the thirties for professional dancers. The aim of the present study is to examine whether there is any underlying physiological data to substantiate these claims. Seventy professional dancers undertook a number of physical fitness tests. Results indicate that age did not influence the physiological data. In conclusion it is suggested that physical fitness is not a performance-limiting factor for dancers, though it is recognized that other factors may also play a part such as age-reduced healing ability.

Keywords: ballet; age; physical fitness; performance

Dancing is potentially the most physical art form not only in its performance demands but also in its training (Allen and Wyon 2008, Koutedakis and Jamurtas 2004). Presently dancers often spend more time preparing to be a performer than they do actually performing (Laws 2005). Dancers' physical fitness levels have been shown to be slightly higher than sedentary individuals, though not as high as non-endurance athletes (Koutedakis *et al.* 1999, Koutedakis and Jamurtas 2004, Koutedakis *et al.* 1997, Laws 2005, Wyon *et al.* 2007, Wyon *et al.* 2004, Wyon 2007), and this seems a dichotomy considering the hours they dance. Part of this can be explained by the fact that as the skill element of an activity increases the physical intensity has to decrease as otherwise the skill element is compromised (Tomporowski 2003). The high skill levels of dancers have allowed them to develop excellent economy of movement so they can cope with these demands without overly stressing their cardiorespiratory systems. The physical demands of dance have only recently been studied (Wyon *et al.* 2002, Wyon *et al.* 2004). Dance has been classified as high intensity intermittent exercise which places a demand on both the aerobic and anaerobic energy systems (Cohen *et al.* 1982a, Cohen *et al.* 1982b, Redding and Wyon 2003, Schantz and Astrand 1984). The cardio-respiratory demands of dance class and rehearsal have been seen to be at a significantly lower intensity than dance performance (Wyon *et al.* 2004), though supplemental training has been shown to have a beneficial affect not only on dancers' fitness levels but also on the aesthetic aspects of dance performance (Angioi *et al.* 2009, Twitchett *et al.* 2011). The aims of the present paper will review the physical demands of dance performance in comparison to physical fitness levels, age, and skill.

METHOD

Participants

Seventy professional ballet dancers (age range 18-45 years) volunteered for the study.

Procedure

All participants underwent a series of physical fitness tests based on protocols set out by the British Association of Sport and Exercise Science (Wyon 2007). These included anthropometric (height, weight, sum of 7 skinolds), aerobic capacity (treadmill VO2 max test), vertical jump, and flexibility (active and passive range of movement). Univariate analyses of variance (ANOVA) were used to analyze the fitness test data with age as well as in comparison with published data on the physiological demands of ballet performance. Significance was set at $p<0.05$.

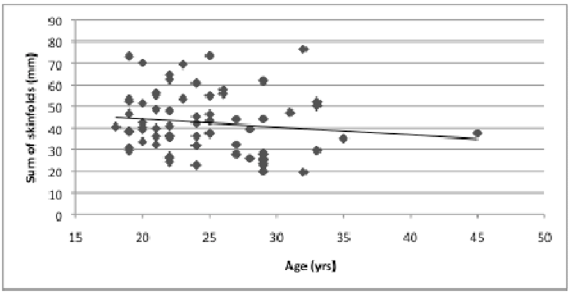

Figure 1. Sum of skinfolds versus age.

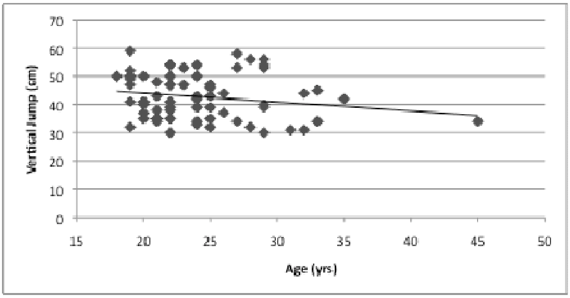

Figure 2. Vertical jump versus age.

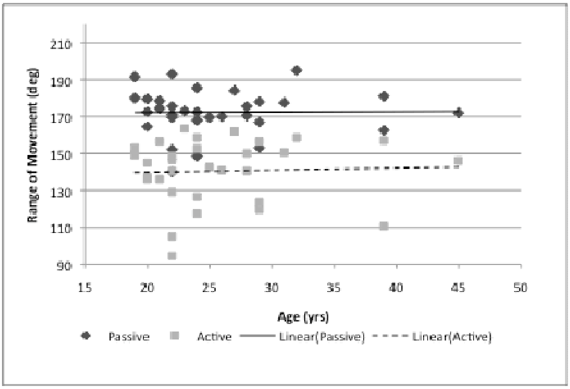

Figure 3. Range of movement versus age.

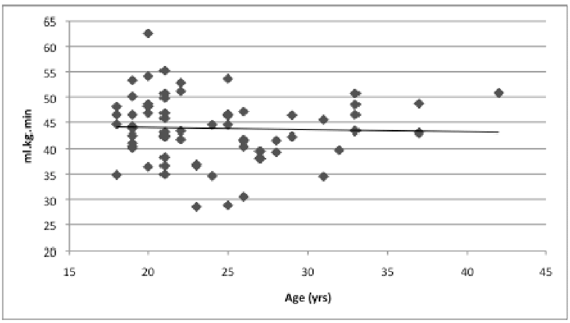

Figure 4. VO2 peak versus age.

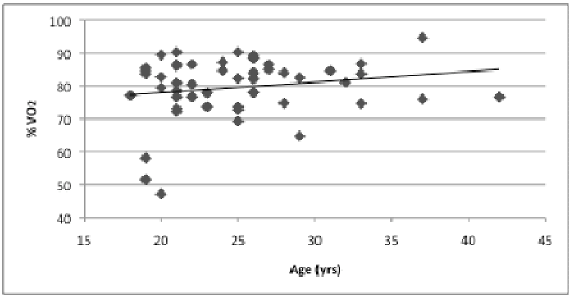

Figure 5. %VO2 versus age.

RESULTS

Statistical analysis noted age did not influence the physical fitness parameters. In comparison with performance data, there is no significant difference between the aerobic capacity demands of ballet performance and aerobic fitness levels of dancers.

DISCUSSION

The present study suggests that age was not an influence on fitness levels in professional ballet dancers. One possible reason is that skill will increase with dance experience and age, thereby improving movement economy and decreasing the cardiorespiratory demands of actually dancing. This benefit has to be coupled with an age-reduced healing ability not only from injury but also daily dancing. The utilization of supplemental training, even just once a week, would help all ballet dancers cope with the demands of dance performance, as presently they are performing at close to their maximum (Allen and Wyon 2008, Twitchett *et al.* 2011). By increasing their varying fitness capacities, it would allow them to operate at a lower relative workload and reduce the stress in their systems.

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Studying embodied knowledge through modeling performer's evaluation parameters: A longitudinal examination of performances using distinct flute headjoints and bodies

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Performers acquire tacit or embodied knowledge about their own playing by practicing their musical instruments. Even though this kind of expertise plays an essential role in the field of skill acquisition, it is rather difficult to create methodologies to study embodied knowledge. This study focuses on how performers evaluate their performances using different instruments. Performers' evaluations are usually qualitative and provide a brief description of a sensation about his or hers own playing. Once the instrument is changed, however, performers need to adapt to new technical requirements. Since this adaptation depends on self-evaluation, by studying how they evaluate their performances after each change of instrument, tacit knowledge may become rather more explicit through reviewing performer's remarks and comparing low-level audio descriptors estimated from analysis of audio data.

Keywords: embodied knowledge; longitudinal experiment; performance evaluation; cognitive modeling; low-level audio descriptors

Acoustic properties of musical instruments (Campbell and Greated 1987) and the correlation between low-level audio descriptors with the perception of musical timbre have been extensively studied (MacAdams and Giordano 2009). Nevertheless, little attention has been given to how musicians understand their own playing based on either of them. This paper investigates the consistence of evaluation parameters used by a flutist in describing the experience of playing with different flute headjoints, and discusses the issue of informing performers via feedback of quantitative results.

The modern flute comprises three parts: headjoint, middle joint, and foot. The Bavarian flutist and goldsmith Theobald Boehm (1794-1881), inventor of the modern flute, describes the headjoint as a cylindrical tube at main part with 19 mm of diameter and observes that the bore of the headjoint is gradually reduced in diameter by two mm from the joint upward to the cork. The air column enclosed by the tube of the flute is set into vibration by blowing across the mouth-hole (Boehm 1908, p. 14). The headjoint contains the crown assembly including a cork or other stopper that determines the total length of the tube, the embouchure hole, and the tuning slide by which the headjoint is inserted on body of the flute (Toff 1996, p. 6).

Comprehensive research on the perception of flute acoustic properties includes: the influence of different materials, such as silver, gold, and platinum (Linortner 2001) and a new method for validating a measure for playability of extended fingering configurations and multiphonics (Botros 2001) of the Boehm flute. Wolfe *et al.* (2001) compared estimated acoustic impedance of the Boehm flute to the historical ones. Campbell and Greated (1987) discuss differences in acoustic properties of headjoints.

Research in timbre classification has two main goals. One is to create algorithms that provide reliable low-level audio descriptors for comparing, indexing, and retrieving audio data (Aucouturier and Pachet 2001). The other is to identify dissimilarity measures that can account for, or at least correlate, with human perception of timbre (Wang and Brown 2006, Donadieu 2007).

Spectral centroid is a low-level audio descriptor that has been persistently utilized due to its relationship with the perception of brightness (Loureiro *et al.* 2004). It can be defined as either the center of the full spectrum or that of a harmonics series. Kim *et al.* (2005) discuss low-level audio descriptors included in the MPEG-7 international standard. Among those are the Audio Spectral Centroid (pp. 27-29) for any kind of audio signal and Harmonic Spectral Centroid (pp. 45-46), which depends on the fundamental frequency. Spectral centroid has also been shown to be highly correlated with spectral envelope (r=0.94) as demonstrated by Krimphoff *et al.* (1994, cited in Donnadieu 2007). Agostini *et al.* (2003) also report the importance of spectral centroid among 18 descriptors. It has also shown to be "sufficient to classify sounds close to 50% of accuracy" (Brown *et al.* 2001, p. 1067).

METHOD

Participants

A single musician with more than 30 years of professional experience performed the same musical excerpt and exercises using eight flute headjoints and two flute bodies. In total, eight sequences of exercises for headjoint (without body) and 16 combinations of flute body-headjoint were recorded using two sets of four microphones. This paper reports results from the first held tone, played as an exercise with each of the eight headjoints.

Materials

Two sets of four microphones (two front in 90° and two rear in 120° angles, respectively) were used. In order to simulate both the performer's and listener's perspectives, the first set was placed on stage, 1.20 m above the stage floor, 2 m away from the performer, whereas the second set was positioned close to the audience seats, on the fourth row, about 7 m from the performer, also at 1.20 m above the audience floor, which roughly corresponds to the distance from the floor to the ears of a seated person (1.70 m tall).

Procedure

Even though no questionnaire was given to the performer, it was required that comments on the same criteria should be drawn after each performance. Before starting the recording session, the performer defined the criteria upon which to comment. Table 1 lists construction materials as well as all comments after the exercises with headjoint without body. [*Note.* Comments drawn after performances of the musical excerpt are not reported here.]

RESULTS

Audio samples were recorded at 48 kHz sampling rate and analyzed using Sonic Visualiser (Cannan *et al.* 2010). Harmonics were estimated from ordinary spectral analysis (Fourier transform) with a Blackman-Harris spectral window, size 2048, with 50% overlap. Audio spectral centroid was estimated using the "general-purpose" setting.

The spectral content of each wooden headjoint (H5 to H8) has shown some similarity to another constructed with metal (H1 to H4). Comments on each headjoint, however, have not always directly reflected this similarity. The pair H4+8 presented the largest concentration energy on the first harmonic, which coincides with comments on "lower partials," and comments on the overall sound quality also coincide. Conversely, pair H3+6 presented the least concentration of energy in the first harmonic, yet comments on both were "darker timbre with lower harmonics enhanced." Comments on pair H2+7 presented a dichotomy that did not reflect their harmonic content. Fi-

Table 1. Description of materials and comments on the exercises using each headjoint.

Headjoint	*Material*	*Comments on timbre and harmonics*
H1	Silver with gold lip plate	Bright, intense, broad sound; high harmonics
H2	Silver	Thinner, clearer sound; high harmonics
H3	Silver	Darker timbre; lower harmonics enhanced
H4	Silver	Broad, darker timbre; low partials enhanced
H5	Wood	Clear sound, defined; lower harmonics
H6	Yellow-wood	Darker timbre; low harmonics
H7	Red-wood	Good, rich, dark sound; rich partials, full
H8	Wood (thick-walled)	Strong sound, dark timbre; low partials

Table 2. Average of harmonics at 500 ms and 1000 ms of each flute headjoint, as well as headjoint pairings based on similarity of average harmonics.

Headjoint	*1st harmonic*	*2nd-3rd harmonics*	*4th-12th harmonics*	*Group*
H1	62.81% (SD 0.87)	32.91% (SD 0.23)	4.27% (SD 0.06)	H1+5
H2	72.99% (SD 4.95)	21.54% (SD 2.36)	5.47% (SD 0.07)	H2+7
H3	44.99% (SD 0.94)	45.96% (SD 5.28)	9.06% (SD 0.07)	H3+6
H4	78.93% (SD 8.17)	16.51% (SD 4.32)	4.56% (SD 0.07)	H4+8
H5	62.74% (SD 0.31)	31.52% (SD 0.08)	5.74% (SD 0.04)	H1+5
H6	45.22% (SD 4.21)	48.30% (SD 1.68)	6.48% (SD 0.04)	H3+6
H7	74.07% (SD 1.99)	20.09% (SD 0.72)	5.85% (SD 0.09)	H2+7
H8	83.36% (SD 2.89)	12.92% (SD 2.66)	3.73% (SD 0.04)	H4+8

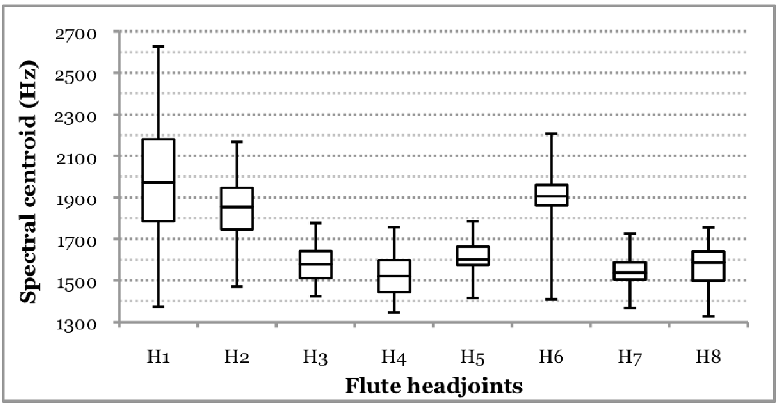

Figure 1. Audio spectral centroid of each flute headjoit.

nally, comments on H1+5 agreed on the overall sound quality, but not in regard to the perception of their harmonic contents.

Audio spectral centroid suggests a different grouping of headjoints: H1+2+6 presented medians around 1900 Hz, whereas all others within 1500-1600 Hz. Audio spectral centroid include partials that are non-harmonic (such as air noise) that also influence the perception of timbre. ANOVA resulted in highly significant differences between means of spectral centroid ($p<0.0001$), and Tukey HSD test resulted in the only difference between the means of H4 and H7 being non-significant, with H3+7+8 significant at $p<0.5$. The other comparisons were statistically significant differences of means at $p<0.01$.

DISCUSSION

The study of embodied knowledge leads to important epistemic problems: on one hand, due to the ineffable nature of embodied knowledge, qualitative methods do not suffice to describe how performers understand their own performances; on the other, quantitative methods may be too detached from the experience of performing music and may not represent it at all. Plausibly, only a combination of both qualitative and quantitative methods may lead to a better understanding of this kind of embodied knowledge. Another problem arises when (cognitive) feedback is provided to performers as quantitative analyses of their performances. Quantitative representations provide a partial representation of performance which cannot account for the whole. Such a limitation may have a positive influence if the goal is to focus on particular aspects of performance, but may also be detrimental if it prevents a more comprehensive (top-down) understanding of performance. Finally, experimental procedures may influence their own results: reflection on how the performer thinks about his or hers musical practice can lead to a different understanding of it, and thus to a different performance. Experimental designs with ecological validity may circumvent this effect.

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Understanding movement during performance: A recurrence quantization approach

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Traditional methods of signal analysis of one-dimensional data have limited use in unraveling how the movements of a musician in performance relate to the musical structure because performers' movements are complex. Methods developed for the analysis of multi-dimensional chaotic systems, such as recurrence quantification analysis, are well suited to dealing with complex data of this type. We compared traditional and non-traditional methods of signal analysis by applying them to the movements of a musician.

Keywords: movement; signal analysis; phase-space reconstruction; recurrence quantification analysis

Watching a musician move in performance can give the audience insight into the musical expression the performer is trying to convey (Davidson 2007). The movements of a musician may also provide visual information about other aspects of the music, such as its musical structure (Shove and Repp 1995). Traditional methods of exploring the complex movements of musicians in performance typically rely on video coding or point light recordings that often provide one-dimensional data (Davidson 1993, Davidson 2007). In addition, researchers have typically used analyses that assume data that meet the requirement of stationarity (i.e. the mean and variance do not change over time). However, movements in performance are neither stationary nor one-dimensional.

By using phase-space reconstruction (PSR), a technique from dynamical systems theory developed for analyzing chaotic systems, movements during performances can be completely reconstructed from information recorded in only one dimension (Takens 1981). Once the complete system has been reconstructed, it can be subjected to recurrence quantification analysis (RQA) to locate self-similarities within a performance. Further, cross-recurrence quantification analysis (CRQA) can compare different performances. RQA and CRQA provide visual and quantitative evidence of both the amount and location of recurrence in the movements as they unfold over the course of the performance.

We compared these non-traditional approaches (RQA and CRQA) to more traditional methods such as Fourier transformation (FT) and Hilbert phase transformation (HPT). We applied both traditional and non-traditional approaches to the movements of a violinist playing a Bach prelude in order to assess their ability to identify regularities in the violinist's movements.

METHOD

The movements of an amateur violinist (the first author) performing the Cello Suite No.1 (Prelude) by J.S. Bach ($^4/_4$ meter and 42 bars long) were recorded on a Nintendo wii Balance Board (at 35 Hz). We extracted data for side-to-side movements (x-axis) from the recordings of three successive performances using Matlab 2009, using the wiimote toolbox and the psychophysics toolbox (Brainard 1997). The three performances were roughly equal in length (135.38 s, 136.87 s, 135.58 s). The location of the beats in the music were extracted manually from an auditory recording of the performances. Figure 1 displays the movements as changes in postural sway in the x-direction for the first 30 seconds of the three performances.

RESULTS

Traditional methods

To explore the periodic components of the movements, the performance was divided into 21 sections, where each section included the movement from two non-overlapping measures. For each section, the average tempo (in Hz) was divided by the peak component frequency of the movement (extracted with FT). As can be seen in Figure 2, each performance contained movements that were roughly in simple ratios to the musical beat (2:1, 3:1, 4:1, and 8:1). However, there was little consistency across performances in which ratio occurred in each section of the music (Cronbach's α=0.60).

To more closely explore the periodic regularities, the phase of movement at each musical beat was determined, using HPT, and analyzed for phase-locking with a Rayleigh test. Phase-locking takes places when the periodic movement occurs at the same point in the cycle at each beat, indicating that the performer's movement is locked in a regular pattern with the beat. Except

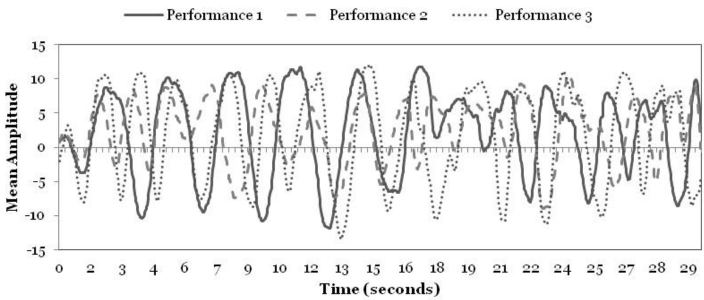

Figure 1. Movement of performer for the first 30 s of the three performances.

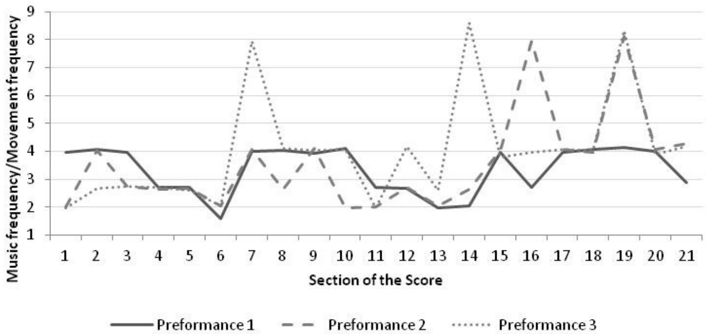

Figure 2. Ratio analysis using Fourier transformation.

for the first performance, there was no significant phase-locking between the music and performance. The presence of simple ratios between movement and musical beat in the FT analysis and the absence of phase-locking in the HPT analysis suggests that the relationship of movement to the musical beat was complex and possibly chaotic.

Using traditional methods, it is difficult to test for self-similarity within each performance. To do so requires searching for a particular movement pattern from one performance in the entire movement time-series, a time consuming process that requires the researcher to set many search parameters, such as the size of the pattern and the degree of similarity to search for.

As a first step, that did not require such complex methods, we evaluated the overall similarity of the performances by performing cross-correlations between the three performances. Since the performances were not exactly the same length, the data were trimmed to accommodate the shortest performance. The results suggested low to moderate levels of similarity between the performances (P1 vs. P2 r_{xcor}=0.45 at lag 1.4 s; P1 vs. P3 r_{xcor}=0.20 at lag 15.5 s, P2 vs. P3 r_{xcor}=0.28 at lag 0.4 s).

Summarizing the results of these traditional methods, the FT showed that the movements over the whole piece were regularly related to the beat; however, the HPT showed that movements often were not phase-locked with the beat. These methods, thus, identified some regularity in the movements. However, the absence of phase-locking suggested that the system might have been chaotic. The next section explores the same three performances using RQA, a method more appropriate for chaotic systems.

Non-traditional methods

To explore regularities and to test for self-similarity within each performance, an RQA was run on each performance. To prepare the data for RQA, each raw time-series was converted to z-scores. Next, a PSR (with a time-delay of 23 and embedding dimension of 4) was used to reconstruct the complete movement of the performance in high-dimensional space. The reconstructed performance was then submitted to RQA analysis (with a radius of 0.81 SD units). To evaluate the degree of structure in the resulting data, the movement from performance 1 was shuffled and plotted using the same parameters (see Figure 3).

Figure 3 shows plots of the time-series of the movement against the musical measures in which they occurred. The analysis compares each data point to itself (points on the diagonal) and to all the other points in the series. Each dot represents a place of recurrence, where the movements in high-dimension space "nearly" overlap. The diagonal line across the centre of the figure (line of identity) shows where the movements perfectly overlap—they are identical because they occur at same time. The shuffled plot contains the same number of recurrence points (dots) as the original performance but in random order. Comparison with the original performance shows that the movements were, in fact, highly structured.

As can be seen in Figure 3, movements in the first five measures repeat in each measure. This initial movement pattern is again repeated whenever the same musical pattern repeats, for example in bars 15-16 and 18-19. Overall, performance 1 showed recurrence in locations where music patterns recurred.

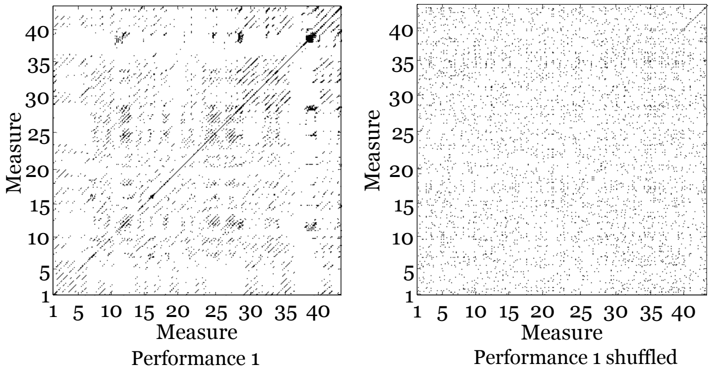

Figure 3. RQA plot of performance 1 vs. performance 1 shuffled.

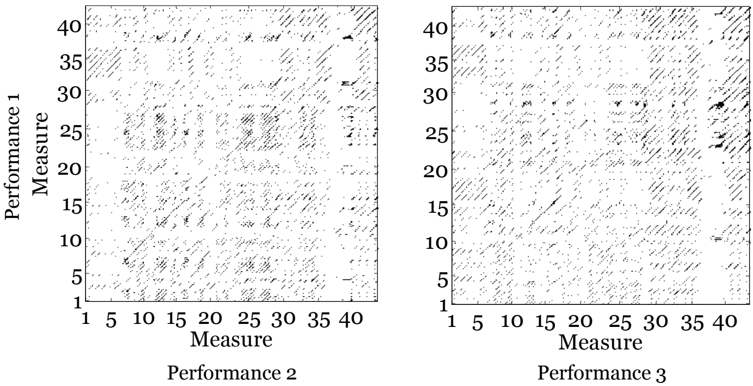

Figure 4. CRQA plot of performance 1 vs. 2 and 1 vs. 3.

Close comparison of the musical structure and the RQA plot reveals a wealth of such detailed relationships between the movements of the performer and the musical structure; the above description provides only a sample. In addition to the visual presentation, RQA and CRQA provide several quantitative measures not discussed here (for a review, see Marwan *et al.* 2007).

To measure similarities across the three performances, we performed CRQA between the performances, using the same parameters for each performance. The CRQA plots for performance 1 vs. 2 and 1 vs. 3 are shown in Figure 4.

As can be seen in Figure 4, there is partial line of identity for performance 1 and 2 indicating similarities in movement patterns between the two performances. For example in performance 1 vs. 2, there were high levels of recurrence starting at bar 24 and stopping at the end of the phrase (bar 29). However, the same pattern is not seen as clearly in performance 1 and 3.

DISCUSSION

Musicians and audiences alike believe that there is an intimate relationship between movement and music, but traditional methods have had difficulty in quantifying that relationship. Traditional methods can show how a performer's movements relate to the musical beat, but they are not well suited to showing more complex relationships, such as the recurrence of movements during performance. RQA and CRQA, in contrast, can reveal similarities between movements both within and across performances. The relationships between recurrence and musical structure that we have identified using these methods suggest that the intuition of an intimate and complex relationship between music and performers' movements is correct.

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Graduate award paper

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Sustained excellence: Toward a model of factors sustaining elite performance in opera

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While considerable research has explored the techniques professional athletes use to sustain performance excellence, much less research has focused on professional musicians. Multifaceted skills are needed to sustain performance excellence. This paper focuses on one dimension of the complex elite performance sustaining system: the deliberate preparation skills professional opera singers employ to maintain elite performance. Data drawn from interviews with five professional opera singers, with a minimum career length of ten years, were analyzed within the methodology of grounded theory. Results revealed a strong role for deliberate preparation in both physical and mental skills which contributed to high levels of self-efficacy, the key factor sustaining performance excellence for these participants.

Keywords: performance excellence; deliberate preparation; physical rehearsal; mental rehearsal; self-efficacy

Applying Dickie's (1974) "institutional" definition of art to performance, excellence in opera can be taken to be continued employment in major opera houses. Continued employment may indicate persistent performance quality and raises the question of how an artist maintains such a demanding standard. Emmons and Thomas (1998) maintain performance excellence in singing is "an outcome of physical, technical, and mental factors" (p. 12). World-renowned soprano Renée Fleming (2004) further articulates the skills necessary by stressing the need for "paying attention to aspects of physical health, the environment, mental fortitude, and, above all, a solid technique (p. 142). Clearly complex combinations of skills are needed to sustain performance excellence in opera.

Although there has been significant exploration into the techniques professional athletes use to sustain performance excellence (Ericsson 1996, Gallwey 1997, Orlick 2007), little research has examined the skills professional opera singers employ to the same end. Highly noteworthy is the fact that most research conducted in the area of music performance has utilized student participants (McPherson and McCormick 2006, Ritchie and Williamon 2011, Bonneville-Roussy *et al.* 2011) rather than successful professionals. The potential transferability of findings from studies of students or pre-professionals to elite opera singers is questionable. In her recent dissertation, Sandgren (2009) investigated the areas of health, personality, and skills of opera singers from a psychological framework and noted: "Less is known regarding how to maintain a high standard" (p. 20).

Reflecting on my own professional performance experiences in opera over the last ten years, including my regular appearances with various opera companies and orchestras across Canada, I find myself questioning: what skills are most important to sustain performance excellence? How do they interrelate for the best results? Are there strong similarities between professional opera singers in the area of preparation and in the cultivation of specific skill sets that serve to sustain performance excellence?

Illustrated in the work of Ericsson (1996, Ericsson and Williams 2007), deliberate practice as it relates to performance excellence is differentiated from other practice strategies in the need for high levels of concentration, motivation, previous experience, feedback, and repetition. In her dissertation, Sandgren (2009) concluded opera singers must include a combination of physical and mental practice skills involving an advanced vocal technique and mental rehearsal to ensure performance success. For the purposes of this paper, the term "deliberate preparation" will be used for greater specificity of the practice behaviors opera singers engage in outside of the traditional solitary practice room environment commonly associated with "practice."

When considering deliberate preparation strategies for professional opera singers the question arises: what is meant by an advanced vocal technique? In the work of Thomasson and Sundberg (1999), Thorpe *et al.* (2001), and Petterson and Westgard (2004), it was argued the vocal technique of an opera singer involves optimized breathing patterns, well-developed muscle memory at the inspiration phase, increased cardiovascular fitness, and a concentration of the singer's formant. A solid vocal technique is a necessary skill in advanced levels of vocal production and in projection levels necessary for performance excellence in opera. This vocal technique must be sustained.

In consideration of the limits of the human voice in relation to amounts of practice time and potential vocal injury, mental rehearsal is an invaluable tool for professional singers. Richardson (1967a, 1967b) provides a workable definition as the symbolic rehearsal of a physical activity in the absence of any gross muscle movement. In its application to music, Connolly and Williamon (2004) provide a synonymous definition, adding mental rehearsal, "predominantly aural, visual, and kinaesthetic for the musician…should be used to create or recreate an experience that is similar to a given physical event" (p. 224). In this article, the term "mental preparation" is used to encompass the specific use of visualization, simulated performance practice and development of cues as it relates to the maintenance of performance excellence for the participants.

With deliberate preparation involving physical and mental skills, Pajares (1996) and Bandura (1997) contend such skills serve to support and contribute to feelings of "self-efficacy," or an individual's belief in his/her own abilities to perform in a specific situation. In the area of music, researchers have begun to explore the relationship between self-efficacy to practice and performance ability (McPherson and McCormick 2006, Ritchie and Williamon 2011), although it must be noted the participants in the aforementioned studies were students. In acknowledgement of the above outlined skills considered necessary for the maintenance of performance excellence, and in the absence of little systematic research examining the specific skills professional opera singers employ to sustain performance excellence, this research study is driven by one comprehensive question: what are the skills professional opera singers use to sustain performance excellence?

METHOD

Participants

Five professional opera singers (1 soprano, 2 mezzo sopranos, 1 tenor, and 1 bass-baritone; age range=35-43 years) participated in this study. All participants are nationally recognized opera singers with Canadian citizenship, a professional career length of a minimum of 10 years, actively performing in top opera houses, with a minimum of 70% of income derived from professional performance. All potential participants were sent a preliminary email outlining the specific details of the intended research study including a formal invitation to participate. Upon acceptance of participation for this research, participants were then provided with a consent letter in accordance with Ethics Review standards with an option to exit the study at any time.

Procedure

The study was conceived and designed as grounded theory (Corbin and Strauss 1990, 2008). Data were acquired through two interviews with each participant that were audio-recorded in a place of the participant's choosing. The first interviews employed the use of open-ended interview questions to elicit general information and knowledge which explored the skills each participant uses to sustain performance excellence. Semi-structured interview questions were based upon the previous findings in the areas of vocal technique and maintenance (Miller 1996, McCoy and Kadar 2004, Sataloff 2006), practice skills (Ericsson *et al.* 1993, Krampe and Ericsson 1996), mental processes involving mental practice, visualization, and development of cues (Emmons and Thomas 1998, Cameron 2002, Ginsborg *et al.* 2006), and self-efficacy (Bandura 1997, McPherson and McCormick 2006). After the initial interviews, text was transcribed and analyzed using open-coding procedures to begin naming and categorizing the data, memos were written, and narratives were developed based on the interviews that were then returned to the participants for confirmation of initial analysis and used as grounds for further discussion in the second interviews. After the second interviews were completed, transcriptions, memos, and narratives were again completed. All interview transcriptions were further analyzed for concepts and similar themes that were then grouped together using constant comparative analysis techniques. Axial coding was implemented to identify the central phenomenon: performance excellence. The relationships of the major themes to the central phenomenon were then identified as physical and mental skills within the context of deliberate preparation. Once the major themes were identified, a conceptual framework was created to portray the relationships of the themes to the core phenomenon.

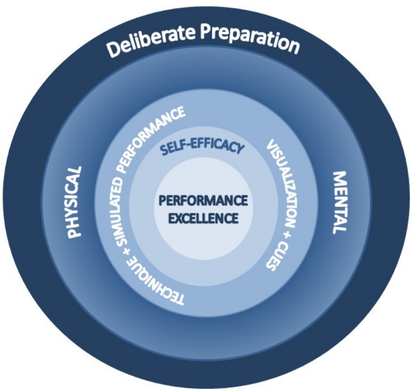

Figure 1. Model of factors sustaining performance excellence.

RESULTS

Findings of this study indicate a complex set of skills, and their continuous interrelation is necessary to sustain performance excellence in opera. Results indicate a process that consists of the combination of high levels of preparation in both physical and mental areas which allows for a greater sense of self-efficacy. With increased feelings of self-efficacy, the maintenance of performance excellence is achieved.

Deliberate preparation

Results indicated all participants reported the use of a regular practice routine in the maintenance of both their instrument and performance levels. All singers reported daily practice of breathing and technical exercises as part of their implementation of deliberate preparation skills.

When discussing the preparation for an upcoming operatic role, all participants described the process of the creation of a road map within their scores: first analyzing and translating the text, then adding the musical notes and phrases, working difficult passages every day in different octaves, working out breathing and appropriate breath support, referring to the score throughout the day, silently engaging in mental preparation in the exploration of the emotions and intentions behind the character, and delineating physical and mental cues necessary to identify the "release" or "space" needed to create advanced vocal production in conjunction with simulated practice of potential stagings and performing. One participant recounted the process of deliberate practice:

> I always translate first, know what I am saying, and then print out a practice sheet. It is a big checklist, and I tape it in the front of my score. There are sections for aria and scene title, text memorized, notes learnt, coached, performed. So I see the ticks and I know "ok, I have done this five times, I have to work on this now, skip this, come back to this later," and then I always coach it.

Physical: Vocal technique

In the area of fundamentals of vocal production from a physical perspective, the most pervasive theme was the importance of breathing as the cornerstone from which all advanced vocal production is based. Participants articulated the importance of practicing breathing and a sense of connectedness to the body as a necessity for sustaining performance excellence:

> I always figure out my breath support an octave lower. [I ask myself] "What is my support doing?" I need to do even more up there [reference to high notes]. I make it a habit now to never attempt another difficult note or phrase until my body say "yes, you can do that!"

Simulated performance

Another sub-theme that emerged in the physical area of preparation was the importance of the physical practice of the simulation of performance. One participant described the importance of this skill as it translates to higher levels of performance:

> I find in things that require stamina, I have to be able to do it in the practice room before I go out there and do it. When it is oratorio, I have to practice standing there, holding the book, re-creating the actual, how it feels to stand up there, whether they make you stand on a pew, one foot behind your head, whatever it is, the choir breathing down your neck, you have to be able to do it when you're practicing, you can't just put the music on a stand and do it because, when you are up there, it is completely different. I am starting to put the same principles necessary in my performance into my practice.

Reinforcing the necessity for the use of simulated practice as a tool for maintaining performance excellence was expressed by another participant:

> So I like to walk through things beforehand.... It is almost like when you see those ski jumpers and beforehand they are [mimes the hand motions and the simulated body movements as physical reminders of the timing of movements] before they even jump.

It is clear in the findings of this study, preparation of vocal technique and the use of simulations of performance emerged as important sub-themes in the area of physical practice as necessary skills in the sustainment of performance excellence. As the interviews progressed an inter-relationship was discovered between the skills involved in both physical and mental practice which then contributed to increased feelings of self-efficacy.

Mental rehearsal through visualization

When discussing the use of mental preparation for performance, all participants reported using mental rehearsal skills through visualization and the development of cues as necessary deliberate preparation skills in the facilitation of better practice and performance outcomes.

> When practicing I visualize the performance. I visualize that I am there, that I am safe and confident, and then I hear myself doing the music more than actually hearing the music, I have a sense that I am safe, confident, and joyful.

Another participant reinforced the necessity for the skill of mental rehearsal through visualization:

> I visualize the stage. I visualize who I am singing to and who I am with…. Any business that has to be done that doesn't feel completely natural, I have to go through in my head.

Development of mental cues

All participants expressed the importance of developing mental cues in their practice and preparation to ensure high levels of performance. In relation to the greater facilitation of vocal colors and intentions relating to the performance of different operatic characters, one participant stated the use of the mental cues "support" and "space." The participant articulated that the use of these mental cues directly applies to her ability to access adequate breath support and achieve high levels of vocal production consistently in public performances.

Another participant reinforced the use of mental cues in his character preparation for recital work which greatly aids in his ability to communicate with the audience. "I do prep work for recitals using key mental cues, usually adjectives describing how I feel...like the word courage." In the interviews with all participants, it became evident that the use of both physical and mental practice techniques in the form of deliberate preparation most effectively produced feelings of preparedness for public performance.

Self-efficacy

With the use of deliberate practice, participants then articulated the development of self-efficacy that evolves from solid preparation, which in turn allows for consistent levels of performance excellence.

> Well, this is the moment you have prepared for. You have done your technique, that is out of the way, you don't have to worry about that. That

> is what you do in the practice room right? Everything is in your muscle memory. You know it is going to kick in at that moment. I just have to go out there and just be. If I just tell the story, all the stuff that I have worked on before kicks in, and I can go out there and rock it.

Results of this study indicate that the use of physical and mental skills in the form of deliberate preparation does enhance feelings of self-efficacy contributing to performance excellence in the opera singers interviewed. It should be noted that all the themes and sub-themes presented in this study and illustrated in Figure 1 work in a continuous reciprocal process that serve to feed and support the maintenance of performance excellence in opera. The findings of this research and subsequent representation provided in Figure 1 are not linear in nature.

DISCUSSION

The importance and uniqueness of this study is twofold. This is the first study to exclusively research the inter-relationship of skills necessary for the maintenance of excellence in professional opera performance. Second, this is also the first study conducted by an active opera performer involving other active performers in the same arena. The situated nature of this knowledge needed as an analytic lens to fully understand the complexities of the data acquired in the study required an "insider's" perspective.

Findings indicated that, within the larger skill of deliberate preparation, a relationship between physical and mental skills exists which serves to contribute to feelings of self-efficacy and the sustaining of performance excellence in opera for these participants.

The relationship between deliberate preparation and levels of performance in this study expands on the past research of Ericsson *et al.* (1993) and Lehmann and Gruber (2006), who reported that to attain high levels of performance one must employ sustained deliberate practice skills. This study takes previous findings past the achievement phase of development to the sustaining of performance excellence in professionals as opposed to results using student samples.

It is also important to recognize the role of mental preparation and simulated performance for singers, as they not only expedite the learning of new roles but also allow for the consideration that singers simply cannot physically practice for the same amounts of time as instrumentalists. These findings extend Sandgren's (2009) earlier work which reported that it is necessary for opera singers to acquire mental practice strategies to prevent voice overuse, tension, and possible injury, and to accommodate for situations where physical practice is not possible.

Findings also uncovered the crucial role high levels of self-efficacy play in the continuation of elite performance levels for these participants. Although recent research by McPherson and McCormick (2006) did examine the relationship between practice, self-efficacy, and performance, the study was again conducted with students. The mental set of one who is developing, aspiring, auditioning, and competing is quite different from one who has already attained the desired status and now is in a position to sustain it.

In conclusion, further research is warranted to facilitate and develop new insights into the skills and processes professional opera singers use to sustain performance excellence. The implications of these new insights are far reaching. Development of knowledge in the area of performance excellence in classical singing can begin to fill the gap of scholarly research and may also serve to enhance the facilitation of better techniques and strategies in the areas of practice, preparation, and performance for professionals and students in performance-based areas of study. Finally, the continuation of this research may also contribute to the earlier development of consistency and maintenance of high levels of performance across performance disciplines at earlier stages of development.

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Dance pedagogy: Myth versus reality

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The teaching of ballet is steeped in tradition. As a dancer retires from the stage, he or she will often embark upon a teaching career in order to provide a continuation of that tradition for the next generation. It is not uncommon for the institutional tenets of training dance skills to be at odds with what is biomechanically sound and, therefore, unsafe for the dancer to repeat in daily technique class. Dance science had its beginnings in the late 1960s. Colleges and universities began to turn a serious eye to the analysis of the physical component of dancing. Rudimentary equipment, such as videography, has given way to very sophisticated movement analysis systems such as 7-camera motion capture systems. As the ability to "see" dance increases with more refined tools, teachers of dance in general and ballet in particular need to make anatomically sound corrections and unassailable decisions in the training of young dancers, as the technique class should be the first stop in injury prevention. This presentation touches on just a few of the discrepancies between what is taught and what is actually possible to achieve in the ballet class.

Keywords: ballet; pedagogy; biomechanics; injury prevention

The technique of ballet, as codified and practiced in a class or studio, was developed at a time when biomechanical and kinesiological principles of movement were poorly understood. Misconceptions then became part of the ritual of dance class and dance training, passing from generation to generation. An important concern here is that such misinformation may lead to injury and decreased aesthetic performance. In recent years, advances in biomechanical analyses have allowed dance researchers to "see" what is occurring during skill execution. In many cases, the instructions given during a dance class do not match biomechanical reality.

It must be pointed out that as this field of dance science grows, the lessons of good research are integrated quite slowly. Jo Anna Kneeland first wrote a series of articles in 1966 on ballet technique with an anatomical perspective for *Dance Magazine* (Kneeland and Joel 1966, Kneeland 1966a, 1966b, 1966c). However, it was more than a decade before actual research actively began looking at the difference between what the dancer is asked to do and what is actually possible to accomplish.

This review, derived from recent work by Krasnow and colleagues (2011b), is intended to give an overview of research in the field of dance biomechanics, with visual demonstrations of how divergent class teaching and actual execution of dance steps can be. Plainly stated, biomechanical efficiency of skill execution often contradicts common teaching instructions. The purpose of this lecture is to gain a greater understanding of how careful a teacher of dance needs to be when clarifying what is "correct" in the acquisition of good dance technique.

MAIN CONTRIBUTION

Dance teachers teach what they were taught. Traditionally, the dance teacher uses the same language, images, technical corrections and approach that they experienced as a student. Books on pedagogy are few. Joan Lawson's (1975) *Teaching Young Dancers,* for example, has long been held as the quintessential handbook on how to consider this strictly codified dance form. It was one of the first ballet books to provide basic anatomy to the reader. However, it clearly presents an incomplete picture of the realities of human movement. There have been nearly a hundred studies on biomechanical assessment in dance in the last 50 years, beginning with quite rudimentary forms of assessment (photographs, single camera videography, pencil and paper assessment of joint angles, and plumb-lines and yardsticks to assess alignment and distance, respectively). This paper and lecture covers just three components of ballet: alignment, the use of the barre in ballet class, and the advanced skills of jumping.

Alignment

All dance technique presumes that the dancer is capable of maintaining good alignment. Alignment is understood to be the cornerstone of injury prevention, as well as aesthetic propriety. This concept assumes that the performer can stand and travel while perfectly upright and balanced with regards to distribution of mass in three planes. It is standard teaching practice to exhort the student ballet dancer to maintain the same upright alignment, no matter the condition (barre, center, traveling). However, in early research, Woodhull-McNeal *et al.* (1990) used photographs to clarify that first position and other positions (3^{rd}, 4^{th}, 5^{th}) had glaring postural differences, standardized to the position, but differing significantly from each other. The point to be made is that alignment is not a stable concept, but is variable depending on one's starting position and one's intent. They also suggested that alignment is variable by condition in individual participants.

Krasnow *et al.* (1997) took the next step, as it were, stating that it is essential to study alignment in dynamic rather than static conditions. They were looking at the effect of imagery on dancers and noted that giving dancers an accurate anatomical image can help assure re-establishment of correct alignment following off-balance movement. Their point was that alignment is a fluid entity and can change depending on the circumstances.

Wilmerding *et al.* (2003) looked at the alignment of children studying flamenco dance, understanding that the heeled shoe is known to alter the postural alignment in adults posteriorly. Statistical analysis evidenced an even division with regards to strategies. Half of the children shifted to greater anterior pelvic tilt and half shifted to greater posterior pelvic tilt when compared with a barefooted stance. As children are known to have poor core strength, care and planning for development of trunk strength in young dancers becomes the take-home message of this research, as again, alignment is important in injury prevention.

Barre

An essential aspect of the warm-up period of a ballet class is the barre, a horizontal bar on which one hand is placed while holding positions and performing movements. Barre use is aimed at providing support to the dancer. The skills required of ballet are first executed at the barre, broken down into small, accessible, and repeatable movements. The dancer is provided in effect with a "partner" by placing one or both hands on the barre. After the skills are practiced at the barre, the dancer proceeds to centre and repeats these skills in increasingly complex fashions without weight support. There is a presumed positive transfer of training when moving the dancer from the barre to center. The exercises practiced with weight support during warm-up are meant to facilitate the execution of the same movements without physical support. However, Cordo and Nashner (1982) found that when leaning on a bar, the postural reflexes did not respond as the subject performed arm gestures that disturbed balance.

The transfer of training from barre to center is undocumented. It is unknown if the muscular and biomechanical movements at barre are similar enough to be appropriately assigned as positive transfer or dissimilar enough to cause a negative transfer. If the latter is the case, the warm-up at barre may be eroding, or at least interfering with, dancing ability.

In a theoretical article, Laws (1985) examined the use of the barre in dance training. Some of Laws's observations include the following: (1) at the barre, more forward shift of torso is possible in performing arabesque than may be possible in center work; (2) the barre allows for stabilization of the torso in movements such as rond de jambe, which may require internal stabilization techniques in center; (3) turn initiations using the barre cannot be executed in center work in the same manner; (4) in summary, the barre has important uses but some of the ways it is currently used may not be transferable to work without a barre.

Unpublished research by Sugano and Laws (2002) indicated that large forces can be exerted on the barre which may substitute for proper muscle use rather than subtly helping to develop technique. The hand that holds the barre may in fact account for extensive changes in biomechanical function of the dancer, changing their alignment, muscle activation, and weight shift strategies. Sugano and Laws identified that dancers may exert strong longitudinal forces on the barre to force turnout; that is, dancers place their feet in an externally rotated position that is beyond the anatomical capacity of the joints of the lower extremities. If the dancer then releases their hand from the barre, the body will rotate towards the barre around a vertical axis. Even when the dancer places a vertical force down on to the barre, weight is borne at the shoulder and removed from the weight-bearing foot.

Wilmerding *et al.* (2001) found that the muscles of the standing leg (abductor hallicus and tibialis anterior) were far less active at barre than they were at center, when the body did not have this external support. It is possible that the results of Sugano and Laws work explain the findings of Wilmerding and researchers. Their findings do suggest that postural responses for balance may not be well trained at the barre. As a typical ballet devotes nearly 50% of the class period to barre-work, it is possible that barre does not accomplish the task that teachers think that it does. Further, devoting this extensive time to barre-work may deny dancers important experiences in center and travelling work, which is essential in fully preparing them for dance practice and performance.

Preparation for jumps and execution of jumps

The end of a barre concludes with big kicks, or grand battement. Grand battement are known to be the precursor to many jump skills, preparing the gesture leg to develop speed and power to propel the body into the air. Lawson (1975) states "…the dancer must clearly understand that the working leg alone performs" (p. 71). The landmark work of Ryman and Ranney (1978) compared four dancers executing a grand battement. They used electromyography and rudimentary motion analysis and noticed that the gesture leg bent in the initiation of the movement, the pelvis tilted posteriorly, and turnout was not maintained in the gesture leg. The researchers suggested that many of the assumptions that dance teachers make in training this movement are not supported by the results of their study. Their findings stand in stark contrast to Lawson's explanation of the same skill.

Preliminary findings in the research of Krasnow *et al.* (2011a) corroborate these results, observing the posteriorly tilted pelvis and the limited turnout of the gesture leg at the height of the grand battement. In a study using 42 dancers of various skill levels, they also found that apparently all dancers involuntarily flex their standing leg at the height of the grand battement.

Ryman (1978/79) studied one dancer's execution of six different jumps, making four conclusions: (1) deeper pliés do not yield higher elevation; in this study, the moderate pliés yielded the best results; (2) suspension at the top of an elevation step is an illusion; that is, the ascent and descent are one continuum; (3) for turning elevation steps, the turn must begin at pushoff, not at the top of elevation; and (4) the foot sickles at the moment of pushoff. All of these findings are contrary to instruction by dance teachers.

Dancers are regularly instructed to land all jumps by focusing on the heel making contact with the floor. Dozzi (1989) demonstrated that forced heel contact or what is called *pressing* the heels into the floor actually caused more "double striking of the heels on the floor," suggesting to the researchers that the teaching cue of pressing the heels to the floor in jump landings is not a good teaching tool and may in fact increase risk of injury.

Laws and Lee (1989) analyzed the grand jeté using videography. One professional dancer performed 10 of these leaps. The researchers calculated aspects of the grand jeté such as velocity and momentum. Results included the following: (1) the time that the head and torso move horizontally at the top of the jeté can be more than half of the flight time; (2) the jeté is less effective if turnout of the push-off foot is maintained during the take-off phase; and (3) about half of the energy of the total jeté is expended in the take-off.

Point 2 stands in stark contrast to the standard instruction to maintain turn-out at all times.

IMPLICATIONS

All told, the pedagogical principles that form the basis of the standard ballet class can be regarded as solid and safe. Class begins slowly and steps to be executed are advanced in speed slowly over the 1.5- to 2-hour class. Class begins with the external support of barre and moves to center. The center work begins slowly (adagio, pirouettes) and moves on to faster, larger jumping skills (petit allegro, grand allegro). The dancers begin in wide, stable stances that place minimal stress on the knee (2nd and 1st position), as found by Barnes *et al.* (2000), and moves carefully to positions of less stability over time (5th position, single leg balances). However, there appears to be a lack of understanding by many who teach dance about the actual biomechanics of steps or skills in ballet. Biomechanical research is beginning to uncover the mysteries of the actual difference between safe, aesthetically pleasing technique and faulty technique. The presumption is that as the body of knowledge develops, the dance teacher will have a greater ability to train a strong and flexible dancer whose health will not be compromised by injury.

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Poster session

International Symposium on Performance Science
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Characterizing accomplished musicians' learning over time

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Previous research has demonstrated that learners performing repetitive movement sequences show evidence of consolidation-based performance enhancements following overnight sleep. But the effects of the organization of musicians' practice on consolidation-based gains have not been investigated. In two experiments, we examined the effects of (1) the presence of an auditory model and (2) learner-regulated practice on performance improvements during and following practice of a 13-note keyboard melody. In the first study, an auditory model of the melody was played at regular intervals throughout practice for one of the participant groups. In the second study, participants practiced the same melody in a self-regulated manner and were not constrained to the rigid practice protocols used previously in this line of research. All participants returned for a retest on the target melody following overnight sleep. We discuss our results in relation to current models of motor performance and memory formation.

Keywords: music; consolidation; sleep; practice; modeling

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Constraints on memory for verse

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Participants learned limericks either while moving rhythmically or remaining still to assess how movement and characteristics of the material act as constraints on memory. During testing, they heard individual lines from the limericks (*originals*) and four types of foils that violated the meaning (*semantic violations*), rhyme scheme (*end substitutions*), rhythm (*rhythm violations*), or surface features (*internal substitutions*). They indicated whether each stimulus came from the limericks they learned and how confident they were. Participants were better able to discern semantic violations from the lines on which they were based than either the internal substitutions or rhythmic violations from their originals. Movement did not have a reliable effect on participants' ability to discriminate between originals and their corresponding foils. Participants were more confident in responses to semantic violations and originals than they were to either the rhythm violations or end substitutions. Meaning appears to be a better constraint on memory than surface features or rhythmic movements. The confidence ratings suggest the participants were aware of this difference. Movement may only act as a constraint on memory if it is instrumental in the production of the material (e.g. music and drama).

Keywords: memory; verse; movement; recognition; constraints

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Coping with performance anxiety: Choral singing, psychological states, and cortisol

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Choral singing has several psychological, physical, and social components that can interact and contribute to feelings of wellbeing. These beneficial and positive effects of choral singing can become relevant particularly in the context of public performances. Performance anxiety is a natural reaction to public performances and an increase in cortisol has been found after a choral performance but not rehearsal. At the same time, it is possible that performance anxiety can be coped with successfully with the help of the psychosocial benefits of choral singing. This study aims to clarify contextual effects of choral singing on cortisol, to clarify the interactions between psychological states and psychophysiological measures of performance anxiety, and to clarify effects of choral singing on wellbeing. Participants recruited from the Canterbury Christ Church University's high performance choir provided physiological (saliva samples) and psychological (questionnaire) measures before and after a choral rehearsal, a choral performance, and a passive control on a different day of the week but same time of the day. The results will be presented at the conference. However, we expect cortisol levels to increase after a performance. The increase in cortisol levels will not necessarily lead to anxiety after the performance and negative affect states will rather be connected with the individual's perception of performance: if the performance is perceived as positive there will be a decrease in negative affect; if it is perceived as negative there will be an increase in negative affect.

Keywords: performance anxiety; cortisol; choral singing

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Verbal expression of piano timbre: Multidimensional semantic space of adjectival descriptors

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High-level pianists refer to and can identify nuances in timbre by way of a wide and rich vocabulary, whose abstract, imaged, and metaphoric terms acutely designate a variety of sounds. This timbre-describing lexicon is hereby studied quantitatively. The semantic proximity between pairs taken among 14 common piano timbre descriptors was evaluated in questionnaires distributed to 17 pianists. Ratings were analyzed with multidimensional scaling algorithms, yielding a four-dimensional space representing the semantic proximity between descriptors. Using cluster analyses, five main subsets were identified, within which the most familiar terms were selected. We thus obtained five descriptors which optimally describe the whole semantic space for the group of pianists taking part in this study: bright, dry, dark, round, and velvety.

Keywords: piano; timbre; verbal description; semantic space; multidimensional scaling

Timbre is an essential feature of musical expressivity in virtuosic pianistic performance. Timbre indeed intervenes, not solely as a characteristic of the instrument, but also as performers can modulate and shape sounds in order to express their musical intentions. Such ability to modulate timbre in very subtle ways usually stems from the piano learning process within which, at the higher level, timbre concepts, emotions to instill, and the adequate sound are conjointly demonstrated to the student through masterly performances. Those come along with an extensive vocabulary, whose imagery in terms such as clear, warm, metallic, or shimmering, aims at evoking the sonic nuances.

While many timbre studies (e.g. Grey 1977, McAdams *et al.* 1995) have dealt with building perceptual timbre spaces, they only compared timbre perception between different instruments without delving into one single instrument's timbral subspace. Others have focused on timbre verbalization and managed to define axes or spaces of timbre description (e.g. Von Bismarck 1974, Disley *et al.* 2006). However, attempts to weld semantic and perceptual spaces (Faure 2000) mostly proved unsuccessful. In the specific case of the piano, Ortmann (1929) linked common piano timbre verbal descriptors with characteristics of touch but only in relation with single notes. More recently, the study of free verbalization (Cheminée *et al.* 2005) revealed the specificity of the pianists' sound-describing lexicon, built upon an affective and axiological vocabulary following two axes: percussion and resonance. Bellemare and Traube (2005) studied piano timbre verbalization through interviews of 16 highly trained pianists—thus was gathered a comprehensive collection of close to one hundred terms, detailed with descriptions, synonymic relationships, and frequency of occurrence.

On the basis of this verbal data collection, our study explores further the piano timbre-describing vocabulary and quantifies its semantic structure. To this aim, pianists were asked to determine the semantic similarities between descriptors. We thus aimed at building a spatial representation of semantic relationships between piano timbre descriptors, while focusing in identifying therein the most encompassing subset of descriptors that would suffice to accurately describe the whole space.

METHOD

Participants

Seventeen pianists, most of them from the Faculty of Music at the University of Montreal, plus others from elsewhere in Canada, France, and Finland, took part in the study by filling in questionnaires, either on paper or electronically.

Materials

The questionnaires were conceived to probe the semantic similarities between common piano timbre descriptors. The 20 most frequently cited descriptors in Bellemare and Traube (2005) were first selected. Then, in light of the synonymic relationships between them, the corpus was downsized to the following 14 terms: brassy, bright, clear, dark, distant, dry, full-bodied, harsh, metallic, muddled, round, shimmering, soft, and velvety.

Procedure

The participants were asked to rate their familiarity with each adjective, then to rate the semantic proximity between each of the 91 pairs of adjectives from

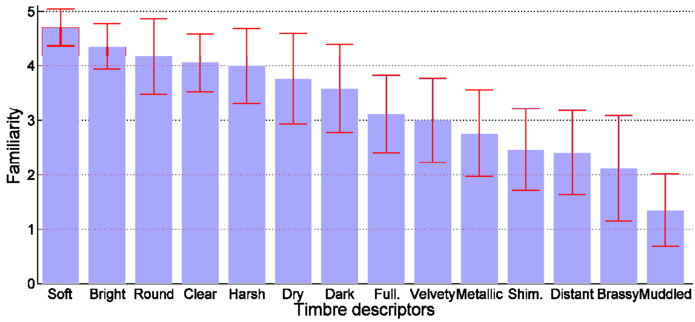

Figure 1. Mean evaluation of familiarity with piano timbre verbal descriptors.

the 14 terms set. All ratings were indicated on six-degree, zero-to-five Likert-type scales. The printout order was randomized for each questionnaire. Questionnaires were filled in and sent back anonymously.

RESULTS

Familiarity with timbre descriptors

The evaluations of familiarity with the fourteen piano timbre descriptors, gathered from the seventeen filled-in questionnaires, were averaged per descriptor. The resulting means are presented in Figure 1.

The large variability in familiarity assessment between participants—as the error bars (±2 standard errors) in Figure 1 indicate—may impair any generalized conclusions, yet shall let us use those familiarity rankings for the sheer purpose of highlighting one descriptor within a subset.

Dissimilarities and semantic space

Meanwhile, the assessments of semantic proximity were compiled as similarity matrices, then reversed and metrically re-scaled in dissimilarity matrices, which were fed into a metric multidimensional scaling algorithm. The optimal dimensionality was set at four, as the fourth dimension yields the last significant stress improvement (over 0.001) and is the last within which distances are of significant range and seem meaningful and interpretable. The resulting space is displayed in Figures 2 and 3. The associated stress value is 0.045. The distances between descriptors in this 4D space show a linear correlation (r-squared) of $r^2=0.931$ with the original 14-dimension dissimilarities. Each dimension accounts for respectively 49.3%, 27.7%, 13.4%, and 9.6% of the MDS reconstruction (by way of the space's eigenvalues ratios).

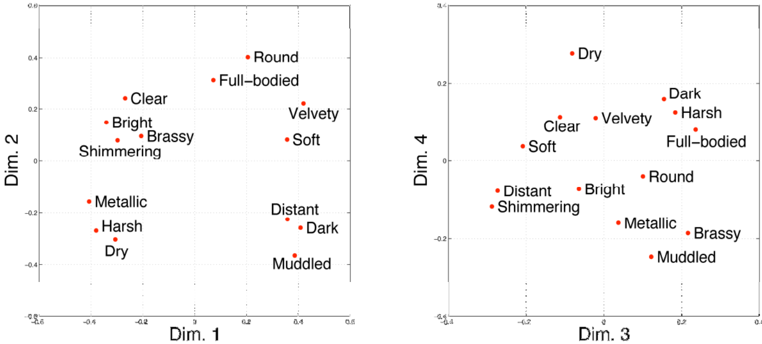

Figure 2. Planar projections of the 4D MDS semantic space: dimensions 1 vs. 2 and dimensions 3 vs. 4.

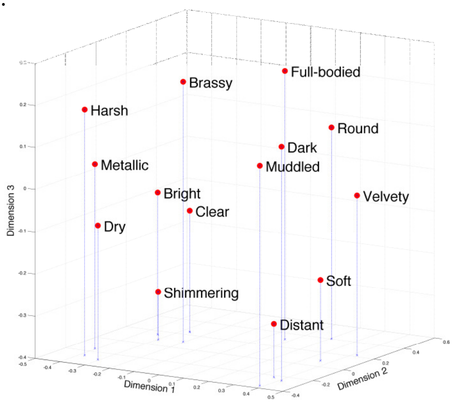

Figure 3. Display of the first three dimensions from the 4D MDS semantic space.

As for accounting for the dimensions' semantic meanings, conjectures may be made that the first dimension is associated to "sharpness" or "brightness"—acoustically, simply put, the relative amount of higher frequencies. The second dimension may account for "warmth"—acoustically, the relative amount of low-to-mid frequencies. The third and fourth dimensions are more difficult to assess, although the third dimension may relate to some inherent timbre "loudness," and the fourth may seem akin to "presence."

Cluster analysis

In addition to the multidimensional scaling of the dissimilarity data, hierarchical clustering was performed with different distance measures: weighted

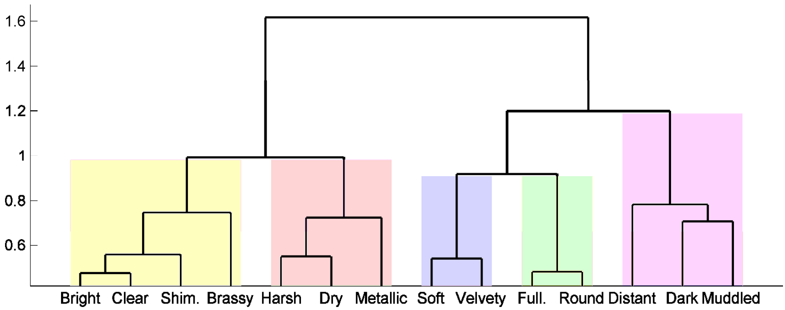

Figure 4. Dendrogram of the descriptors' dissimilarities hierarchical clustering. (See full color version at www.performancescience.org.)

and unweighted average (WPGMA and UPGMA, respectively), furthest distance, and inner squared distance (i.e. minimum variance). K-means partitioning algorithms were likewise ran. Results were essentially similar between methods, with the only difference the strength of linkage between "brassy" and "metallic" at the sixth-cluster level. The semantic clustering tree of descriptors, with UPGMA as distance measure, is presented in Figure 4.

DISCUSSION

To identify the clusters within the semantic structure of piano timbre descriptors, the MDS semantic space was first examined. Over the dimensions 1-vs.-2 plan—which accounts for 73.5% of the dispersion—five groups were singled out within the descriptors' set: [brassy, bright, clear, shimmering], [full-bodied, round], [soft, velvety], [dry, harsh, metallic], [dark, distant, muddled]. Those exactly match 5-branch subsets resulting from the cluster analysis (see Figure 4). For each of those five clearly identified subgroups, one single representative term was sought out with regard to the familiarity ratings and also to the relations between timbre and dynamic levels (see Bellemare and Traube 2005). Timbres too dynamically constrained or which double as dynamics descriptors, especially when unfit for a *mf* dynamic (i.e. soft and distant), were discarded. Also favored were the descriptors that best helped describe the MDS dimensions 3-vs.-4 plan, whose subsetting outlook is less salient. Finally, the five terms that best represent the whole semantic space of piano timbre descriptors are: bright, dry, dark, round, and velvety.

The spatial representation of piano timbre descriptors may prove a useful pedagogical tool for pianists, in facilitating access to understanding timbre as a multidimensional concept. The selection of the most encompassing piano timbre descriptors will now be employed to study the gestural control of piano timbre. Miniature piano pieces were composed so as to fit each of the five timbres, and the gestures applied by pianists to color their performances will be analyzed, in the aim of obtaining a gestural mapping of piano timbre that could prove relevant to piano pedagogy and software modelization.

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"I kind of get lost in it": Experiences of learning to perform music in older adulthood

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This study reports data collected as part of the *Rhythm for Life* project in the UK. Running from 2010-12, *Rhythm for Life* provides free programs of instrumental music lessons to adult beginners aged 50 or above. Through phenomenological interviews and analysis, the paper aims to understand the experiences of learning to play a musical instrument in older adulthood. Based on semi-structured interviews with ten adult learners, Interpretative Phenomenological Analysis (IPA) revealed four emergent themes that characterize the learners' experiences: (1) learning music as offering enhanced social interaction, (2) learning music as offering enhanced (musical) self-confidence, (3) learning music as a form of self-regulation of mood and emotion, and (4) learning music as offering scope for transcendence. This paper considers each of these themes in turn to discuss an emerging "model" of how learning to play a musical instrument in older adulthood is experienced by learners.

Keywords: older adulthood; learning; wellbeing; instrumental music; qualitative research

The *Rhythm for Life* project, based at the Royal College of Music (RCM), aims to enhance wellbeing among older adults through creative music-making. Running from 2010-12, the project provides free programs of instrumental music lessons to adult beginners aged 50 or above, facilitated by specially-trained RCM students. Taking the theme of the conference as a point of departure, this exploratory paper discusses an emerging "model" of how learning a musical instrument in older adulthood is experienced by learners.

Research in this area, while rapidly developing, remains somewhat limited. Much current literature exploring the role that music plays in the lives of older adults has focussed on the therapeutic uses of music, casting the participant in a passive role of listening to, or consuming, music. Indeed, listening to music is shown to play a large part in the lives of older adults and particularly as a self-regulator of wellbeing (Laukka 2007) or in order to give meaning to life's experiences (Hays 2005). Another body of research has begun to investigate the impact of *making* music on aspects of wellbeing. For example, Koga and Timms (2001) reported decreased anxiety, depression, and loneliness in those that participated in music lessons, while Cohen *et al.* (2006) conclude that sense of control, as well as social engagement, is enhanced through participation in arts programs. Furthermore, piano instruction has been shown to increase cognitive abilities related to attention and concentration (Bugos *et al.* 2007), and more recently, Clift and Hancox (2010) reported increased wellbeing among 1124 singers drawn from Australia, England, and Germany.

Despite an increasing focus on the role of lifelong learning in the mental wellbeing of society (see Field 2009), however, there is little UK research that explores this in specific relation to learning a musical instrument, nor that seeks to understand beginner adults' experiences of such endeavour (for a useful exception, see Taylor and Hallam 2008). This paper, then, aims to meet these gaps by qualitatively understanding the experiences of learning to play a musical instrument, from beginner level, in older adulthood.

MAIN CONTRIBUTION

Participants

Ten older adults were recruited to take part in the study (mean age=66.7 years; eight women and two men), all of whom had participated in a 12-week *Rhythm for Life* program of free instrumental lessons between April and July 2010. Four of the participants were djembe drum learners (all group learners; labeled henceforth as D1, D2, D3, D4), three keyboard learners (two individual learners and one group learner; K1, K2, K3), and three recorder learners (two individual learners and one group learner; R1, R2, R3). All described themselves as beginners, with little or no previous instrumental learning experience.

Materials

Working within an interpretative framework, the study adopted a phenomenological approach. A semi-structured interview schedule elicited spoken responses to participants' subjective experiences of learning a musical instrument in older adulthood. Specifically, the interview schedule focused on

(1) subjective experiences of learning an instrument and (2) subjective experiences of the link between music and wellbeing.

Procedure

The ten participants were sampled from a larger group of 33 older adults who had participated in the *Rhythm for Life* program. Sampling was predominantly convenience, with emphasis also placed on equally representing the instruments being learned. Participants were interviewed individually by the first author either at their homes or at RCM offices. All interviews took place following the learner's final lesson, were recorded with permission, and fully transcribed. Analysis was guided by Interpretative Phenomenological Analysis (IPA) to construct emergent and preliminary themes that elucidate the topic under study from the learners' perspectives.

RESULTS

Preliminary analyses reveal four emergent themes, each of which unpacks different aspects of the experiences of learning a musical instrument in older adulthood. Here, they are presented in order of qualitative strength.

First, learning music appears to offer an opportunity for enhanced social interaction. For group learners, this manifests itself both in and out of the actual lessons: "Just being part of a group is really good…. Learning together is really good" (D4). "We often, not too long, but often sit outside [of our homes] on the bench practicing together" (D3). This effect, however, is not limited to those learning in a group. For one-to-one learners, regular interaction with their teacher—and the regular appointment of their lesson—also appears to be important, both in mitigating against loneliness (R1) and in providing a point of enjoyable social contact: "these lovely people come into your house, and they are so nice and sweet and so on and they lighted your life" (K2). For both group and individual learners, then, their music lessons provided a welcome enhancement to social interaction.

Second, learning music operates as a means of enhancing (musical) self-confidence: "I just played it and I think I obeyed all the instructions, and it sounded good and I was really chuffed with myself you know" (K1). "Now I feel more confident I can go, and even if it's no good I can still—that is where it has helped out, confidence and expressing myself" (D2). Indeed, while fun and enjoyment are pivotal to the learners' experiences, this is balanced with a strong sense of seeking, and achieving, progress: "It gives me personal involvement with music and a way of concentrating on certain pieces and the satisfaction of knowing that I am making some progress however slow in the special subject of my choice" (R2). For these adults, many of whom have waited many years for an opportunity to learn music, being able to make—and recognise—progress emerges as an important part of their experience.

Third, learning music appears to act as a form of self-regulation, or as a catalyst for changing or monitoring one's emotional state or mood. At one level, this seems to operate by offering a form of release, "[it] relieves tension for one thing" (D1), or through providing a means to "transform your mood" (K2). At another level, though, it also provides a means for learners to *connect* with emotions that may hitherto have been suppressed:

> I think with something like learning…to play the recorder, it will help me to express emotions which otherwise it, how do you say express an emotion, you can cry, you can eat too much or whatever but there is the very fine sensibilities of a sensitive person. Well, in business that is not an asset you know and in various things you do you suppress that, and you're sort of being something else; you are decisive or you are being, talk firmly and loudly blah blah blah, but with music it is quite okay to be sensitive, so I think this is a good side of things (R1).

For this participant, learning the recorder has provided a "way in" to an emotional world that enables him, and permits him, to express his emotions. While such self-regulation has been observed in *listening* to music (Laukka 2007), these findings suggest that the same may be true for *making* music.

Finally, learning music emerges as a form of transcendence, or the opportunity to move beyond everyday worries. This transcendence appears to be manifest through a sense of becoming "lost in it" (K1), with attention focused solely on the multiple demands of learning music: "you can't think of anything else but the music itself" (R2). Furthermore, learning an instrument can offer learners the chance to "escape" from the day-to-day: "I think if you're ever feeling a bit down or got some problem you forget about it for a little while because you are having a bit of fun" (K3). Indeed, fun or enjoyment was a recurring focal point within the interviews, as captured by one of the drummers: "I really enjoyed it. I loved it. I just loved the rhythms and the sounds and working together and just creating the different rhythms. Yeah it was really exciting. I really enjoyed it. I loved it" (D4). For these participants, then, learning music can be said to create a space in which it is possible to transcend the day-to-day.

DISCUSSION

While preliminary and small-scale, the insights generated in this study suggest that learning a musical instrument in older adulthood is experienced as offering (1) enhanced social interaction, (2) enhanced (musical) self-confidence, (3) a form of self-regulation of mood and emotion, and (4) scope for transcendence. Cutting across this entire emerging model is the strong presence of individual motivation, life circumstance, and musical history in shaping what, and why, adults experience when they learn music. Knowing this, provision in *Rhythm for Life* and other such initiatives can be tailored to maximize the positive impacts of learning music in older adulthood. In particular, the results indicate that learning music can provide a valued "space" for fun, enjoyment, escape from everyday concerns, self-regulation of mood and emotion, and social interaction. Additionally, learning music is something that participants take seriously, that allows them to fulfill often long-term goals, and that contributes to musical and non-musical confidence. It appears important, then, for provision for older adults to respect both the space for transcendence and the space for progress.

Our ongoing research continues to unpack the themes described here, extending the dataset in order to draw comparisons between individual and group learning. Additionally, a quantitative dataset is also being compiled in order to permit a mixed-methods approach that will allow for triangulation and development of these emergent findings. Preliminary results, though, indicate that learning a musical instrument in older adulthood is a multi-faceted experience that can bring with it powerful benefits to aspects of wellbeing.

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Music performance learning model

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The present article proposes a model for music performance learning based on three root principles: motion, memory, and consciousness. Broader viewpoints are proposed, such as recognizing intuition as forms of knowledge. Sources from various scientific areas provide solid bases and dialogues, favoring better understandings of music performance and definitions of learning strategies. Implications point to the need for improved performance pedagogy within music institutions.

Keywords: music performance; music education; performance pedagogy; learning model; interdisciplinarity

Since the first rudiments of musical activity in civilization, about 40,000 years ago (Chailley 1970), knowledge transmission for music performance experienced a rich variety of techniques and approaches, from observation and aural transmission to scientific-based instruction. Gordon analyzes the history of performance pedagogy for keyboard instruments (Uszler *et al* 2000), and Uszler suggests transdiciplinary approaches as a pedagogical strategy for pianists (Uszler *et al.* 2000). Both authors reinforce the applicability of any reference, as desired by this work. Although science brings considerable contributions to music, empirical and subjective insights will always play an important role due to the artistic nature of music. Thus, there may be body demands common to any instrument and musical style, disregarding its complexity level.

MAIN CONTRIBUTION

The basic dimensions involved in music performance, as proposed by this model, are motion, memory and consciousness. These aspects are always integrated during practice with equal importance, so this distinction remains just for theoretical purposes. Definitions for each aspect follows below:

- *Motion:* Physiological aspects of music performance. A considerable amount of research and didactic material focuses primarily on this aspect (Uszler *et al* 2000). Motor learning theory (Schmidt and Wrisberg 2008) may help to understand the process for skill acquisition, and movement analysis is also an important role to acquire motor skills, developing analytical self-observation to avoid motion constraints (Jerde *et al.* 2006). Less-oriented attention can develop bad motor habits, leading to occupational health problems (Chong *et al.* 1989).
- *Memory:* Storing of data through the sensorial system, which can be theoretical knowledge, motion commands, sensations, and emotions. Storage is acquired through association of previously-stored information (Dickinson 2007), and aural, visual, and kinesthetic memories, as described by early pedagogues, are interrelated. General musical knowledge may reinforce memory for music performance (Aiello and Williamon 2002), and information processing theory may be applied to enhance the memorization process (Uszler *et al* 2000). Attention (or concentration) is a fundamental concept for memorization, because it deals with the brain's limitation for storage and performance activities (Schmidt and Wrisberg 2008).
- *Consciousness:* Voluntary intervention in any process, through either analytical thinking or intuition. Acquired skills, knowledge of music history, theory, idiomatic techniques, aural perception, stylistic identities, music imagery, emotions, and empirical practice, among others, are the source of an individual's personality, changing music interpretation, and both motion and memory. Rink's (2005) and Sloboda's (2000) works may be related to this aspect. Intuition is also considered a form of knowledge: it constitutes a field of possibilities with deliberate decisions taken by personal experiences (Lieberman 2000). It may confirm the efficacy of empirical approaches traditionally applied in music performance Learning.

After the presentation of the principal concepts, the model may be introduced, showing specific concepts originated from the combination of main aspects (see Figure 1).

Music performance learning model

The model shows the relations between main concepts and the originated concepts. Centralized along with the circles (in black smaller font in Figure 1) are the following elements:

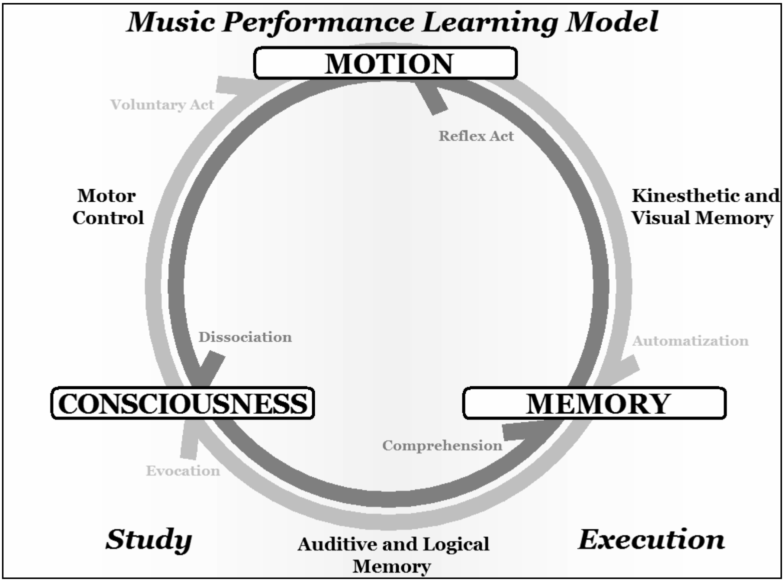

Figure 1. Music performance learning model.

- *Auditive and logical memory:* Types of stored information related to consciousness, dealing with abstract knowledge—musical structures comprehension, sonorities, and aural images (Ginsborg 2004). Although types of memories are not related to cognitive neuroscience definitions—it may be similar to semantic and emotional long-term memory (Sprenger 1999)—the terminology is applied here to link between concepts described by early pedagogues (see Aiello and Williamon 2002).
- *Kinesthetic and visual memory:* Types of information stored by motion, dealing with information obtained via sensorial system, relating to episodic, procedural, and automatic long-term memory (Sprenger 1999). Thus, visual information may not have the same use for all musical instruments.
- *Motor control:* Development of interactions between consciousness and motion. Understanding the motor control (coordination) process to acquire motor skills (Kaplan 1987) can accelerate learning time considerably. It also can be linked to the maturation of the nervous system (Kaplan 1987). Theories of brain development, such as Piaget's studies, cognitive neuroscience (Peretz and Zatorre 2004), and motor control development,

may help to establish age-related learning strategies. Uszler (2000) mentions five stages of motor learning with teacher's participation, while Schmidt and Wrisberg (2008) reinforce attention and memory in the process.

Returning to the model (Figure 1), the words in a smaller font, aligned to the circles, show concepts related to specific dimensions. Below follows explanations about the outer circle (light gray, in clockwise direction):

- *Voluntary act:* Conscientious action externalized in form of motion (Kaplan 1987), which implies a more advanced stage of motor control.
- *Automatization:* Storage of a voluntary act (Kaplan 1987). For cognition, the act passes from short-term to long-term memory, in which repetition is a fundamental learning strategy (Schmidt and Wrisberg 2008). This activity is crucial to establish the "kinesthetic memory."
- *Evocation:* Recall of stored information, not just kinesthetic but musical knowledge, aural image, emotion, and intuition (Cerqueira 2010). The constant process of learning generates new voluntary acts as a way to externalize new findings, starting the cycle again.

Now follows the conceptualization of words present in the inner circle (dark gray, in counterclockwise direction) presented in the model:

- *Dissociation:* Improving of motor control, relating to coordination level exposed in any execution situation. Kaplan (1987) reinforces the importance of developing dissociation to acquire instrumental technique, searching for lesser efforts and better musical results.
- *Reflex act:* Exposure of a stored motion, associated by Kaplan (1987) to conditioning. It may expose a motor skill that was not acquired by adequate procedures, such as proper attention to motion. Motor problems (bad habits) may be exposed by reflex, showing the need of proper postural and motor re-education.
- *Comprehension:* Understanding of presented musical context (Cerqueira 2010). It consists of the learning of a piece or repertoire, dialoging with musical experience (evocation) to establish a musical interpretation. As with other concepts, it does not involve only theoretical knowledge. Also, understanding and association with stored information will be helpful to develop solid memorization, due to the nature of memory: "the brain is always seeking meaning" (Sprenger 1999, pp. 49-50).

Returning to the model (Figure 1), it is possible to see two major divisions, named "Study" and "Execution." It may be useful to define proper study tools for specific situations: repetition, study from reference points, variation, etc. (Cerqueira 2010). Considerations are made below:

- *Study:* Initial stage of preparation. It involves great amounts of attention, focused on the construction of musical interpretation and development of proper motor skills. The emphasis occurs on consciousness and motion dimensions, due to the still incipient memorization.
- *Execution:* Final stage of preparation. The main objective of this stage is to keep information stored, trying to avoid "memory slips" in public presentations. Schmidt and Wrisberg (2008) reinforce that, for athletes, being under psychological pressure decreases attention efficiency. It may be associated to performance anxiety. Use of proper strategies may decrease anxiety in public exposure (Wilson and Roland 2002).

Finally, the "Performance" concept in this model refers exclusively to the moment of public presentation. Also, music performance needs instruction from publicity and administration, due to the social and cultural nature of the event, involving further approaches.

IMPLICATIONS

The immediate objective of this work is to offer proper instruction for music performance learning through training and improvement courses, attending any musical style or musician profile. Most of Brazil's music institutions still preserve ideologies from nineteenth century conservatoires, showing the need for deep educational reform. This work may also help to offer the basis for both music performance practice and instructional material development.

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The art of "repetitive practicing": Torture or meditation?

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"Repetitive practicing" is often considered to be an activity that is obsessive, mindless, and damaging, leading to many forms of repetitive strain injury. However, all practicing employs some form of repetition—it is proven scientifically to be the way to secure long-term memory in any motor activity—and in biological terms, the memory process actually alters gene expression in neurons to produce long-lasting synaptic growth. The question, therefore, is *how* and *how much* repetition should be executed to ensure that results are entirely beneficial. This article explores how extreme numbers of repetition that are often considered "torturous" might in fact be a way of attaining the highest level of artistry by consciously developing a "relaxed force" in the process of practicing. This is compared to the principles of the ancient Chinese martial-art form *Taijichuan* and can ultimately be deemed a genre of meditation. The article also poses the question of whether further neurological scientific experiments could help define the optimum number of repetitions each individual needs to suit their genetic requirements to produce the desired artistic results.

Keywords: repetitive practicing; Griller; relaxed force; motor memory; *Taijichuan*

As a young violinist, I studied at the Royal Academy of Music under the great quartet leader and teacher Sidney Griller. He was (in)famous for being a strict taskmaster—some would even say that his teaching methods, particularly of practicing, were "torturous." His main approach to practicing was to repeat difficult passages, sometimes just a bar or a note, 50-100 times, each time requiring absolute perfection. This taught me a kind of discipline and level of artistic responsibility that I had never encountered before or since. However, it is apparent that not every performer would practice in quite such a manner, as verified in writings (and in practice) by many eminent performers, teachers, and theorists such as Kato Havaš (1986), Leopold Auer (1980), and Heinrich Schenker (2000), to name but a very few across a wide range of musicians.

"Excessive" repetitions in practicing are often regarded as a mindless activity and a waste of time as compared with mindful, consciously analytical practicing. Indeed, many young or inexperienced violin students would imagine that "diligent practice" simply means repeating difficult passages numerous times, without full attention to how the repetitions are enacted; and then they are surprised and frustrated that not only do they achieve very little in the process, they become victims of many cases of "repetitive strain injury" (RSI)—a subject that has been explored exhaustively (e.g. Jabusch and Altenmüller 2006, Byl and Priori 2006)—demonstrating that it is a widespread problem. It is due to such an incorrect, neurotic approach to working that "repetitive practicing" has acquired such a bad reputation. The crux of the matter lies in *how* repetitions are executed: what the aims are and the philosophy behind such an approach. Repetitive practicing is torturing and damaging if it is done excessively willfully, with misplaced determination to "get it right," such that one is actually practicing bad habits and nurturing tension. However, if one is able to cultivate "an art of repetitive practicing" that consciously aims to focus the mind and constantly strives for maximum relaxation of body muscles, then not only could one resolve technical problems but also develop a kind of motor memory and power in execution that engaging in non-repetitive, analytical practicing alone could never produce.

I propose that if we are more consciously aware of how our brain responds to repetitive motor activities (Jäncke 2006, Kandel 2006), and combining that with an understanding of the concept of "relaxed force" (Wee 2003) and effects of meditation on neuroplasticity (Lutz *et al.* 2008), a model of "repetitive practicing" could in fact be the key for preparing a musician to perform at the highest artistic level.

MAIN CONTRIBUTION

Although I never witnessed Griller's practicing at first hand, every evidence points to the fact that he practiced (literally) what he preached. [*Note.* By the time I studied with Griller, he had stopped playing; so I never heard him practice or perform live.] Firstly, I have evidence in some of his quartet parts to show that he developed a habit of counting the number of times he had repeated a passage, by recording multiple IIII strokes in the margin of the music next to difficult passages. [*Note.* That was also how he, as I experienced, kept count of how many times a student had repeated a passage in a lesson; see also accounts given by the Alberni and the Lindsay Quartet in Potter (1994).] Secondly, his mode of repetitive practicing was never mechanical. In fact, he would practice a technical exercise in as musical a way as, for instance, a phrase in a Mozart Quartet. [*Note*. This fact was related to me by his son, the composer Arnold Griller.] This last point gave me the greatest insight into his philosophy of repetition.

It is clear that, in Griller's terms, "perfection" implies not only technical perfection but also expressive perfection: that is, to play a note, a bar, or a phrase with full commitment to *how* it needs to be executed musically and developing the deepest and subtlest *sensing* of how to achieve such results by the most economic and relaxed physical means. The cultivation of this level of sensitivity requires practice that is beyond the "normal" amount of repetition. Despite the Quartet's extremely busy schedule and his own relentless practicing, Griller never had any issues of muscle pain or fatigue. I have come to realize that, in fact, the more one practices a physical activity repeatedly in a calm and relaxed way, the more one develops a soft but powerful relaxed force that can only tone and strengthen muscles rather than damage them. Therefore, if one engages in this kind of repetitive practicing, not only would one never suffer from RSI but it seems that beyond a certain point, an effect akin to that acquired by deep meditation could kick in and one could only become stronger and develop more plasticity in both bodily and brain functions. [*Note*. In three articles referring to focal dytonia, the authors' findings allude to the fact that the onset of such a disorder could be related to a "deficit in inhibitory mechanisms" in the cortex of the brain (Jabusch and Altenmüller 2006), and "may develop in individuals with a genetic history of dytonia or physiological dysfunction of the basal ganglia or the sensory motor cortex" (Byl and Priori 2006). From these points of view, it has to be acknowledged that some people are probably genetically more disposed to long hours of practicing than others.]

An analogy with the practice of *Taijichuan*

It is through the practice of *Taiji* that the power of "relaxed force" can be felt and understood most acutely. [*Note*. *Taiji* is a form of Chinese martial art developed some 700 years ago. There are several different spellings and translations of the Chinese terminology. I will employ the most commonly-used shortened form *Taiji*. Many musicians learn Alexander Technique which, in many respects, is based on the same principles. But the art of *Taiji* is closer to the art of instrumental playing (and conducting) because it has movement, and one needs to learn to balance in a static posture as well as in motion.] *Taiji* practice demands a constant engagement in finding balance in the body structure by getting rid of all unnecessary muscular tensions. It is the extremely counter-intuitive technique of "emptying" (relaxing the whole body completely) to develop a supple form of energy, rather than using brute force that separates *Taiji* from any other form of martial-art techniques. In the words of one of today's most accomplished *Taiji* masters, the practice is about "maximizing the efficiency and effectiveness of movements and minimizing the effort and energy used to produce them", thus "eliminating any dependency on brute strength" (Wee 2003, p. 7).

Motor memory

Experiments in motor memory have been done in a particularly revealing way by the Nobel Prize winning neuroscientist Eric R. Kandel. [*Note.* There are references in many articles and in lectures that could be accessed online, but his findings are illustrated most summarily in Kandel (2006).] It is clear that in order to learn the very intricate task of playing a musical instrument, and to learn and memorize all the music that goes into every performance, one has to practice for long hours to secure the long-term memory required to reproduce the many different categories of learned tasks.

From a neuroscientific point of view, it seems that by choosing to engage in Griller's type of "repetitive practicing," the performer would be ensuring that the motor activity learned is memorized *implicitly* (i.e. tasks learned are recalled unconsciously) on a *long-term* basis (see Kandel 2008). All this could then be reproduced more or less as a form of reflex action in concert, such that the performer literally does not need to *think* anymore. [*Note.* This approach is perhaps particularly pertinent in high-level chamber-music playing, as the degree of spontaneity is less flexible than in solo playing.]

However, the leading question here is whether Griller's method goes even beyond what is necessary to *memorize* an effective reflex response. Does it lead to a state of transcendence that induces greater electric impulses to develop in brain-cell circuits, thus increasing neuroplasticity? [*Note.* There has been a birth of neuroscientific studies of meditation in the past decade showing exact neuro-responses to regular, long hours of meditation.] If so, does it enable the brain to become more available to musical impulses and hence enhance further creativity? Was Griller's method torturous only for those who are "unenlightened," but for those who understand the pathway required to develop the most refined form of relaxed force, it could be deemed and keenly felt as akin to a highly-developed form of meditation?

IMPLICATIONS

Science has allowed us to understand the mechanism of memorizing and the effect of meditation. Is there also a way of measuring the effect repetitions in performers' practice has on the brain and help individuals design their own most efficient practicing routine to achieve the highest level of artistic results?

In the words of one of the last century's greatest *Taiji* masters, Cheng Man-Ching, "after achieving accuracy, practice faithfully and power will appear. When power is sufficient and the will undivided, one gradually reaches a spiritual state and it is then not difficult to achieve transcendence" (Cheng 1985, p. 154). This, I believe, is a most pertinent description of the ideal of the "art of repetitive practicing."

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Reaching for the stars: Dance talent program at Singapore International School (Hong Kong)

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This article illustrates the framework of a dance talent program at Singapore International School (SIS) in Hong Kong. SIS was established in 1991 and serves as one of the few private schools in Hong Kong that offers a primary and secondary dance curriculum. At the time of this research, dance was offered to primary one to four students and to secondary one and two students and an ad hoc dance talent program was offered to selected primary five students. This paper raises the question: what kind of dance talent program will address the needs of the diverse communities in the school? The dance talent program framework that emerges from the research describes rationale, content, and approaches as identified by the data and research participants. Research data collected includes dance syllabi from the established Dance School of Excellence in Queensland; questionnaires and/or interviews with selected parents, students and staff at SIS and with the head of modern dance at the Hong Kong Academy of Performing Arts. It is hoped that this case study will allow the transferability of a dance talent program to other schools in the near future.

Keywords: dance talent; dance curricula; dance talent identification; dance talent program; giftedness

The need to identify talents at a young age is essential, as appropriate resources could then be provided to nurture their development and to boost their interest (Ericsson 2006, Noice and Noice 2006, Renzulli 2005). The need for a dance talent program to cater to young dance talent is accentuated by Walberg and Paik (2005): “without large amounts of intensive practice, parental support and expert instruction, giftedness rarely comes to full fruition” (p. 395). Therefore, it is crucial to develop concrete strategies for talented dance students to succeed within the realm of dance education today. The strategies are consolidated to illustrate the framework of a dance talent program for a pilot group of primary five students aged ten at Singapore International School (SIS) in Hong Kong. The reason for choosing this site for investigation was due to the familiarity and easy access this researcher has to the site. This researcher was the only dance teacher and dance curriculum writer at the school since 2008.

MAIN CONTRIBUTION

The rationale of this dance talent program is to address the needs of young dance talent at SIS and to prepare them for tertiary dance education. Teacher-participant A accentuates this by writing that a dance talent program should be "a sound program with a balance of academic dance studies as well as practical application. The goal is for students to further their dance studies at a tertiary level and contribute to the society anywhere in the world." To limit the scope of this research, tertiary dance education refers to the only institution in Hong Kong that offers professional dance training at diploma, degree, and post-graduate level: the Hong Kong Academy of Performing Arts (HKAPA) School of Dance. The third rationale is to encourage the young talents to become unique individuals. This is voiced by student-participant C who "[does] not want to be the same as other dancers." In order to create a framework of dance talent program at SIS, it is fundamental to refer to similar programs in Hong Kong and beyond to glean from their expertise and experience. City Contemporary Dance Company (CCDC) in Hong Kong and Queensland Dance School of Excellence (QDSE) are chosen as a result.

CCDC offers two dance talent programs that are relevant to this dance talent program in terms of age group and content. The first talent program for 6-12 year-olds is a ten-month modern dance training program. The aim is "to enhance their ability in dancing and performing, and to provide a solid foundation for their future development in dance" (CCDC 2010). The criteria to be a *612 Mini Dancers* are candidates who are aged 6-12 years, committed to dance and willing to work hard and face challenges in dance. *Teens of Colours* offers free tuition to talented dance students in dance technique training, creative improvisation training, dance appreciation, and public performance. The course is conducted from September to July for two hours every Saturday. All classes are conducted in Cantonese.

Queensland Dance School of Excellence (State of Queensland Department of Education and Training 2009) enjoys the accolades for producing graduates for Queensland Ballet and other world-class professional dance companies. Its year 10 program is a performance-based elective carried out within school hours. Students undertake the following units of study: classical ballet (core unit), jazz dance, and contemporary dance techniques. Students attend four dance classes per week, amounting to a total of at least six hours. From the talent programs mentioned above, it appears that the content is led by the outcome: CCDC teaches modern dance as the company is of this genre while QDSE has an emphasis on ballet as it feeds its graduates to the country and state's ballet companies. It seems reasonable that the SIS talent program will be molded by the requirements of HKAPA School of Dance and balanced by the needs of the students.

The requirements of the School of Dance at the HKAPA, at least of its contemporary dance department, are revealed explicitly in the three days' audition process. The first day consists of dance classes. The second day is the physical report in which candidates go through medical and physical tests. Selected candidates will be called back on the third day for classes and repertoire. There is also an improvisation section on the third day of the audition; this allows all candidates to demonstrate their creative aptitude and also provides an opportunity for candidates with little or no formal training in ballet or contemporary dance to show a movement vocabulary they may have specialized in which has not be seen in the audition process. Improvisation refers to "spontaneous, transient creation; it is not fixed, it is not formed" (Autard 2004, p. 30). The contemporary dance department will consider candidates with folk and/or hip hop dance experience. In addition, the School of Dance seeks to recruit talented dancers who are "personally driven" and are able to develop into "autonomous learners" (telephone interview with teacher-participant B). After all it is a massive leap from secondary school to tertiary level in which most candidates' ability to express themselves in English, either in verbal or written form, remains "a common challenge."

Once the requirements of HKAPA School of Dance become apparent, they are compared with the needs of the students. If there were a dance talent program at SIS, student-participant A would like to "learn about what it takes to be great dancer." Triangulation is applied here as I probed her further on another occasion whether she minds learning ballet, contemporary dance, and/or world dances. Her willingness to learn any dance style was assured: "I'd like to learn new dances and new techniques that [I] can use when [I] dance." Student-participant B would like to "learn dances to songs that everyone knows." When probed further on another occasion, he highlighted his interest in learning popular dances, especially to "Korean pop songs." When asked what he likes about studying dance at SIS, he replied: "we learn more dance moves, and we are able to make our own dance moves." Student-participant C has the same interest in creating dance movements: "I'd like to learn more about different choreographic methods." Student-participant A would like to "share the moves with everybody so that people can learn from [her]" because she likes to teach her classmates, and this is a trait of an autonomous learner in which interpersonal skills is displayed (Betts 1985).

The research findings above reveal that the framework of the dance talent program should include:

- students' own choice of dance projects (appreciation mode),
- improvisation (choreography mode), and
- cultural dances (performance mode).

To elaborate the above framework, students could choose a topic of own interest for further investigation. S/he could investigate the development of ballet during the eighteenth century and submit it in a written format. Students will be introduced to ways to improvise so that they will be familiar with this choreographic method when they choreograph and when they enroll at HKAPA School of Dance. In addition, it has become more demanding in today's dance companies (even in ballet companies) in which dancers are required to improvise with impetus given by the company's artistic directors. So it is not sufficient to just know how to dance well. Lastly, it will be limiting to students' knowledge and understanding if they are just introduced to Western dances such as contemporary dance and ballet. It will be beneficial if they are acquainted with other dance styles and to understand why people in other cultures dance. It is hoped that they could use this understanding of cultural diversity to "promote social capital and to make the world become a better place" (Renzulli 2011).

Other than the content of the program, the question about the duration of lessons is raised. According to student-participant B, he does not like the dance curriculum as "there is only one session every week". When questioned, he wishes there were more sessions per week. Student-participant A indicates at least "one hour a week." Parent-participant A voiced that there should be at least three dance classes per week. Due to the constraints of this researcher's timetable and to fit this special group of students into a common timeslot, it is suggested that the program be conducted during lunchtime twice a week.

Since the dance talent program will be a specialized, individualized training program for a small group of people, it is essential to devise strategies to cater to their individual needs. One of the teaching and learning approaches is to offer students different ways to communicate with the dance teacher if s/he cannot be located (Strip and Hirsch 2000). Moreover, the role of the dance teacher will become more like a facilitator so as to make the learning student-centered (Parke 2003). The conventional pedagogy that dance teachers adopt is to teach dance movements to students and students try to copy and perform them. This has to change to allow students to take charge of their own learning. Another approach is to include the students in decision-making and policy-making as this may have an impact on his/her life (Strip and Hirsch 2000, Parke 2003). Next, students are encouraged to take risks (Strip and Hirsch 2000). One possible way of risk-taking is to encourage them to go for dance scholarship auditions; some of them may feel they do not have the potential.

It is important to involve students' parents in the teaching and learning process. Trust must be established between students and at least two or three significant adults—i.e. parent and teacher (Strip and Hirsch 2000). The dance teacher will share his/her observations with parents (Parke 2003) and update them periodically of their child's progress.

IMPLICATIONS

There are several conditions necessary for the dance talent program to be sustained in this school and transferred to other schools in Hong Kong and beyond. From the research findings, the conditions seem to be a driven dance teacher, an open-minded school leader, supportive parents, a group of passionate dance students, and the availability of dance studios. The limitation of this small single school study is that it does not lend generalizations to programs in dance talent development in other international schools in Hong Kong.

The benefit of implementing a dance talent program at SIS is that young dance talent could be identified, guided, and given strategies to excel. The other benefit is that the program allows the developmental of skills from one level to another to become more structured and defined. Finally, having a full-time dance teacher at the school that conducts all dance lessons in English will benefit the young talent as they could then cope well with the transition from SIS to HKAPA School of Dance (where the medium of instruction for the contemporary dance and ballet faculties is English).

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Three stages of listening during preparation and execution of a piano performance: Exchanges on the model and its application

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As a pianist, the author of this paper has previously investigated the listening activities which occur during the preparation and execution of a piano performance. Three stages of listening were established: the first involves basically inner hearing or "listening from the score," the second consists of consciously monitored practice combining inner hearing and physical hearing, and the final stage, the performance itself, gives evidence of what the performer was able to hear from the score. Reviewed literature involving musical analysis, psychology, perception, and cognition was combined with the results of interviews conducted with selected pianists of international renown, generating suggestions/guidelines for the proposed listening stages. For the present experiment, the author has worked with a graduate student in piano performance during the preparation of Brahms's *Fantasien* Op. 116, applying these guidelines as a means to optimize performance preparation. The whole process is hereby described and discussed, exploring the connection between listening parameters and the achievement of coherent execution both during preparation process and final performance.

Keywords: performance; preparation; listening; optimization; pleasure

The listening process during performance and practicing has been explored from psychological, cognitive, analytical, and historical aspects (see Aiello and Sloboda 1994, Miklaszewski 1982, Reimer and Wright 1992, Rink 2002), and yet, it is almost impossible to be fully accessed, since it occurs in the performer's inner ear. The three stages' model which guided the present research is based on the fact that listening is the essence of music making. The first stage involves basically inner hearing or "listening from the score," the second consists in consciously monitored practice combining inner hearing and physical hearing, and the final stage, the performance itself, giving evidence of what the performer was able to store his/her inner-ear during this whole process.

Needless to say, these three stages are not disconnected from each other; trying things on the piano during the first stage is not unthinkable, and obviously, analysis continues during the second stage, enriching the relationship with the piece. Verbalizing this process is impossible for an outsider; the performer is the only qualified person to do that. Therefore, interviews were conducted with great pianists such as Alfons Kontarsky, Rudolf Buchbinder, András Schiff, Jörg Demus, among others, whose experiences were undoubtedly successful, who described their own process, confirming the pertinence of the proposed three stages. The experiment which followed is summarized in this paper. It consisted in supervising the conscious appliance of the model by a piano graduate student preparing a recital.

Brahms's *Fantasien* Op. 116 was chosen by the student, and during instructions and exchanges, references were made only to the score and to performances recorded during practice. The graduation recital was considered as a final result, where the extension of the proposed model's application could be verified. The research's main purpose was to explore ways to optimize performance's preparation process by means of well defined parameters. During the experiment, the student's own decisions, even if diverging from initial instructions, were not commented or altered.

METHOD

Participants

A masters student in performance and the author took part in the research.

Materials

Voice and Sound Recording MP3 archives sent-by email were used for process description, as well as professional video recording for concert performance, provided in DVD format.

Procedure

According to the proposed model, the student was instructed to avoid listening to any recording. After having built a sound image of Brahms's Op. 116 as a whole, practicing on the instrument should follow a certain order, namely, *Intermezzi* 5, *2*, *4*, and *6* followed by the *Capricci 3*, *7*, and *1* due to musical complexity and related technical issues. The student was also recommended to establish an aural connection between pieces, so that one would sound in the inner ear as soon as the previous was performed. Verbalized initial analysis, away from the piano, was accessed via MP3 archives and author's comments and guidelines were sent in writing. When instructions were not strictly followed, the student provided detailed explanation for personal listening choices. Similarly, performances during preparation were recorded and sent by email; the relationship between student's listening parameters and subsequent performance results were verified and registered.

RESULTS

The student has followed the recommended order of pieces for a first approach on the piano (*Intermezzi 5*, *2*, *4*, and *6* followed by the *Capricci 3*, *7*, and *1*) which she understood as based on form and structure complexity level. In her first testimony, she declared that not having to play at once has helped to mentally build a "phrasing map" of each piece, as well as enhancing consciousness of their different characters. Listening parameters determining form are shown in Table 1.

First reading followed this order, which the student admittedly did not keep for practicing; order of pieces during the second stage, on the piano, were based on musical preference as well as inner-hearing easiness. It is important to mention the misunderstanding which occurred here: the proposed order was meant for practicing, regarding the second stage of listening; the first stage's main goal, away from the piano, was to build a sound image of the work as a whole. However, as intended, no comments were made by the author, and the experiment followed.

Some discrepancies were verified between student's previous analysis during the first stage, and what could be perceived through recorded performances. For instance, although perceiving one "big picture" based on harmonic structure of *Intermezzo 5*, she declared not being able to determine phrases in section B. However analytical issues did not prevent good performance achievements; we hear the tension held by the V chord on bar 24, and the subtle rest implied by the subsequent resolution (V-I, bars 24-25) which initiates immediately another intense phase. Similar discrepancies were observed as in *Intermezzo 2*, as illustrated in Figure 1.

After having heard a first recording of this *Intermezzo*, the author suggested a relaxation of the hand, "closing it" after each time she reached the top notes of the sixteen notes groups; according to her response, it did indeed work.

Table 1. Parameters of listening after a first approach of the score away from the piano.

	Cap. 1	*Int. 2*	*Cap. 3*	*Int. 4*	*Int. 5*	*Int. 6*	*Cap. 7*
Harmonic rhythm	x	x	x	x	x		
Rhythm patterns		x		x	x	x	x
Tonality changing			x			x	
Texture							x
Phrasing	x	x*	x	x*		x*	
Metric accentuation	x						x
Polyphony		x					x
Tempi		x					
Elements' recurrence					x		

Note. * Items mentioned during previous analysis but not entirely verifiable during performance.

Figure 1. Intermezzo 2, section B. Left: Description. Right: Performance.

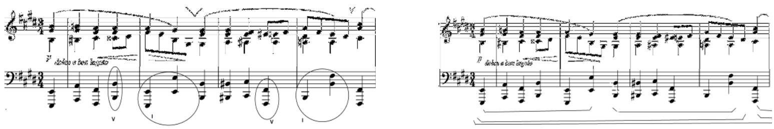

Figure 2. Intermezzo 6, bars 1-4. Left: Description. Right: Performance.

Phrasing described for *Intermezzo 4* did not actually influence phrase shaping. For instance, in bar 4, V-I is considered (2nd to 3rd beat), disregarding the tonic sustained in the bass which is exactly what keeps the flow of the discourse. However, the final performance naturally reveals what is actually written. Phrasing described for *Intermezzo 6* was also not heard in recorded performances. Following what is registered in the score, discourse flows from bar 1-8, according to hierarchic concepts, as proposed by Lerdahl and Jackendoff (1983), illustrated in Figure 2.

Similarly, the student's previous analysis of *Capriccio 3*, section B, reveals a somewhat disconnected phrasing, which is not present in the final performance.

Analytical features that could be easily verified in performance include the three sound plans in section B of *Capriccio 7*, and phrasing for *Capriccio 1*

Table 2. Brahms's *Fantasien Op. 116*: Tonal plan.

Dm	*Am*	*Gm*	*EM/Em/EM*	*Dm*
I	V	IV	II	I

guided by metric accentuation and special harmonic features, such as the II chord in bar 8.

The student affirms that approaching the piece away from the piano has facilitated her reading and understanding. Declaring not to be particularly skilled on first-sight reading, this first approach has helped her defining musical goals to guide her reading. However, she declared having managed to build an idea of the piece as a whole only one month prior to the aimed performance; her own deduction was that this was due to having approached pieces separately during the first stage, delaying the performance of the entire work as presented in the score for too long. Even when feeling more familiar the whole, she was still unable to establish an aural connection between pieces.

DISCUSSION

During this experiment, we have dealt with possible "hearings" of Brahms Op. 116, and recorded performances proved to be the best way to access musical results.

When hearings coincide, verbal exchange is rather facilitated. For instance, the specific technical procedures indicated to perform *Intermezzo 2* middle section were successfully applied, because both student and instructor were listening to the implied linear polyphony.

Most of the discrepancies perceived between analysis and performance are related to "whole and detail," which could have prevented simple analytical synthesis during the first steps, such as a tonal plan, as exemplified in Table 2.

The fact that the order suggested by the instructor for a first approach on the piano was followed during the first reading away from the piano instead, might be considered as one of the reasons for not having interiorly built a sound image of the whole piece from the beginning; afterwards, practicing could focus on any of the pieces.

The student declared not being able to establish aural connection between pieces, except for *Intermezzi 4, 5,* and *6*. It is apparently easier to connect those; *Intermezzi 4* ends with an E Major chord, whereas *5* begins with an E minor chord; similarly, *Intermezzo 5* ends with an E Major chord, and *6* begins with the same chord. Nevertheless, this approach does not reflect the multi-piece established by Brahms himself; besides Op. 10, this is the only case of a group of pieces meant to be published together.

Reading the piece as a novel is what brings to the performer's inner hearing the story to be told. We are facing two concepts: the notion of the piece as a whole which guides practicing and building of interpretation, versus the same notion built during practice. Of course, initial analysis is carried through the second stage of listening, being reinforced and enriched, but approaching the piano with a broad idea already built of the whole piece, is comparable to the actor who goes to the first rehearsal having incorporated his/her as part of a context. Chosen listening parameters should guide musical discourse's direction from the first to the third stage of listening; connection between analysis and performance must be continuous and coherent.

As it has been perceived in this particular case, and frequently happens with talented musicians, innate musicality surpasses lack of analytical awareness; however, it should be captured and verbalized, either for teaching purposes, or to communicate with others, but mainly to build conviction, the main priority to go on stage.

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The role and value of implementing health screening programs within music conservatoires

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Interest in musicians' health and wellbeing is growing, reflected by increasing numbers of investigations into the physicality and psychology of music performance. Within sport and dance, screening and profiling programs have furthered understanding of not only physical and psychological capabilities and demands, but also injury mechanisms and susceptibility. Drawing on experience gained from musicians' screening conducted over a two year period, the current paper engages with questions relating to the development and delivery of musician-specific health screening programs. An effective screening program can offer a variety of benefits and provide informed recommendations for musicians' training. Employing an interdisciplinary approach when developing screening programs is essential, as is the ecological appropriateness of the measures used. At present, three types of musician-specific screening programs are currently in use at Trinity Laban. These programs, together with implications inherent in the delivery of successful screening programs, are discussed.

Keywords: musicians' health; screening; injury prevention; program development; interdisciplinarity

Music making is an activity with high physical and mental demands that put musicians at risk in the execution of their art form. For a long time, our understanding of the musician's body has been anecdotal, typically based upon tradition and personal experience rather than scientific principles. However, more recently, interest has been shown in the potential usefulness of practices normally employed in the field of performing arts medicine and science and how such practices might contribute to an interdisciplinary understanding of musicians and music making. While interest in musicians' health and wellbeing is steadily growing, the application in music of relevant science-based physiological and psychological research is considerably behind that of sport and dance. For example, dance wellness programs have been implemented into some dance schools and institutions with a view to promoting dancer health (Potter *et al.* 2008). Such programs also provide a means of collecting information regarding dancers' physical and psychological wellbeing. The comparative infancy of music-specific research may in part be because much of what has been learned about the musician's body has come from research focusing predominantly on treatment of, and rehabilitation from, injury (Hansen and Reed 2006). While contributing to our understanding of the individual musician, this approach has arguably created a treatment-orientated culture that could be counterproductive to our understanding of the musician as a "whole."

This paper therefore addresses questions relating to the development and delivery of musician-specific health screening programs. In particular, it suggests why a music conservatoire may wish to instigate some form of physical and psychological screening for students, and also considers the wider implications surrounding the development and delivery of a music-specific health screening program.

MAIN CONTRIBUTION

Benefits of screening

An effective screening program can offer a variety of benefits for musicians, teachers, and those researching music performance. Screening programs can facilitate health promotion and injury prevention among students (Fuller and Peirce 2009). While it has yet to be scientifically proven that screening programs can predict injuries, the identification of individual characteristics can inform recommendations for supplemental training and appropriate support for musicians. In addition to promoting optimal health for students, screening may help institutions promote safe and healthy music practice.

More broadly, screening can generate an understanding of the "whole" musician. Screening programs help establish norms for various performance-related parameters and question the significance of those parameters to the functionality of learning and performance. Although screening and profiling musicians does not define the physical and psychological demands of music performance, longitudinal screening programs can enable assessment of the impact of music training regimes on musicians across time. Additionally, the development of musician profiles at different levels of expertise provides the opportunity to identify and examine adaptations resulting from long-term intensive involvement in an activity. This information may allow researchers to provide informed recommendations for those entrusted with developing musicians' training programs.

Variables to include

When developing screening programs, an interdisciplinary approach comprising physiology, biomechanics, psychology, health, and behavior has been shown to be important (Ostwald *et al.* 1994). Within dance, it has been recommended that medical, musculoskeletal, fitness, technical dance skills, psychological, and nutrition areas are addressed (Potter *et al.* 2008). Collaboration and reflection are fundamental within this. Consequently, the content of screening programs needs careful consideration, in order to ensure that variables tested are both ethically and ecologically appropriate, as are the tests used to measure them. Additionally, given the varying biomechanical demands associated with different instruments and musical styles and genres, and subsequent playing-related injuries (Greer and Panush 1994), screening programs need also to be instrument-specific. Furthermore, the variables tested will largely depend on the overall objectives of the screening program; what might be tested within an injury prevention program could very well differ from what might be tested within a profiling program. For example, a recent musicians' health profiling program assessed psychology, health attitudes and behaviors, body composition, balance, flexibility, upper body strength, and fitness in order to examine music students' physical and mental fitness for performance (Williamon *et al.* 2009).

The development of screening programs for musicians is currently hindered by a lack of understanding of the physical and psychological demands of musical performance. For instance, while there is growing advocacy for the importance of fitness for musicians (Llobet and Odam 2007), very little is known about what aspects of fitness might facilitate performance and help prevent the onset of performance-related injuries. Of what is known, the presence of hypermobility in musicians has been linked to pain in joints such as the knees and spine (Larsson *et al.* 1993) and finger/hand span has been linked to pianists' pain (Yoshimura *et al.* 2006). It also seems that many musculoskeletal problems in musicians arise from faults embedded in the playing, such as poor technique and posture and inappropriate practice procedures (Wynn Parry 2004). It is significant that musicians are often unaware of their own postural misalignments

(Dommerhold *et al.* 1998). Given these factors, assessment of musicians' physical interaction with their instrument and postures assumed while playing clearly warrant inclusion within screening programs.

Musician screening programs at Trinity Laban Conservatoire of Music and Dance

At Trinity Laban, we currently run three screening programs for our music students: one for instrumentalists, one for singers, and one for musical theatre students. The objectives of the programs are to: (1) identify and support students potentially at risk of developing playing-related injuries ; (2) determine the interactive relationship between biomechanical, physiological, and psychological factors relevant to music performance in order to better understand the "whole" musician; and (3) empower students to feel responsible for their own training, development, and health promotion.

The screening programs comprise three parts (with some variations between the programs) and have developed and evolved via an action research-type methodology (Zuber-Skeritt 1990). [*Note.* "Inst" refers to instrumentalists completing the assessment only, "Voc" refers to vocalists, "MT" refers to musical theatre students.] In the first part, students complete a series of surveys and questionnaires addressing demographic and background information, practice and exercise behaviors, past medical history, eating behaviors (MT), and psychological variables. In the second part, the students are taken through a range of physiological and biomechanical assessments. These include body composition, finger and hand span (Inst), balance, core stability, arm strength (Inst), joint flexibility and range of motion, hypermobility, and proprioception. In the third part, students undertake a postural assessment while playing or singing, with the singers and musical theatre students also receiving a vocal health assessment. In addition, musical theatre students take part in our dance-specific screening program. Following their assessments, all students are given a full explanation of their results. Students for whom concerns surrounding injury susceptibility have emerged are offered referral pathways to relevant therapists.

IMPLICATIONS

Understanding the whole musician from a psychological, physical, and behavioral view point clearly has implications for the practicing musician. If screening results can be disseminated back into the study context (namely the practice room) students will have the advantage of understanding risk factors involved with music making and be able to take responsibility for both their training and their journey into the music profession. Arjmand (2009) states that music training needs to produce a curriculum representative of the inter- and multidisciplinary nature of the performing arts. But despite inferring that musicians should draw from other disciplines as a way of understanding their bodies, screening programs can only be implemented if training institutions are proactive in their responsibility for students' health (Brandfonbrener 2004) and committed to health screening as an integral part of music training. Lastly, program effectiveness requires detailed knowledge of the unique characteristics of each instrumental/vocal group, to ensure that music-specific testing parameters are found, and supplementary programs are introduced.

In terms of implementation, collaboration with institutional members of staff is of the utmost importance. Similarly, advice from experts within each field must be sought to ensure that the delivery of tests and dissemination of feedback are carried out appropriately. It is also important that educators and administrators involved with the implementation of a screening program are aware that participants may still be reluctant to undergo screening. A common misunderstanding is that the application of scientific principles may in some way change the artistry of music performance. Further intervention and longitudinal research will assist with determining associations between screening results and outcomes, the relationship between various characteristics and music-making, and variance between vocalists, instrumentalists, and composers. Further research will provide the impetus for the development of standardized music-specific screening procedures together with a better informed understanding of the music student, who ultimately represents the future of the music profession.

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Piano repertoire preparation from a praxial perspective

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This study investigated the repertoire preparation of eight graduate and undergraduate piano students and revealed a variety of strategies dependent on their levels of expertise. The one or two pieces were selected from each student's program for the semester. Data were collected using semi-structured interviews followed by observations of participants' recorded performances. Most of the students (n=6) also based their practice on *praxial* knowledge, which in the present sample corresponded to very elementary means of approaching a challenging task, usually far from the ideal type of solution needed at this particular point. Within the investigated sample, the more the students were able to make connections and direct their practice based on expressive intentions, the more they were able to learn at a faster rate. Not surprisingly, then, graduate students engaged interpretive-type strategies far more often. Nevertheless, most of the students (n=6) also based their practice on *praxial* knowledge—i.e. they started out employing very elementary means of going about a challenging task. In fact, strategies based on expressive intentions and specific contexts led to productive knowledge (*poiesis*)—i.e. practical judgments about how to act in situations that involve the physical realization of one's own ideas.

Keywords: piano repertoire; praxial knowledge; productive knowledge; strategies; poiesis

In higher education, undergraduates studying instrumental music are expected to prepare a diverse repertoire not only according to very specific stylistic requirements but also to meet definite deadlines. In this scenario, a *praxial* perspective can serve as a potential tool for grounding the investigation of repertoire preparation. The preparation of a repertoire in academic circles is a main concern for most students and from the standpoint of music education; it involves the manipulation of several types of knowledge. Working from an Aristotelian perspective, knowledge includes theoretical knowledge (*theoria*), productive knowledge (*poiesis, techné*), and practical knowledge (*praxis*), with the three types of knowledge forming a tripartite relationship (e.g. see Elliott 1995, 2005, Regelski 1998, 2005a, 2005b, Bowman 1998, 2005). In a previous investigation based on a phenomenological approach, the repertoire preparation of three undergraduate students (a junior, a sophomore, and a senior) was closely monitored during an academic semester (Santos and Hentschke 2009, 2010). The students reported their use of strategies that differed in purpose and nature. The purposes of these strategies were then related to the quality of their piano practice. These strategies could be described as either creative (*poiesis*) or learned actions (*praxis*) (Santos and Hentschke in press). As an extension of the previous study, we investigated the repertoire preparations of eight graduate and undergraduate piano students and revealed a variety of strategies conditioned by different levels of expertise.

METHOD

Participants

From a total of eight piano students (four male, four female; mean age=23.3 years, SD=4.2, range=20-28 years old), five were undergraduates (U), and three were graduates (G).

Materials

The one or two pieces were selected from each student's program for that semester.

Procedure

The data were collected using semi-structured interviews followed by observations of participants' recorded performances. The students were questioned about the procedures employed in the preparation of the piece. Moreover, they were also asked about which aspects were considered to be important during the first approaches to the piece. Our monitoring aimed to reveal the kinds of tacit and non-verbalized knowledge used by the students. The evaluations were based on the data collected during three individual interviews. The data were transcribed and coded into categories by means of interactive processes.

RESULTS

During a semester of study, the preparation of a repertoire seems to elicit the following types of global procedures in students' routines:

- Some students tended to concentrate on one piece at a time during any week of their practice, while other pieces remained untouched and/or overlooked.

The main purpose and challenge of the practice sessions seemed to be related to quick memorization so that the piece could be "heard" rather than "read" (students G1, G2, U1, U4, U5).

During the very first readings, the majority of the participants (7 out of 8) read the works at the instrument while attempting to grasp the whole picture, even in an elementary fashion, to play as many notes as possible. This initial approach became more proficient as the level of the student increased. The following two excerpts are rather distinct from each other and indicate differences in proficiency.

> During a period of two weeks, I tried at the first reading to group as much as I could.... There would be no sense in thinking first on articulation...then dynamic.... Some variations I could already do more, others I could not.... Many variations are not about the theme but variations of the previous one.... (G1, male; Mendelssohn's *Variations Sérieuses*, Op. 54 in D minor).

> [After a month of study] I'm not doing so good.... I'm having a hard time transcending the difficulties found in the score, getting familiar with this fourth movement...that is, not to see only notes, but [to be able] to see lines, phrases.... I still see notes only!!! I need to go beyond in order to understand the patterns and to be able to play them! (U1, female; Beethoven's *Sonata*, Op. 31 No. 3, fourth movement).

In the initial stages of preparation, students seemed to rely on procedures based on their abilities irrespective of the style or the results eventually to be attained. Most students felt the keyboard and looked for topographical recognition as well as a kind of a sound envelope. Therefore, it is not surprising that the level of success at this time seemed to be intimately connected to the student's level of expertise. During the first readings, we were able to identify a few major strategies:

- A very slow and tentative reading from beginning to end in order to "try to get most of the elements that need to be included…" (U5, male).
- Learning by persistent repetition: playing small sections with separate hands, from the beginning to the end of the whole piece.

This repetitive procedure seems to be a part of all students' routines in spite of competency and assimilation levels.

> I practice a lot by blocks…. In some situations I do separate hands, too… (U3, male).

> I get fragments…. I select a block and solve it…. I practice until I'm satisfied…. I play until I can no longer stand it… (U1, female).

> [I] increase the size of segments at each repetition. [I] repeat the section until it is good, if necessary; otherwise, I do not overexert myself by needlessly playing the same passage over and over again (G1, male).

> I do not repeat too many times; I try different possibilities… (G2, female).

- Resolution of very specific technical difficulties.

> [I] choose fingers that make *legato* touch possible, finger substitution…. In order to get a good *legato* I do not mind doing a weird fingering, that is, to do contortions with the hand… (U4, female).

> I keep looking until I find the best way to play as *legato* as possible (G1, male).

Six out of eight students worked passages in blocks, using both hands, searching for each note before playing it. Other technical difficulties they reported related to developing fluency in quick passages (U1, U2) and to isolating the difficult parts and practicing similar passages intensively (G2, U4).

- Approaching difficulties by focusing on expressive intentions or decisions:

  Independence and sound fluency of polyphonic lines:

> [I] practice polyphonic passages with different kinds of touches (U5, male).

> [I] try to listen for the notes that are being held (U3, male).

> [I] underline salient notes in chords by pinching each one and by playing the top line very legato (G3, male).

Sound quality and technical fluency:

> [I] look for the same sound quality and articulation whether I play an arpeggio with one or both hands (G1, male).

Sound quality and hand position at the keyboard:

> The touch influences the sound quality, most of the time from the key down and the key proximity lets me have more means of expression (G3, male).

> I choose the hand position I'm going to play, depending on the piece.... At this first part, I prefer a lower wrist [so that] the attack gets to be slower, and the finger position in itself influences the kind of sound (G2, female).

DISCUSSION

As far as *techné* is concerned, the strategies employed by the students differed unambiguously depending on the students' level of competency. From an Aristotelian perspective, *techné* involves sets of procedures and resources learned from cultural tradition by instrumentalists seeking to play with skillfulness and competency. Within the investigated sample, the more the students were able to make connections and direct their practice based on expressive intentions, the more they succeeded and were able to learn at a faster rate. Not surprisingly then, graduate students engaged interpretive strategies far more often. In fact, strategies based on expressive intentions and specific contexts were the results of productive knowledge. Productive knowledge can be equated to *poiesis* (i.e. practical judgments about how to act in situations that involve the physical realization of one's own ideas). Nevertheless, most of the students (n=6) also based their practice on *praxial* knowledge (i.e. they started out employing very elementary means of going about a challenging task). Most of the time, these types of attempts at recognition are not context-specific and are far from the ideal solutions needed at particular points in repertoire development.

This study shows the need to foster individual learning processes by calling attention to strategies developed not only on a personal level but also with expressive intentions. Instrumental music teachers can also encourage an ongoing dialogue with students to improve the quality of their practice time and to enhance their focus on the development of personal and musical problem-solving solutions.

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A steady pace: The effects of musical expertise on tempo memory

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Remembering tempi and keeping in time are important skills in music performance, particularly for conductors, solo performers, and instrumental groups. Twelve musicians and 12 non-musicians were asked to listen to a metronome at three speeds (40, 110, and 180 beats per minute), clap with the metronome for one minute, and then clap as regularly and accurately as possible from memory later in the session and the following day. Results show that the slow speed was clapped too fast; the medium and fast speeds clapped too slowly. Musicians were significantly more regular in their clapping than non-musicians, but musical expertise did not affect memory for tempo. Medium and fast clapping were more regular on day 2 than day 1, but slow clapping was less regular on day 2. Slow and fast tempi were better remembered than medium tempi. Experts were thus no better at remembering speeds than non-musicians but were more accurate at clapping regularly.

Keywords: memory; speed; clapping; regularity; musicians

Timing and tempo are important in the execution and perception of musical performances (London 2004). Pieces need to be performed at an appropriate speed (as directed by the composer, the performers, or both). Music performed too slowly can impair structural and perceptual coherence and cause performers technical problems (e.g. breathing for singers and wind/brass players). Music that is too fast can become unplayable, sounding blurred and muddled. London (2004) and McAuley (2010) suggest that tempi between about 30 and 240 beats per minute (bpm) are practical for performance.

Certain performers, specifically conductors and unconducted soloists, must determine tempo internally, although on occasion they may use external devices such as metronomes. Expert performers tend to play the same piece of music at approximately the same tempo in multiple renditions

(Gabrielsson 1987). This suggests that the performer remembers the tempo, perhaps as part of the overall cognitive model of the piece. This ability can be designated absolute tempo (AT), analogous to absolute pitch (AP) (Levitin 1994, Ward and Burns 1999). The latter is the ability to recall at will a specific pitch with no external comparison stimulus. Likewise, AT is the ability to recall a musical tempo without an external time-giver and so start a piece at the right speed (McAuley 2010).

Previous research (Bergeson and Trehub 2002, Levitin and Cook 1996) suggests that people, including non-musicians, store the tempo of familiar songs in long-term memory. Levitin and Cook's (1996) participants sang popular songs from memory; 72% of their performances fell within 8% of the original tempo. Bergeson and Trehub (2002) showed that mothers singing to their infants varied tempo by only 3.1% on average across a week, considerably smaller than the 20% variation for spoken utterances. Research has also investigated people's ability to remember the tempo of isochronous beats in the absence of a specific piece. Fine and Bull (2009) investigated musicians' and non-musicians' memory for the tempo of a metronome. They found that a medium tempo was recalled significantly more poorly than fast or slow tempi, but there was no effect of musical expertise.

Fine and Bull (2009) measured participants' tempo recall after a delay of a few minutes. The present study extends Fine and Bull's findings by investigating tempo memory over a delay of a day, both for musicians and non-musicians.

METHOD

Participants

The 24 participants, 12 musicians (6 male, 6 female) and 12 non-musicians (5 male, 7 female), were obtained by opportunity sampling from various locations in England. The musicians had at least 3 years of musical experience and practiced at least 3 hours per week but were not necessarily professional. Musicians ranged from 21 to 62 years old (mean age 31.7), non-musicians from 21 to 42 (mean age 28.6).

Materials

A metronome providing a clearly audible isochronous beat was used. This was set to beat at three speeds: 40 bpm (1500 ms interstimulus interval [ISI]), 110 bpm (545 ms ISI), and 180 bpm (333 ms ISI). An iPhone 3gs was used to record the participants' clapping, which was then downloaded to computer and converted to mp3 files using iTunes.

Procedure

Participants first listened to the metronome beating at the three speeds (slow, medium, fast) for one minute each. They were asked to listen carefully to the metronome and try to remember the speed. They were then asked to clap along with the metronome, again at each of the three speeds for one minute. They then continued clapping once the metronome was muted for one minute. Finally they were asked to recall one of the speeds by clapping for 30 seconds, after a minimal time delay. The order of speeds was counterbalanced between participants, both at the presentation and testing phases. The participants returned the following day and were asked to clap the three speeds for 30 seconds each. Recall trials were recorded and then analyzed for mean tempo and regularity of beat using the program Praat (Boersma and Weenink 2011).

RESULTS

Tempo memory

Recalls for participants in both groups tended to be too fast for the slow tempo and too slow for the medium tempo. The medium tempo was remembered less accurately than either the fast or the slow. Recall on day 2 was more accurate for the slow tempo and, for non-musicians, the fast tempo, but worse for the medium tempo, than day 1 (see Table 1).

The mean inter-clap interval (ICI) data were analyzed using a 3 (tempo) x 2 (day) x 2 (musical expertise) ANOVA. There were significant main effects for tempo ($F_{2,44}$=250.11, $p<0.001$) and day ($F_{1,22}$=23.75, $p<0.001$). Day interacted significantly with tempo ($F_{2,44}$=15.61, $p<0.001$), with recall on day 2 being slower for slow and medium tempi but faster for fast tempi than on day 1. There was no effect of musical expertise.

Clapping regularity

More regular clapping leads to a smaller standard deviation in the ICI. The regularity data (shown in Table 2) were analyzed using another 3-way ANOVA. There was a significant main effect for musical expertise ($F_{1,22}$=13.75, $p=0.001$) and a significant interaction between day and speed ($F_{1.61,35.50}$=6.30, $p=0.007$, Greenhouse-Geisser correction). Musicians clapped more regularly

Table 1. Clapping tempo of recall trials (values in bpm, SD in brackets).

	Musicians		*Non-musicians*	
	Day 1	*Day 2*	*Day 1*	*Day 2*
Slow (40)	62.6 (13.7)	51.5 (11.5)	50.0 (10.3)	42.4 (8.7)
Medium (110)	91.0 (28.9)	70.9 (29.9)	77.0 (21.8)	74.8 (20.5)
Fast (180)	180.3 (27.5)	184.6 (26.0)	168.0 (34.4)	175.7 (44.0)

Table 2. Clapping regularity of recall trials (values are ICI standard deviations in seconds).

	Musicians		*Non-musicians*	
	Day 1	*Day 2*	*Day 1*	*Day 2*
Slow (1,500)	0.026	0.035	0.042	0.082
Medium (545)	0.019	0.019	0.055	0.043
Fast (333)	0.016	0.017	0.038	0.024

than non-musicians, and overall day 2 clapping was more regular for medium and fast tempi, but less regular for slow tempi.

DISCUSSION

Musicians' and non-musicians' accuracy in remembering beat speeds and regularity of clapping were investigated. Musicians were able to clap significantly more regularly than non-musicians. This is not surprising, given that much musical performance relies on keeping the underlying beat (tactus) in mind. There was a general improvement in clapping regularity from day 1 to day 2 for medium and fast speeds, particularly for the non-musicians, but participants were less regular when clapping the slow speed on day 2. This might be due to two non-musicians being particularly irregular in their day 2 slow recalls.

The musicians were not, however, any better at remembering specific tempi than the non-musicians. Experienced musicians might be expected to remember the speeds of the pieces they play, unlike non-musicians. However, Fine and Bull (2009) also found no effect of musical expertise, and McAuley (2010) suggests that "there is converging evidence that musicians and non-musicians alike develop fairly precise memories for the absolute tempo of music" (p. 177). It is possible that certain groups of musicians, in particular solo instrumentalists (e.g. pianists) and conductors, who are responsible for setting the speed of performances, might show better tempo memory, but the present group of musicians was not homogeneous, being of varying standards and playing different instruments. There is also evidence that people remember the tempo of a specific piece as an attribute of that piece (Levitin 1994, Levitin and Cook 1996). In this case, however, participants were just asked to remember a metronome tempo without any reference to a particular piece of music.

Similarly to Fine and Bull (2009), people were worse at remembering medium speeds than slow and fast tempi. On average over both the present study and Fine and Bull (2009) combined, participants overestimated the slow tempo by 7 bpm and underestimated the fast tempo by 13 bpm, but they underestimated the medium tempo by 30 bpm, despite a large difference in retention intervals. It is not clear why this is so, but might feasibly have to do having to remember three tempi simultaneously and thus connected to memory load.

Future research could address this by varying the number of different tempi that participants are asked to remember. Also, the present study lacked ecological validity, whereas clapping in time to real (or imagined) pieces of music would be more realistic, so this study could be repeated using actual music. Overall, then, people are able to remember metronome speeds fairly well, but this ability, perhaps surprisingly, does not seem to be superior in musicians.

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Qigong, singing, and health: A possible composition?

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This study aimed to search evidence available in literature on the effects of *qigong* as a breathing relaxation technique to reduce music performance anxiety, as well as its effects on singers' health and wellbeing. Integrative literature review was selected as the method of research. The inclusion criteria were: (1) publications in English, Spanish, and Portuguese from January 2000 to December 2010; (2) publications with abstracts available at and indexed in PubMed, Web of Science, PsycINFO, and LILACS. Twenty-two articles met the inclusion criteria. The results provided interesting tools for performers to integrate emotional, mental, and physical skills to efficiently and effectively improve their performance. Applied research through cross-disciplinary collaboration and innovative methods, such as *qigong*, may offer new possibilities to meet these challenges.

Keywords: breathing exercises; health; music; task performance and analysis; anxiety

The singer is the instrument and he/she needs special care to keep body and mind in first-class order (Wynn Parry 2004). Even years of practice acquiring adequate musical knowledge are not enough to become a professional singer. In order to achieve the highest levels of performance, a performer needs to be physically, emotionally, and mentally fit, in what is a hugely demanding profession (Wynn Parry 2004).

According to the Medical Subject Headings (MeSH), the National Library of Medicine's controlled vocabulary thesaurus (National Center for Biotechnology Information 2011), breathing exercises may be defined as therapeutic exercises aimed to deepen inspiration or expiration or even to alter the rate and rhythm of respiration. *Qigong* is a traditional exercise consisting of breathing allied with gentle movements. It is considered the ancient root of all traditional Chinese medicine, and many branches of qigong have developed over 5,000 years (Cheung *et al.* 2005, Rogers *et al.* 2009). Many well-known energy exercises in Western society, such as breathing exercises, meditation, yoga, and reiki, could be labeled as qigong in China and in other countries as well (Chen *et al.* 2006). Previous researches have suggested that qigong can be an effective technique for stress management and anxiety reduction in different populations (Li *et al.* 2002, Skoglund and Jansson 2007, Johansson and Hassmén 2008, Rogers *et al.* 2009).

This study aims to seek evidence available in the literature about the effects of qigong as a breathing relaxation technique to reduce music performance anxiety, and above all to improve singers' vocal health, wellbeing, and building up of a vocal body.

METHOD

Materials

The articles were included in the study based on the following criteria: articles published in a peer-reviewed journal between January 2000 and December 2010; printed in English, Spanish, or Portuguese; publications with abstracts available; and qigong described as the primary intervention. Articles that presented other breathing exercises techniques, such as *yoga*, *tai chi chuan*, and meditation as interventions were excluded.

Procedure

The integrative literature review was selected as the research method, with the following steps: problem identification, article selection, definition of information to be extracted from reviewed articles, result interpretation, discussion, and knowledge synthesis (Whittemore and Knafl 2005). The authors looked for publications with abstracts available at and indexed in PubMed, digital databases produced by the National Library of Medicine (USA) in the field of Bioscience; Web of Science, which refers to a set of databases (Science Citation Index, Social Science Citation Index, Arts and Humanities Citation Index, Current Chemical Reactions and Index Chemicus); PsycINFO, a reference in psychology, behavioral sciences, and education; and LILACS, which covers scientific publications in health from Latin America and the Caribbean.

Table 1. Distribution of bibliographic references according to keywords, retrieved from PubMed and Web of Science.

Keywords crossed search	*PubMed*	*Web of Science*
Breathing exercises x anxiety	56	38
Breathing exercises x health	69	61
Breathing exercises x music	6	20
Breathing exercises x task performance and analysis	7	1
Health x anxiety	1340	17696
Health x music	105	601
Health x task performance and analysis	748	286
Music x anxiety	135	534
Music x task performance and analysis	110	81
Task performance and analysis x anxiety	158	242

The following keywords were used: breathing exercises, qigong, health, performance, music, and singer. They were combined and then further narrowed. The following variables were analyzed: professionals who elaborated the articles, publication year, country of origin, and study design characteristics.

In PubMed, ten crossed searches were conducted using keywords combined two-by-two to maximize the search process (Table 1). Through this process, 2734 references were found, 884 were published before 2000 and 108 were published in languages the inclusion criteria did not cover. Among the 1742 remaining publications, the abstracts of 151 did not have their abstracts available. After that, 1591 abstracts remained, and they were exhaustively read by the authors to make sure that qigong was the main study object. Twenty articles were selected at the end of the search process. The manuscripts were entered into a table for further comparison and analysis and were compared for consistently confirmed health benefits, design, strengths, and limitations and to identify the next steps in research in this important area of study.

Web of Science database offered different search tools, which allows the use of electronics resources to select the manuscripts, instead of doing manual search through reading, as in PubMed. The searches were performed using the same keywords crossed two-by-two; however, it was possible to eliminate the articles that did not cover the inclusion criteria without read their abstracts, thirty-one articles were founded. In the end, discarding the repeated articles on PubMed, only two new articles were retrieved from that database. In PsycInfo and LILACS, four articles were found at the first database, and nothing was found in the latter. However, it was not possible to access those articles online.

RESULTS

After the aforementioned process, 22 selected articles addressed the main aim of this study and complied with previously established criteria.

Analysis of these articles showed that most of them had been elaborated by a collaborative team—e.g. physicians participated in eleven and nurse researchers in nine, in partnership with other professionals, such as occupational therapists, physiotherapists, physical educators, and trained qigong instructors. Nine articles were developed at centers of integrative medicine and/or qigong/tai chi chuan societies, located in different countries. Some homogeneity was found in the articles' distribution in terms of publication year, concentrated especially in 2008 (six articles). As for the country of origin, China and the USA led the number of publications (seven for each). Although some studies had different origins, English was the predominant language.

As for the study design characteristics, among the 22 studies included in the review, fifteen were randomized clinical trials, five were literature reviews, and two were case reports.

DISCUSSION

The analyzed data reveal that, when looking at the country of publication, the USA and China led the ranking of publications in which qigong was the main object of study. However, no research was published in the last 10 years focused on qigong as a relaxation breathing training technique to reduce music performance anxiety nor, above all, to improve singers' vocal health and well-being. There is a need for further research in this area.

Chow and Tsang (2007) in their recent manuscript proposed a biopsychosocial model of qigong, where they integrated the psychosocial and physiological perspectives with mind regulation (*tiao xin*), body regulation (*tiao shen*), and breath regulation (*tiao xi*) as frameworks of qigong. Physical training may enhance the autonomic nervous system (ANS) activity. An improvement of heart functioning and central nervous system activity may be achieved by practicing long, smooth, and rhythmic diaphragmatic breathing (Chow and Tsang 2007), as singers usually do. Researchers suggest that such rhythmical and diaphragmatic breathing possibly serves as an autonomic or endocrine training that improves cardiac output, ventilation efficiency, oxygen consumption, carbon dioxide production, mood stabilization and flexibility of ANS, consequently achieving a homeostatic state (Chow and Tsang 2007, Rogers *et al.* 2009, Posadzki *et al.* 2010), essential to musical performance. Regular qigong practice may result in effortless concentration and self-realization, thereby facilitating an individual's sense and ability to control their own bodily processes (Posadzki *et al.* 2010).

The authors' intention was to indicate the potential benefits of qigong as a relaxation breathing training technique. To the authors' best knowledge, there is no research conducted in this field. A limitation of this study was the impossibility to follow all the steps of the integrative review because of the lack of publications focused on qigong, singing, and health. However, it was possible to confirm the future potential of new studies of implementing and evaluating qigong as an effective resource to reduce music performance anxiety, and above all to improve singers' health and wellbeing. The review revealed how challenging it is to work with qigong in performance science, once the manuscripts retrieved were published exclusively by healthcare professionals. On the other side, it provides new perspectives in cross-disciplinary approaches to improve singers' performance and wellbeing. In this context, tools from different arenas may be combined to help singers reach excellence on their musical performance.

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The role of cerebral resonance behavior in the control of music performance: An fMRI study

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Mirror neurons in the cerebral cortex have been shown to fire not only during performance but also during visual and auditory observation of activity. This phenomenon is commonly called cerebral resonance behavior. This would mean that cortical motor regions would not only be activated while singing, but also while listening to music. The same should hold true for playing a music instrument. Although most individuals are able to sing along when they hear a melody, even highly skilled instrumentalists, however, are frequently unable to play by ear. They are score-dependent—i.e. they are only able to play a piece of music when they have access to the notes—while musicians who are able to play by ear and improvise are non score-dependent; they are able to play without notes. Our hypothesis is that score-dependent instrumentalists will exhibit less cerebral resonance behavior than non score-dependent musicians while listening to music. Using fMRI to measure BOLD response, subjects listen to two-part harmony presented with headphones. The following experimental conditions are distinguished: (1) well-known vs. unknown music (2) motor imagery vs. attentive listening. A voxel-based analysis of differences between the condition-related cerebral activations is performed using Statistical Parametric Mapping.

Keywords: non score-dependency; cerebral resonance behavior; motor control; music performance; brain imaging

Playing a music instrument may superficially appear to be a somewhat difficult but straightforward task, differing from other manual tasks only in its complexity. Functionally, however, instrumental playing is different from day-to-day grasping and pointing movements. In the sense that the goal of such movement is to produce sounds and that these sounds can be represented by a symbolic system, instrumental performance would seem more analogous to speech than to otherwise similar forms of manual dexterity.

Like language, music is a complex, rule-governed form of behavior (Lerdahl and Jackendoff 1983) and appears to be associated with specific brain architecture (Schlaug 2001). Just as native speakers invariably learn to speak their mother tongue before learning to read and write, jazz musicians generally learn to play an instrument competently before mastering the notational system, frequently never mastering it at all. As they are not dependent on written notation for the practice of their art, we may term these musicians *non score-dependent*.

Many classically trained musicians on the other hand are unable to play unless they have access to the notes of the pieces they play. We may, therefore, term them score-dependent. Up until now, neuroscience research into music performance has concentrated almost wholly on the professional classical musician and thus mainly on score-dependent musicians. Mismatch negativity (MMN) research in which the pre-attentive listening paradigm was applied suggests, however, that there could be a relevant distinction between score-dependent and non score-dependent musicians. Non score-dependency possibly facilitates recognition of melodic contour (Tervaniemi 2003).

The cerebral commands for fine-tuned movements are funneled through the motor cortex on the precentral gyrus. Beyond the primary motor cortex, the organization of goal-directed movement is particularly embedded in parietal-premotor circuitry (Wise *et al.* 1997, de Jong *et al.* 2001, Castiello 2005). Neuronal activity in these cortical regions is associated with the preparation of movement as well as imagining of movement without overt execution (Ehrsson *et al.* 2003). Moreover, this motor circuitry includes mirror neurons, characterized by their selective responsiveness to the observation of specific goal-directed movements performed by others (Gallese *et al.* 1996, Rizzolatti *et al.* 1999).

In a wider sense, this motor circuitry can be elicited by the sound of specific actions performed by others (Kohler *et al.* 2002). Sensory stimuli thus facilitate the motor system to express "resonance behavior." These neuronal qualities fit the concept that the cerebral representation of movement includes a representation of its goal (Mountcastle *et al.* 1975, Rijntjes *et al.* 1999). Both the motor theory of speech perception (Liberman and Mattingly 1985) and the direct-matching hypothesis (Buccino *et al.* 2004) propose that individuals are able to recognize goal-directed activity of others by "mapping" the observed activity onto their own motor representation of that activity.

It is plausible that, when listening to music, not only musicians but also non-musicians map what they hear onto their own vocal motor representation of the melody, which would also explain why people either hum along with the melody of a popular song or tap the beat. Among instrumentalists, the aural imagination of a melody or chord progression is frequently accompanied by mimed playing movements (Haueisen and Knösche 2001). These movements are not instrument-specific. A pianist may "feel" the chords in his hands while listening to a string quartet or a choir.

Instrumentalists who are not only able to play what they hear in the original key, but also in any other key, must code music in terms of action goals, making it possible to "unpack" complicated movement patterns, very similarly to speech: transposition of a theme or chord progression to another key requires totally different motor commands, just as the translation of the meaning of a sentence to another language.

Non score-dependency could therefore be the manifestation of enhanced efficiency of sensori-motor transformation in premotor-parietal circuitry associated with activity of the hands; score-dependency on the other hand could point to reduced motor resonance in those areas implying that score-dependent musicians' listening might rely on different cognitive strategies.

Our main hypothesis is that, while listening to music, the non score-dependent musician will exhibit an automatic, non effector-related facilitation of the motor cortex manifesting itself in the recruitment of premotor and parietal cortical fields normally active when playing the instrument he has mastered. Score-dependent instrumentalists on the other hand will either not experience this facilitation or at least to a lesser extent.

METHOD

Participants

Task-related cerebral activations were studied in three subgroups of healthy right-handed subjects (18-65 years old): (1) skilled non-score-dependent organists and/or pianists, (2) skilled score-dependent organists and/or pianists, and (3) musically unskilled controls. Each group consisted of 12 participants.

Materials

The stimuli consisted of 48 tonal pieces composed in two-part harmony. Half of the pieces were composed for the experiment. The other 24 pieces were taken from the classical repertoire. These pieces were made available to the participants in advance so that familiarity was ensured. The pieces were recorded for the experiment on brass instruments.

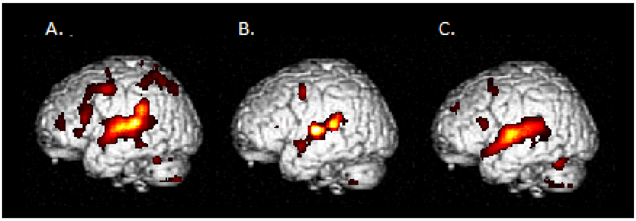

Figure 1. Regional cortical BOLD response in non score-dependent musicians (A), score-dependent musicians (B), and musically unskilled controls (C) during attentive listening to both familiar and unfamiliar music at a threshold of $p<0.001$ (uncorrected), k=8, projected onto a standard MNI brain.

Procedure

In a sparse-sampling paradigm with acquisition every 16 s, a 3T fMRI is used to measure task-induced BOLD response. This measure provides an index for the distribution of local neuronal activations. Participants listened to 24 s recordings of music examples presented by headphone. The following experimental conditions were distinguished: (1) unfamiliar music, (2) familiar music, (3) motor imagery task (asked to imagine performance of the piece), (4) attentive listening task (asked to make internal comments regarding the performance). In an auditory baseline condition, natural noise (waves of the sea) was presented.

RESULTS

Final results will be presented at the symposium. Preliminary results at submission of this report pertain to first-level analysis of individual subjects only. Bilateral activation of the premotor-parietal network during both motor imagery and attentive listening is a common feature of the non score-dependent participants, regardless of familiarity with the music (Figure 1a). Score-dependent musicians scanned to date, on the other hand, exhibit little activation of this network, also regardless of familiarity with the music (Figure 1b), quite similar to the musically unskilled controls (Figure 1c).

DISCUSSION

While preliminary results do not allow generalization, they nevertheless suggest that familiarity with the music is not a major factor in the elicitation of motor resonance behavior by tonal harmony. As in this study, the musicians are all classically trained and the stimuli belong to the classical style, it is seems possible that familiarity with the style might be more important than familiarity with the actual pieces.

The pattern of activation in non score-dependent musicians suggests that facilitation is indeed non effector-related as was hypothesized. Two-part harmony played on wind instruments does elicit ample motor resonance in this group of subjects.

The results suggest moreover that attentive listening can elicit a pattern of activation not unlike motor imagery and that the pattern of activation is greater in non score-dependent musicians than in score-dependent musicians.

While this study does not pretend to infer the possible importance or necessity of non score-dependence for performance, the finding that score-dependent musicians may resort to alternative motor strategies should be of interest to all involved in instrumental pedagogy.

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Non score-dependency: Theory and assessment

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Untrained listeners demonstrate implicit knowledge of syntactic patterns and principles. Untrained generative music ability, for example singing, humming, and whistling, is a largely unconscious or intuitive application of these patterns and principles. From the viewpoint of embodied cognition, listening to music should evoke an internal representation or motor image which, together with the perception of organized music, should form the basis of musical cognition. Indeed, that is what listeners demonstrate when they sing, hum, or whistle familiar and unfamiliar tunes or when they vocally or orally improvise continuations to interrupted phrases. Research on vocal improvisation using continuations sung to an interrupted musical phrase, has shown that one's cultural background influences the music generated. That should be the case for instrumentalists as well: when they play familiar or unfamiliar tunes by ear in different keys (transposition) or when they improvise variations, accompaniments, or continuations to interrupted phrases, the music they generate should reflect the same cognitive structures as their oral improvisations. This study is attempting to validate a test of (non) score-dependency that will enable assessment of the music student's implicit knowledge of these structures during performance on the principal instrument.

Keywords: non score-dependency; improvisation; assessment; oral proficiency; performance

Both language and music as auditory phenomena are unique to the species (McDermott and Hauser 2005). Both are ubiquitous elements of all cultures (Molino 2000) and develop spontaneously during childhood. In the temporal domain both are rule-based systems composed of sequential events that unfold in time (Lerdahl and Jackendoff 1983). Both exhibit specific rhythm and specific segmental and suprasegmental information organized into (recursive) higher-order structures (Besson and Schön 2001, Raffman 1993).

Syntactic knowledge allows the mind to accomplish a remarkable transformation of the input: a linear sequence of elements is perceived in terms of hierarchical relations that convey organized patterns of meaning (Patel 2003). Listeners demonstrate implicit knowledge of syntactic patterns and principles in a number of ways, including judgments of correctness, memory advantages for rule-governed sequences, and production of plausible substitutions when linguistic or musical sequences are recalled less than perfectly (Blacking 1973, Sloboda 1985).

With the Shared Syntactic Integration Resources Hypothesis, Patel (2003) posited that overlap in syntactic processing of language and music would correspond to overlap in the neural areas and operations which provide the resources for syntactic integration.

There are, therefore, many reasons to expect that proficiency in language might exhibit similar characteristics as proficiency in music. Specifically, oral proficiency in a non-native secondary language may exhibit characteristics similar to non score-dependent proficiency in playing a music instrument. Just as in the case of a foreign language, mastery of a music instrument is not learned spontaneously during childhood. Unlike singing, instruments are frequently learned in a formal educational setting.

Oral (second) language proficiency can be assessed in functional situations including a large number of components, for example: vocabulary, syntax, pronunciation, accuracy, spontaneity, fluency, understanding, etc. (Kramsch 1986). Similarly, non score-dependent proficiency could be assessed by observing richness of musical vocabulary, correctness of musical syntax and comprehensibility of phrasing and prosody in the context of replicative, manipulative, and generative performance.

The purpose of this study was to validate an assessment protocol for the purpose of determining the measure of (non) score-dependency among instrumentalists, for example as part of an entrance examination. To that end, an assessment protocol was tested with conservatoire students. A brief description of the protocol follows.

Recordings of short tonal fragments were played and test subjects given various musical tasks to perform after listening to each fragment. Participants were requested to replicate, manipulate, or generate a response to a range of aural models.

- *Replicate:* (1) Repeat the music fragment exactly as heard, (2) transpose to another key, (3) transpose to the relative minor, (4) play a similar melodic contour starting at a higher note, while maintaining the same tonality.
- *Manipulate:* (1) Add a second voice (descant, bass, or alto voice, in thirds/sixths), (2) harmonize the melody (for keyboard players), (3) play a variation on the theme.
- *Generate:* (1) Play a continuation to an interrupted phrase, (2) play a spontaneously improvised melody, (3) whistle or hum a spontaneously improvised tune.

Analysis of the results is based on:

- In the case of replication, melodic similarity between model and performance.
- Appropriateness of substitutions and additions.
- Richness of musical vocabulary.
- Correct syntax.
- Dynamics and timing to discover discrepancies between structure and expressive performance.
- Results of the two conditions "play a spontaneous melody" and "whistle or hum a tune" are compared with discover discrepancies between the oral and manual domains.

Possible tools for analysis are:

- Tonal and harmonic analysis to uncover discrepancies in structural richness and regularity.
- Discrepancies in timing and dynamics between both domains.
- Statistical analysis to reveal discrepancies in, for example, variation in the frequency of appearance of the seven tones of the scale.

Results of the various tests are being correlated to validate their use within the test battery in instrumental performance. At submission of this report no results are yet available.

MAIN CONTRIBUTION

This study hopes to establish an assessment procedure that would allow conservatoires to test non score-dependency of prospective students at application to professional institutes as well as later in the course of their studies. In addition the results of this study are being used to distinguish between score- and non score-dependent musicians in an associated fMRI study on the role of cerebral resonance behavior in the control of music performance.

IMPLICATIONS

The disappearance of improvisation from the curricula of conservatoires challenges educators not only to develop adequate teaching methods for tonal improvisation but also to develop assessment procedures to measure their effects.

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How expert pianists interpret scores: A hermeneutical model of learning

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Many studies evaluate listeners' perceptions of performed music; fewer explore performers' perspectives on learning music. This study generalizes a model of learning from over 175 open-ended and semi-structured interviews of expert pianists. Such a model can suggest pedagogical goals to improve students' learning and factors that lead to different interpretations of the same musical score. A macro-micro-macro process of learning is described as a hermeneutic circle in which the parts and the whole inform one another simultaneously. The parts, consisting mainly of the notation in a score, can be divided into fixed, variable, and implicit qualities. Each part maintains a specific relationship to the whole: a pianist's learning of fixed qualities (pitches and rhythms) is informed by the whole; variable qualities (expressive markings) reciprocally inform and are informed by the whole; and implicit qualities (inferred structures, historical information) either inform or are informed by the whole. Expert musicians arrive at different interpretations of a score when they prioritize the whole or the parts to varying degrees. Implications for pedagogy include drawing greater attention to how the parts relate to the whole, and encouraging students to explore resources beyond the score.

Keywords: macro-micro; intuition; analysis; perception; hermeneutic circle

This study compares over 175 interviews of internationally renowned pianists. The interviews were either open-ended (Brower 1915, Cooke 1917, Mach 1991) or semi-structured (Dubal 1984, Noyle 1987). The purpose was to determine how expert pianists develop different interpretations of the same score while practicing. Understanding how experts accomplish their goals can be beneficial for the teaching of students (Sloboda 1994, Lehmann 1997).

The study confirms that experts overwhelmingly perceive their learning to be a macro-micro-macro process (Lane 2006): first they gain a conception of the composition as a whole, then they work out technical and interpretive problems, then they integrate the parts back into the whole. Students, however, often fail to attain a macro picture; they immediately begin working on technically difficult passages and do not address larger interpretive issues (Chaffin *et al.* 2003). A key to developing students' learning is to understand the differences between their approach to the score and an expert's. Bautista *et al.* (2009) explore how students conceptualize scores; this study focuses on experts' perspectives, highlighting in particular their perception of the relationship between the parts and the whole. To identify similarities and differences between musicians' approaches toward interpreting the score, the macro-micro-macro process of learning is explicated as a hermeneutic circle, whereby the parts and the whole simultaneously inform each other.

MAIN CONTRIBUTION

A score can be categorized by three qualities—fixed, variable, and implicit—to which musicians respond differently during their learning. For Western art music between the seventeenth and nineteenth centuries, the fixed qualities are pitches and rhythms: the musician makes no overt changes to them but strives to follow these notations precisely. Variable qualities include indications of tempo, articulation, dynamics, phrasing, and expression; the musician has a range of options for satisfying these markings. Implicit qualities are those inferred from the fixed and variable elements in the score as well as historical treatises and writings. These qualities include structural, harmonic, melodic, rhythmic, and textural relationships, stylistic performing traditions, and biographical data on the composer and time period. Musicians can intuit this information or consciously seek it through research and analysis of the score. Differences in musicians' approach toward each of the three qualities reveals specific areas in which their interpretation of the score can vary.

Fixed qualities: Pitches, rhythm

Every pianist develops a physical technique to enable him to play pitches and rhythms accurately. Technique determines the pianist's general posture at the piano, the position of the wrists, the curvature of the fingers, the use of arm weight, the movement of the trunk, the location and type of tension in the body, and other relevant physical features. A pianist's technique determines his maximum tempo and level of accuracy in difficult passages of music, and influences phrasing, tone color, and articulation. Different schools of technique produce audibly different sounds and hence contribute to variety in performance, even when two musicians otherwise share similar mental conceptions of a composition (Gerig 2007).

Aside from physical facility, the main difference between students and experts in this area is the relationship between the score's fixed qualities and a conception of the whole: experts practice technical passages with a musical purpose in mind, while students focus on playing the notes correctly and lack a musical goal to their practicing. Numerous experts warn of the dangers of technical practicing without a sense of the whole: far from allowing the musician to "add" interpretive elements later on, technical practicing both enforces and reinforces a pedantic interpretation (Hofmann 1976, Noyle 1987, Barenboim 2003).

Variable qualities: Expression, tempo, dynamics, articulation

The score's variable qualities require the musician to solve interpretive rather than technical problems. Experts explain that they have to discover *why* an interpretive marking is in the score and not just reproduce it mindlessly (Mach 1991, Browning 1995). Research confirms that some musicians unimaginatively treat variable qualities as instructions to follow rather than as prompts to be explored and understood in context (Hultberg 2002, Clarke *et al.* 2005).

The relationship between the score's variable qualities and the whole is closely intertwined. Experts try to understand the function each marking has in communicating their sense of the whole. This process reflects the macro-to-micro aspect of learning, where the whole informs the parts. At the same time, variable qualities that may appear to conflict with the musician's conception of the whole may cause him to change or develop the whole to be more in keeping with the score. Such a process reflects the micro-to-macro aspect, where the parts inform the whole. In this area the reciprocal nature of the hermeneutic circle is most evident: the whole informs the parts at the same time that the parts inform the whole. Such interdependence exemplifies the musician's multi-layered understanding of music as observed by Williamon *et al.* (2002).

There are numerous opportunities for differences in interpretation with the variable qualities of the score. Students who lack a firm sense of the whole attempt to reproduce, with greater or lesser skill, the denotative meaning of indications without understanding their connotative purposes. Among experts, it is self-evident that those who have differing conceptions of the whole will interpret the markings in contrasting ways; but even musicians who share similar conceptions of the whole are likely to express a range of tempos, articulations, and dynamics. Such variation is particularly noticeable when a single musician, performing a composition numerous times, intentionally produces different interpretations of it.

Implicit qualities: Structure, style, history

Whether intuitively or consciously, expert pianists have structural, biographical, and stylistic knowledge of a composition, all implicit qualities of the score. There is variety in the structures and information each musician deems important (Williamon and Valentine 2002), which can sometimes lead to audible differences in interpretation, such as accentuating a rhythmic motif rather than a harmonic progression or melodic sequence. Experts give conflicting advice on how to increase understanding of the score's implicit qualities: some suggest engaging in extensive analysis or studying biographical and historical information on the composer (Mach 1991, Dichter 2010), while others recommend trusting one's own musical instincts and individuality (Cooke 1917, Dubal 1984). Musicians' self-perceived roles can be significantly contrasting, even conflicting, as has been noted by Holtz (2009), who categorized musicians as avant-gardist, neo-romantic, or self-disclosing.

The model of the hermeneutic circle illustrates the primary differences between two distinct approaches to learning the implicit qualities of the score. Musicians who consciously analyze or do historical research give themselves as many additional parts as possible with which to build a well-formed sense of the whole. It is their priority to avoid imposing inaccurate conceptions on parts that might not easily fit their macro picture. By contrast, musicians who look to their own intuitions and prior experiences lean toward using their conception of the whole to inform the parts. They spend less time researching additional parts and more time experimenting to make the score's fixed and variable qualities accommodate their sense of the whole. They may allow themselves significant latitude in interpreting the markings in the score.

Stylistic practices and some structural features can be audible in a performance, such as ornamentation, phrasing, important harmonic cadences, metrical pulse, and thematic relationships. Other features, like biographical information or deep structures, cannot be directly linked to an interpretation (Lane 2006). This lack of correlation suggests that the different methods of learning the score's implicit qualities may be more evident in how the musician apportions his practice time than in the performance.

IMPLICATIONS

The model of the hermeneutic circle generalizes how experts can develop unique interpretations in their practicing. Studying individual musicians' approaches to learning within this context may illuminate specific differences between a student and an expert's perception of the score. A student, for example, may be shown to lack an understanding of how variable qualities fit into the whole, or that he mistrusts his own intuitions. Teachers may find it helpful to discuss or demonstrate the whole with students at the start of learning new compositions, then guide their practice of technical passages toward both physical and musical fluency. They can encourage students to learn implicit qualities by doing extra research or by experimenting instinctively.

An additional implication for researchers is the potential distinction between a musician's method of learning the score's implicit qualities and listeners' perceptions of the performance. Expert pianists may assert that their particular method of learning is superior to others, but there is a paucity of evidence that one method can consistently produce a more effective performance from the listener's perspective. Studies comparing musicians' performances to their self-described methodologies and to the score may begin to substantiate or refute such claims.

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Piano concerto "Yellow River": Chinese pianism in the second half of the twentieth century

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In this paper, with various recordings of the Piano concerto "Yellow River" as the example, we focus on different styles of performance by some important Chinese pianists in the later half of the twentieth century. Yellow River, a Piano concerto based on Xian Xinghai's cantata with the same name, was composed by some prominent Chinese composers and pianists in 1969. The piece was often considered as the most famous and popular Chinese piano concerto by critics and became the favorite among many Chinese pianists. Therefore, the study on different records of such a piece from both personal interpreting and technical approaches could reflect the typical characteristics and gradual change of the pianism by Chinese pianists during second half of the twentieth century. According to our analysis on different interpretations of the Piano concerto, we found that the Chinese pianists often combined their academic background on pianism with their own personality, and even added their understanding of Chinese culture. The study indicated that, although largely affected by western cultural tradition, the Chinese pianists were always trying to find their unique interpretations on piano playing in many ways.

Keywords: Chinese; recording; interpretation; piano; culture

Although pianism was introduced into China in the early twentieth century, and several music schools were built during the same period, it was not until the 1950s that Chinese pianists began to perform abroad. The pianists during that period included: Fu Ts'ong, Liu Shi-Kun, Gu Sheng-Ying, Yin Cheng-Zong, Li Ming-Qiang, and Bao Hui-Qiao. At the beginning of the second half of the twentieth century, Chinese conservatories mainly used the Russian piano pedagogy system and some pianists also studied abroad in Russia. However, the condition changed in the 1980s after the Great Cultural Revolution and more young pianists preferred to go to America, France, or other Western countries for studying pianism, including Li Jian, Kong Xiang-Dong, and Xu Zhong. The pianists from these two generations comprised the main Chinese pianists during the later half of the twentieth century.

The piano concerto “Yellow River” was adapted by some prominent composers and pianists in 1969, including Yin Cheng-zong, Chu Wang-hua, Liu Zhuang, Sheng Li-Hong, Shi Shu-Cheng, and Xu Wen-xing. Most of the themes were taken from Xian Xing-Hai’s cantata, also “Yellow River”; the melodies of “The Internationals” and “The East is Red” were also added. The concerto consists of four movements: (1) Prelude: The Song of the Yellow River Boatmen; (2) Ode To the Yellow River; (3) The Yellow River In Anger; (4) Defend the Yellow River; all of these titles were also from Xian’s cantata. Although the adapters tried to introduce some Chinese musical forms into the concerto, the work was still influenced by European musical traditions; some critics also said the piano part was “decidedly Lisztian in style.” The piece was welcomed by Chinese critics and became popular to the present time.

Many famous Chinese pianists have played the piece and made it part of their repertoire, thus the analysis of different recordings of this piece could be helpful for understanding Chinese pianism in the later half of the twentieth century.

METHOD

Participants

Four representative pianists were selected in order to examine the characteristics and change of Chinese pianists’ performance style in the later half of the twentieth century. Among them, Yin Cheng-Zong (born 1941) and Shi Shu-Heng (born 1946), who began their careers in the 1950s and 1960s, and Kong Xiang-Dong (born 1968) and Xu Zhong (born 1968), who began their careers in the 1980s.

Materials

Six recordings of the piano concerto “Yellow River” by the four pianists were used. For the older pianists, two recordings were selected from different times. For younger pianists, one recording was selected for each of them. There are three different versions of this piece; in addition to the original

Table 1. Recordings list of piano concerto Yellow River (see also Discography).

Performer	*Time*	*Version*
Yin Cheng-Zong	1971	Original version
Yin Cheng-Zong	1991	Original version
Shi Shu-Cheng	1994	Original version
Shi Shu-Cheng	1991	Revised version
Kong Xiang-Dong	1988	Original version
Xu Zhong	Date unknown	Original version

version, two other revised versions based on it were arranged by Shi Shu-Cheng and Du Ming-xin. In our study, only Shi Shu-Cheng's version was used. The details of the six recordings are shown in Table 1 and in the Discography.

Procedure

Both personal interpreting and technical approaches of the piano part from the six recordings were analyzed; we focus on factors such as the musical structure, tempo, touch, and sound.

RESULTS

Yin Cheng-Zong gave the work's premiere and recorded it first with the Central Philharmonic Society of China directed by Li De-Lun in 1971. Yin had studied piano under the direction of T. Kravchenko in Russia and his performance style was strongly influenced by the Russian piano school. As a pianist, Yin was in his prime at that time, and his interpretation was full of dramaticism and passion. In the first movement, for example, he played the numerous arpeggios in the cadenza smartly and vigorously, different from performances nowadays. He emphasized the accents and linked four "arpeggio waves" together at the same time, thus forming a huge force running through the cadenza. He also played the ascending octaves scales and descending chords precisely and expeditiously. In this recording, Yin mainly blended the notes together and focused on the whole effect of musical expression. However, in the recording made in 1991, Yin presented a more grainy sound, his touch with a strong penetrating power, and the accents were full and with fine proportion of structure. Obviously, the pianist's performance style turned to be more introspective and paid more attention to musical structure rather than "external effect."

Shi Shu-Cheng, another main arranger of this piece, also made some important recordings. His performance was strict to the original score. In the theme of "The Song of the Yellow River Boatmen" from the first movement, although two eighth notes were marked as *martellato*, many pianists executed them as accents. However, Shi's recordings were always loyal to the text, and the theme had a balanced dynamic and clear texture. His performance had colored sound and the control of touch was strong and solid. Furthermore, he arranged the piece again in 1990. In this version, he enriched the original piece with more themes from Xian Xing-Hai's work. As a pianist who understood Chinese traditional culture deeply, he also added more elements of Chinese traditional music, such as melodies from Peking opera, and removed the theme of "The Internationals" and "The East is Red" from the concerto.

The interpretation of younger pianists often presents a unique style. Kong Xiang-Dong, who graduated from the Curtis Institute of Music, recorded the piece in 1999. In his performance, he emphasized a series of sixteenth notes in the internal voice part and used the sustaining pedal several times to make the musical structure clear. Kong controlled the dynamics with changes in tempo of octave-chords in the low parts in the fourth movement. In addition, Kong's sonority was enough to contend with the orchestra, which showed that his control of weight was strong.

In contrast, Xu Zhong, who was affected by the French school and good at playing impressionist works, gave a different interpretation; his playing was supple and clear in structure. The expression of scales and chords were moderate and colored and the relation between different sound parts was subtle.

DISCUSSION

Although Chinese pianism originated from and was influenced by Western cultural traditions, the characteristics of Chinese pianists were still distinct during the second half of the twentieth century. That was partly due to their different academic backgrounds and personalities, but more importantly they insisted on seeking their own interpretation. According to the different performances of Yellow River piano concerto, we found that the expression of the same piece was changed a lot in different times. This implies that the older pianists always made active reconsiderations concerning their performance style and managed to change the older interpretations which then endowed new vitality on this piece. However, the younger pianists were freer in their interpretation, thus they brought more unique styles into the piece.

Note

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From traditional to constructive practices in music education: Materials with which to study conceptual change in string teachers

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There are three essential moments during a lesson: (a) *planning* the activities, (b) *supervision* of the strategies involved, and (c) the *evaluation* of achievements. However, the ultimate aim of instrument lessons which are structured in this way is not always to give the student cause to reflect or engage in metacognitive activity. Music teachers have a variety of ideas about what and how their students learn, as do teachers from other educational fields. At conservatoires, these conceptions change depending on the relationships that are established between the teacher, the student, the score, and the instrument. In this article, we address the existence of three conceptions or *implicit theories* about instrument teaching and learning (TL) as follows: (1) *direct conception*, according to which the student has a passive and reproductive role; (2) *interpretative conception*, which assumes that the student is engaging in cognitive activity, which is subordinate to the achievement of results; and (3) *constructive conception*, in which the mental activity of the student is the main goal of learning. Starting with the implicit assumptions which are inherent in these conceptions, we created nine videos representing dilemmas (three per essential moment), in order to show the different ways in which teachers can help students to solve a tuning task, by both inferring TL conceptions and studying *conceptual change*.

Keywords: conceptual change; teaching and learning; goals and strategies of teaching; string teachers; researching materials

Recent investigations have shown that both students and teachers hold different conceptions about how musical instruments should be taught and learned (Bautista *et al.* 2010, López and Pozo 2009, Torrado and Pozo 2008). On the one hand, there are teachers who respond to a more traditional approach to teaching (what we have defined as direct and interpretative conceptions, in accordance with the work of Pozo *et al.* 2006), who tend to focus on technical and interpretative skills during lessons (Hallam 1998), and whose students tend to practice more technical and less artistic skills (e.g. Davidson *et al.* 2001, López *et al.* 2009).

Teachers have to do a great deal to help their students to reach a satisfactory standard of playing (Davidson *et al.* 2001) and to practice for the 10,000 hours which, according to Ericsson *et al.* (1993), are necessary in order to become an accomplished musician. This means that it is necessary to advise students on how to practice at home, how to reflect on their actions (Schön 1997), and how to ensure that their practice is worthwhile (Sloboda 1985). In other words, teachers should focus their practices on the cognitive processes of their students rather than on musical outcomes. However, according to Gaunt (2008), the lifelong learning skills that are necessary in order to develop a long-lasting career are not emphasized enough by too many teachers in their practices, in the context of what Gaunt calls one-to-one tuition in conservatoires. These kinds of teachers seem to maintain more complex conceptions than practices (Gaunt 2008, Torrado and Pozo 2006), in a similar way to the proverb "it is easier said than done." They use all kinds of justifications for why they do not teach the artistic levels of performance (Davidson *et al.* 2001). In this sense, we know that what teachers say and do directly affects the agency and conduct of their students, which influences their motivation enormously as well as the achievement of 10,000 hours spent in metacognitive and reflective practice.

It is clear that there are remarkable differences between the strategies for practice adopted by students and the metacognitve skills involved, although their development seems to be inextricably intertwined with the acquisition of knowledge (Hallam 2010). Teachers need to connect with the cognitive and emotional resources of their students, making learning an instrument more student-centered, which could have important implications for motivation and retention (O'Neill and McPherson 2002). The teacher must not tell the student what to do, but instead guide him or her in how to do it. That is what we call a constructive teacher (Pozo *et al.* 2006), one who is able to make the necessary connections between technique and expression (Davidson *et al.* 2001) and one who moves from limiting to expansive conceptions of learning (in the words of Reid 2001), thanks to experiencing a real *conceptual change* in his or her conceptions of TL.

We understand and assume that *conceptual change* (in the words of Vosniadou *et al.* 2007) makes it possible to implement progressive change in teaching practices, so that they become more constructivist, evolving from repeated and regular traditional activities to the aforementioned student-centered learning. It is clear that both teachers and students experience difficulties in consciously accessing their own cognitive and metacognitive processes. We believe that creating effective tools for pre-service teaching programs could enable teachers to observe the different models of teaching as outsiders (e.g. Schmidt 2005) by accessing the conceptions and not the practices, as it has been shown that it is easier to access conceptions than practices (Pozo *et al.* 2006) and that a useful tool should be designed according to the daily practices and interests of teachers (Argyris and Schön 1974).

The tools which have been developed in order to solve those problems have a double purpose. On the one hand, they are designed to investigate the TL conceptions of teachers; second, they have been created in order to study *conceptual change*. Last but not least, these tools are designed to organize materials for *planning*, *supervision*, and *evaluation*, testing the trustworthiness of these materials through both their inter-rater reliability and several discussion groups.

MAIN CONTRIBUTION

We have developed an effective tool by means of video dilemmas which allows us to infer the conceptions of TL that are held by teachers and also students, making the relevant theory easily comprehensible for them. After our investigations using these videos with children, we are aware that they could also work easily with teachers, and we can say that these tools can break down the barrier between theory and practice, in accordance with our objectives and theoretical framework.

Description of the research materials

In this study, we took as a starting point the metacognitive approaches (*planning*, *supervision*, and *evaluation*) involved in a traditional one-to-one lesson in a conservatoire, and following the *ontological*, *epistemological*, and *conceptual* assumptions of these conceptions (Pozo *et al.* 2006), we developed nine videos representing dilemmas which were tested according to their inter-rater reliability and several discussion groups with experts in the field. These videos were used in three pilot studies and one investigation (with a total of 80 children), supported by our research project.

These dilemmas posed three problematic practical situations which were related to teaching moments in a cello lesson, and each item was followed by three response options (see Table 1) regarding the TL conceptions, which can

Table 1. Extracts from the transcription of video dilemmas relating to lesson planning.

	Lesson planning
Direct theory	*T:* Very well Andrea, so for next week, study the scale of C, and remember that we are going to play that scale in the exam in two weeks, so study it properly and focus on the tuning. Ok Andrea? *S:* Ok!
Interpretative theory	*T:* Remember also that you have to play these two scales for the exam in two weeks, so be careful where you place your hand. It has to be at the same height all the time, so that you can play in tune. Ok Andrea? *S:* Yes.
Constructive theory	*T:* How is it going, Andrea? *S:* Well, it is not good enough yet.... My hand is still moving on my fingerboard a little bit. *T:* Yes, and could you think about something else to improve it and to control your hand? *S:* Singing it in tune, imagining it in my mind, and listening to it while I play.

be used to ascertain the responses of both teachers and students. By this logic, we were able to infer their conceptions of TL.

Usually, these three moments take place before, during, and after a task, but in many cases not necessarily as a linear sequence, as they interact in complex ways, thereby influencing each other. In this article, we show only one example of the conceptions relating to lesson planning.

Planning instrument lessons

Prototypically, planning is the organizational moments at the beginning and end of a lesson, or in other words, the point when the homework is set and the point at which the teacher and student try to remember what they worked on during the last lesson. However, the processes involved (according to Pozo 2008) could be more or less metacognitive and focused depending on what position the teacher holds with regard to learning.

Supervising instrument lessons

This involves stating explicitly the aims of the tasks and any problems or difficulties which appear, as well as strategies to solve them. This can go from repetitive exercises "on the fly" to conceiving learning as problem solving with conscious control (Torrado and Pozo 2008).

Evaluating instrument lessons

This is usually the final part of a lesson. It can entail comparing the student's performance with an established rule or helping him/her to understand what s/he is doing well, what s/he is doing wrong, and how to improve.

IMPLICATIONS

According to the work of Schmidt (2005), planning, teaching, and reflecting after a lesson is too difficult for many teachers. This is even more true when reflection takes place during the action (in the words of Schön 1997). A traditional conception of how we should help our students to learn does not help to create the "internal order" which is necessary in order to promote the students' motivation, self-confidence, and capacity to reflect on the 10,000 hours of action proposed by Ericsson *et al.* (1993), which are required in order to become a professional musician in our society. For this reason, some questions have arisen, such as: how can teachers organize their teaching, while being focused on stimulating the motivation and previous knowledge of their students? How is this possible in the classroom? It seems clear that the difference between students and teachers who are competent and those who are not is their ability to control their own teaching and learning resources.

We have made complex assumptions of TL that are implicit in the theories understandable for everyone in the musical field. This represents a chance to further the improvement of performance education in music conservatoires. These new materials have helped theory and practice to share a common space, making reflection on practice easier than it was before.

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Behind closed doors: Emotional abuse in the music studio

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An issue of concern that emerged during interviews with six adolescent elite-level classical musicians was emotional abuse from their teachers. Three of six musicians interviewed reported examples of abuse. The purpose of this paper is to discuss the topic of emotional abuse from the perspective of these three musicians. A phenomenological methodology was used in order to capture the essence of their unique "lived experiences." A thematic analysis was performed on the data, which was gathered via in-depth interviews and questionnaires. It can be concluded that: emotional abuse does indeed occur but is rarely talked about; musicians and their parents often justify abuse believing that it is "normal" or even "needed" in the quest to become the best; for some students the need to please their teacher is so strong that, despite emotional abuse, they will do anything in order to gain approval and acceptance; and confidence, a solid sense of self, and resilience are all important attributes for dealing with potential abuse and "surviving" in the world of elite-level music.

Keywords: emotional abuse; classical musicians; student-teacher relationships; elite talent; resilience

According to Bartel and Cameron (2004), emotional abuse by music teachers is an under-researched area. They remark, "in music education we have essentially no research looking at [the issue of verbal and emotional abuse] and little if any acknowledgement it even exists" (p. 40).

One recent study in the field of sports by Stirling (2011) clearly identifies emotional abuse in the coaching of athletes, and develops a model of the contributing factors. In the small amount of research that does exist in music education (Bartel and Cameron 2002, 2004; Cameron and Bartel 2000; Jacques 2000), emotional abuse was found to be prevalent during teaching sessions between elite-level classical music students and their teachers.

Moreover, when the abuse did occur, many students continued their lessons because they felt that the abuse was needed in order to make them better performers.

Jacques (2000) discovered that many music students suffered verbal, emotional, and even physical abuse from their teachers during music lessons and also tended to "justify" it. Bartel and Cameron (2004) are in agreement. They found it disturbing that:

> ...students often do not leave harsh and demanding teachers, and may in fact consider them necessary to the difficult challenge of conquering the "monster" of the non-compliant body or instrument (p. 48).

The purpose of the article is to discuss the topic of emotional abuse from the perspective of three classical musicians who admitted to experiencing emotional abuse from at least one of their private teachers, and their parents also openly voiced their opinions that emotional abuse did occur.

METHOD

A hermeneutic, phenomenological methodology, based on van Manen's (1997) "lived experience" model was used in this study in order to capture the unique stories of the participants. Recruitment of participants was done through snowball sampling, a technique where existing study subjects recruit future subjects from among acquaintances.

Participants

Six elite-level classical musicians (5 female and 1 male, aged 19 to 26 years) were interviewed and three reported explicit experiences of emotional abuse inflicted by their teachers, and so were included in this study report. All participants resided in Ontario, Canada, although one was studying at an American university at the time of her interview. Parents of the three musicians reporting abuse were also interviewed resulting in a total of six interviews. This paper is based only on data collected from these three participants and their parents.

At the time of their interviews, Jenna was active as a violinist, and Emily, who had recently quit both her violin and piano lessons, was teaching privately and thinking about composing and singing pop/rock music. Margaret had finished her music education degree and was currently deciding whether to pursue an additional degree in psychology or join the workforce. In this article, all names have been changed to protect identities.

Procedure

In-depth interviews were conducted with the three participants and their parents. Participants were encouraged to talk freely about their experiences of what it was like to be an elite-level musician, or the parent of an elite-level musician. Interviews were voice-recorded, transcribed verbatim, and later verified by the participants for accuracy. All data was kept confidential.

A thematic analysis (van Manen 1997) was conducted and general themes emerged. One of those themes was that of emotional abuse from teachers during private music lessons and/or orchestra rehearsals. Within this broad theme, several sub-themes emerged, although in this paper I will limit these themes to the teacher-student relationship (in the context of individual student attributes) and justification of emotional abuse. The focus of the rest of this paper will be based on the experiences of the three musicians within the context of these sub-themes.

RESULTS

The teacher-student relationship

Most teachers believe that the success of their students is partially a direct result of their instruction and their reputation (and egos) may be affected by how well their students perform. They are often in competition for the "best" students. Margaret is a very disciplined, self-described perfectionist, at one point practicing over eight hours per day. She developed tendonitis and was required to rest her arm during her first semester of her final year of university. Although she had asked but was given no answer as to what music she should bring to her first lesson in the New Year, she brought some music that she had been working on with her ensemble coach. Her teacher responded with jealousy:

> This is our time together, I don't want to work on [teacher A's] stuff in our time...and then he just lost it.... He was just screaming at me telling me my tendonitis was my fault 'cause I had emotional problems blocking the energy flow to my arm.... I was lazy.... I was a procrastinator.

Margaret put up a fight after breaking down during her lesson. She explained that it took:

> three weeks to find someone to finally teach me because [my teacher] had bad-talked me to everybody in the entire [Orchestra X cello] sec-

> tion…. I wrote a formal letter of complaint to the dean, and then he tried to fail me for my lessons, and I had to go through the appeal process…but I won.

Jenna remembered a competition she was in. She recalled that:

> a judge tore me apart…. She accused me of listening to a recording and copying it…. For things like that, you just throw them off…. People are allowed to have their opinions and yell because of their own insecurities.

Not only does this quote illustrate a fragile teacher/judge ego, but it also illustrates Jenna's resiliency and solid sense of identity.

Emily described an incident where she was in the midst of performing a Bach Prelude and Fugue in front of a packed recital hall. Her teacher was seated in the audience. According to Emily, partway through the piece, one of her hands went in the wrong direction, but she was able to improvise and "save herself" from having to stop playing. However, her piano teacher heard the small glitch and from her seat in the audience, yelled, "STOP…. START AGAIN!" After her performance, she sat on the stairs lining the side of the stage, her mother trying to console her, when her piano teacher approached her and proudly told her that that had been the best she had ever heard that piece played. It is in my opinion that doing something of this nature suggests that she may have an issue with ego.

Justification of emotional abuse

Bartel and Cameron (2004) ask the question "is there justified abuse in the pursuit of excellence?" (p. 50). In the examples cited in the literature section, students tended to stay with teachers who emotionally abused them. Some felt that they needed to be yelled at and criticized, as this was what motivated them to continue to practice or to become "the best." Although all three participants agreed that emotional abuse from teachers does occur at the elite level and that they had experienced it first-hand, they could not agree on whether or not it is justified and how one should cope with it if it occurs.

Both Emily and Jenna justified abuse from their music teachers. Margaret, on the other hand, fought back with the one teacher who abused her. She did not justify it (see example below). Despite feeling like she was useless, worthless, and no good at playing the violin and that she should "give up," she felt that she needed to continue her lessons in order to become a better violinist. She recalls:

> [I felt that I] needed to endure this type of abuse…that this teacher was going to help [me] become a better player…. I was pushing myself…and without a doubt those three years I improved the most that I've ever improved in my violin playing…but they were [also] the most miserable.

Similarly, Emily's mother was in agreement with her daughter and revealed:

> …I felt that [the teacher] was pushing [Emily] too hard…like if he had to cancel [the lesson] at the last minute, she was happy and relieved…. She ended up in tears quite a bit at his lessons…. *I* thought he was starting to cross a line…. He'd make comments about her playing and make it sound like she was terrible…. I think that [he] was psychologically abusive.

Emily's mother attended all of her daughter's lessons because the teacher wanted her there to take notes. She felt that this teacher's toughness was a "normal occurrence" for talented kids because she "didn't know any different…and that it was needed in order to make her daughter a better player" (once again, justification).

Jenna believes that "teacher toughness" is a positive trait when she refers to one of her past violin teachers as:

> …amazing…. He was harder on me than anybody—he *ripped* me apart in one master class…in front of all my peers, but he did it in a way—it was just so genius…. He knew exactly how to tear into me at the right spot, and I was *so* devastated, but you know, it was great because two weeks later, that piece sounded amazing…. I have the most respect for him.

The ambivalence that Jenna voices in this quote is clear. She oscillates between positive and negative feelings, describes verbal abuse, and then justifies how it was doled out with "genius." Although she felt "devastated," she still had great respect for her teacher because he ultimately made her a better player. It sounds from this quote as though Jenna either justifies abuse or is simply very resilient to it. She may, like many others, believe that it is a normal and necessary part of becoming a great musician.

DISCUSSION

Let us return to Bartel and Cameron's (2004) quote, "is there justified abuse in the pursuit of excellence?" for a moment. The quote suggests that in order to excel and reach excellence in a domain, one must suffer. In my opinion, there is a very fine line between what constitutes abuse and what does not. I do believe that it occurs but I do not believe that it is necessary in order to reach a high standard of excellence. The participants and their parents were in agreement that emotional abuse sometimes occurs during music lessons at the elite-level and both tended to justify the actions of the teachers. They generally felt that this negativity or harshness was a necessary component on the path to excellence.

We cannot ignore the fact that emotional abuse in music education at the elite level is an issue that must be addressed. Just how prevalent it is requires further research. This is an introductory study on the topic and is too small to make broad generalizations. As in all professions, the vast majority of teachers do not fit into this category. However, as Tindall (2005), a retired professional oboist turned journalist, said, even one is one too many.

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An inquiry into the function of the torso and its potential for a relationship with the music

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Movements of the body in piano performance have been largely discouraged by pedagogues and performers alike, according to accounts in historical treatises from 1650 onward. This is not surprising, since the ideas controlling piano pedagogy and performance have been largely allied to the structure of Western thought which nurtures a mind/body dualism. The torso is the central axis of the body, upon which the pianist depends for support, and while its function is now attracting the attention of researchers in fields such as human movement sciences, its potential for moving in synchronism with the rise and fall of the music is not.

Keywords: piano performance; torso; circumductory movement, closed and open loop movements; musical analysis

The paper is presented in three parts. First, we show that the "circumductory" movement, so described by kinesiologists Tyldesley and Grieve (1996), maybe an effective use of the torso in piano performance. We follow this in the second part with an analysis which shows that the temporal flow of bars 27-35 of the *Valse Romantique* by Debussy is carried in the linear patterns of notes such as the ascending and descending diatonic, scales, and small chromatic details. Finally, we show how the pianist's torso, with its facility for making circumductory looping movements (henceforth CLM) is able to move synchronously with rise and fall of the notes and bodily control the pacing of their accelerations and decelerations.

MAIN CONTRIBUTION

The circumductory looping movement

Research has not yet focused on analyzing the kinematic features of the torso in piano performance, so we shall depend upon Tyldesley and Grieve's (1996) predication that most movements of the body are a combination of "closed loop" and "open loop" movements (p. 306). The closed loop movement is a guided movement which depends upon visual, auditory, and tactile information as the movement proceeds. During piano performance, this sensory information enables the pianist to make fine adjustments to the movement of the torso. Distinct from this, the open loop movement is a "response to activation of the motor programme, which once initiated must follow its course" (p.306)—pressing the piano key being an example. On this evidence we suggest that the CLM is a combination of these movements which maybe effectively employed in piano playing.

There are two muscle systems which collectively perform the extending, flexing and lateral movements which make up the CLM of the torso. The *erector spinae* is the largest muscle system and lies deep in the back. Its origin is on the sacrum and at the back of the head, and it "acts strongly to raise the torso [from a backward position] to an upright position" (p. 247). The internal and external oblique muscles are situated on both sides of the abdomen and flex the torso forward. Lateral movements of the torso also involve the external and oblique muscles but on one side of the torso only (i.e. the side of the torso which is moving laterally). Smooth muscular changes such as these minimize "the strain they must sustain," while preserving "their natural physical structure" (Epstein 1995, p. 420).

Figure 1 represents the shape of a single CLM of the torso. In piano performance its shape does not change, although its amplitude will vary according to the spatial demands of the music. To perform a complete CLM, the two deep muscles systems described above combine to shift the centre of gravity from one *ischial* or "sit bone" at the bottom of the pelvis to the other.

The analysis

While Debussy instructs that bars 27-35 should be performed *Tempo rubato*, problems can arise for the performer, since at first glance there seems to be scant evidence about how the material therein may be performed in diachronic terms (i.e. in terms of time and process). We have not, therefore, applied "rigorous and theoretically informed analysis" (Rink 2002, p. 35), but relied upon "informed intuition" to determine how to perform these bars. For example, Figure 2 shows that between bars 27-35 of the *Valse Romantique*, there is a succession of thickly textured chords whose function may be best understood "less in terms of root function" but more, as Devoto (2003) suggests, "in terms of specific sonorities deployed as a colouristic expansion of a single melodic line" (p. 186).

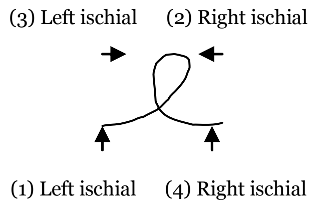

Figure 1. The CLM of the torso begins on the left ischial (1) It then moves to the right of the curve onto the right ischial (2), before shifting along the left of the curve onto the left ischial (3). The CLM is completed as the torso shifts further down along the left of the curve onto the right ischial (4). This pattern may be reversed according to the direction of the music.

Figure 2. Bars 27-35 of the *Valse Romantique* by Debussy.

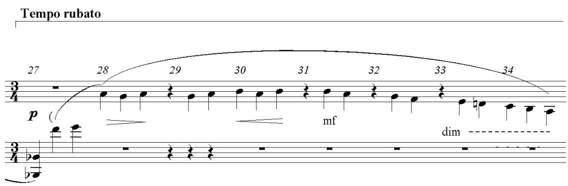

Figure 3. The ascending and descending diatonic scale and small chromatic details extracted from bars 27-35 of the *Valse Romantique* by Debussy.

In this instance, we consider that the chords, which are written in the bass and performed with the left hand, are not merely coloristic but function as a vehicle for the continuing rise and fall of the scale pattern through bars 27-35. As may be seen in Figure 3, we have extracted the ascending and descending diatonic scale and small chromatic details that carry the temporal flow linearly and that are artfully embedded in the chords.

However, *how* the temporal flow is to be paced is dependent also upon other analytical decisions, which in this instance are the dynamics and, since Truslitt (1938) writes "every *crescendo* and *decrescendo,* every *accelerando* and *decelerando*, is nothing but the manifestation of changing motion energies" (p. 52), we suggest that the pacing of the decrescendos in bars 28 and 33-35 maybe achieved by a subtle deceleration of the temporal flow, while the crescendo in bar 30 may be performed with a subtle acceleration of the temporal flow. The chromatic activity in bar 28, from A*b* to G and back to A*b*, and similarly in bar 33, E*b*-D, suggests that these are expressive moments which also help to underpin the deceleration in the temporal flow of the music. It now remains to show how the CLM of the torso can move synchronously with the rise and fall of the notes and bodily control the pacing of the temporal flow. It should be noted that during the performance of the *Valse Romantique*, each CLM must necessarily be connected (see Figure 4) to achieve a smooth pacing of the temporal process.

The performance

The following description of the CLM of the torso in the *Valse Romantique* is to be used in conjunction with Figure 5. The performance begins with center line of the torso positioned approximately in front of B below the center line E. It begins its ascent in a CLM from the octave B*b* on the first beat in bar 27 to position itself approximately near the chord on the first beat in bar 28. The analysis shows that chromatic activity in bar 28, from A*b* to G and back to A*b*, with the small *decrescendo* marked beneath it, is an expressive moment. Here the torso performs three small, slower CLM toward each chord in bar 28 which controls the subtle deceleration in the temporal flow of the music at this juncture. This deceleration is aided also by the "time" it takes the performer to make a large CLM to the left in the direction of the octave B*b* on the first beat of bar 29. The torso then performs a large CLM to the right toward the chord on the third beat of bar 29, before returning in an equally large CLM to the left to play the acciaccatura B*b* on the first beat of bar 30. Then, with a small acceleration of the torso indicated by the *crescendo* through bar 31, the torso moves to the right and performs three small CLM near each chord of bar 30 before moving in a CLM to the left toward the chord on the first beat of bar 31. Thereafter, the torso performs a large CLM to the right toward the chord on the second beat of bar 31, and a CLM to the left toward the chord on the first beat of bar 32, and a large CLM of the torso to the right toward the chord on the second beat of bar 32. An equally large CLM of the torso to the left positions it near the B*b* on first beat of bar 33 and the torso then moves in CLM toward the E*b* on the second beat of bar 33. Bars 33, 34, and 35 are marked "*dim*". This suggests a deceleration in the pacing of the temporal flow, which again may be bodily controlled by a deceleration in the CLM of the torso as it moves toward the octave E*b* at the beginning of bar 35.

Figure 4. A representation of the CLM's of the torso connected one to the other. In piano performance these connections create a smooth "momentum of return," from point A to point B at the keyboard, without having to perform a second muscular impulse to return from point B to point A.

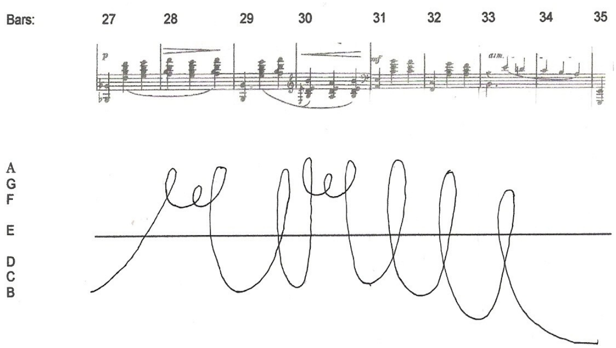

Figure 5. The score above, shows the left hand part of the *Valse Romantique* which has been extracted from the complete score of bars 27-35 shown in Figure 2. The drawing below represents three variables. (1) The progression of time is represented by the horizontal line. (This same line also represents E which is the center of the piano.) (2) The vertical letters BCD E FGA on the left represent the lateral displacement of the torso. (3) The curves in the line drawing represent the anterior-posterior displacement or CLM of the torso. These curves are not intended to prescribe the exact position of the torso other than to say that for the purpose of performing these movements through bars 27-35, the centre line of the torso may align itself (as suggested above) approximately between B below the centre line E and A above E, according to the direction of the notes, and the height, breadth, and length of arm of the player.

IMPLICATIONS

This is a performative approach to performance which stresses the inseparability of the mind and the body. The strategies, while not intended to be prescriptive, aim to show the potential for linking the music with the role of the body during preparation for performance. As Williamon (2004) points out, "the direction and quality of one's practice are integral to performance enhancement" (p.5). The recent "rethink" in academic musical circles has enabled the development of more "informal" analyses, while recent research into the kinematic features of the torso has proved invaluable, since it has underpinned the premise that the torso can perform CLM's which synchronize with the rise and fall of the notes, and bodily control their accelerations and decelerations. Nevertheless, this is a hitherto unexplored area of piano performance which could benefit from an interdisciplinary approach to generate more innovative methods for investigation.

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Taste, again: Naïve listener's preferences of performed tonal music

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Prior investigation by the author shows that recorded interpretations of Beethoven's *Waldstein Sonata* (2nd movement) receive higher preference ratings (e. g. expressiveness, fluency, global evaluation) by expert music listeners (1) when expressive deviations correlate to Lerdahl's theorized concepts of "tension" and/or "attraction," (2) in case of repetition, and (3) when agogics correlate to dynamics. The studies now reported replicate such investigation in naïve music listeners. The results confirm prior findings regarding preferences in cases in which expressive deviations correlate to tension and/or attraction, but not in cases in which agogics correlate to dynamics, nor regarding repetition.

Keywords: interpretation; reception; tonal pitch space

Prior research shows Lerdahl's (2001) theory of tension and attraction developed in Tonal Pitch Space (TPS) to be an efficient tool for understanding performed deviations from strict tempo and dynamics (Martingo 2005), as well as perceived tension and attraction (Smith and Cuddy 2003), on Beethoven's *Waldstein Sonata* (initial 8 bars of the 2nd movement). Further perceptual research (Martingo 2006, 2007a, 2007b) carried out with expert musicians (university music students) showed that higher ratings (e.g. expressivity, coherence) are assigned to recordings in which expressive deviations correlate to music structure as represented by Lerdahl's concepts of "tension" and "attraction," as well as to interpretations in which expressive factors correlate to each other (agogics and dynamics), than to recordings in which no such correlations exist. The research reported in this article replicates with naïve music listeners the perceptual research previously conducted on music students, in order to ascertain whether musical instruction determines musical preferences, and, concomitantly, whether Lerdahl's cognitive theory holds with non-musicians.

METHOD

Participants

The same sample participated both in Study 1 and in Study 2: 76 university students who, on average, were 22 years old, had 0.54 years of aural training, and 0.62 years of instrument training; 71% of the sample were women and 29% men.

Materials

Study 1

A set of seven recordings of the initial nine bars of Beethoven's *Waldstein Sonata* (2nd mvt.) were used in Study 1. Two presented a correlation between dynamics and tension and/or attraction: Kempff (Deutshe Grammophon DG 429306-2, Recording B) and Barenboïm (EMI C25762863-2, Recording F). Two presented a correlation between timing and tension and/or attraction: Guilels (Deutshe 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). The seventh recording, presented as Recording G, was in fact the same as Recording F (Barenboïm, EMI C25762863-2, Recording G).

Study 2

A set of three recordings of the same musical excerpt were used in Study 2: one presenting a significant positive correlation between timing and dynamics (Tipo, EMI 74788625 PM518, Recording AA), one presenting no significant correlation between timing and dynamics (Genov, Chamber CH-CD 106, Recording BB), and one presenting a negative significant correlation between timing and dynamics (Horowitz, Sony 518802-2, Recording CC).

Procedure

Participants were briefly informed of the purpose of the studies, asked to listen sequentially to each of the interpretations of the musical fragment, and were then provided with an answer sheet and asked to successively listen and rate on a seven point scale (1=minimum, 7=maximum) each of the interpret-

Table 1. Principal Components Analysis.

Recording	*KMO*	*Bartlett test*	*Variance explained*	*Cronbach α*
A	0.578	<0.0001	69.444	0.772
B	0.689	<0.0001	77.341	0.852
C	0.657	<0.0001	79.451	0.868
D	0.624	<0.0001	77.869	0.852
E	0.666	<0.0001	77.544	0.852
F	0.760	<0.0001	85.760	0.916
G	0.682	<0.0001	83.889	0.903

tations according to three parameters: expressivity, fluency, and global evaluation. Data analysis was carried out using Factor Analysis.

RESULTS

Exploratory Factor Analysis was applied to data using the Principal Components method to reduce the original parameters (three criteria per recording) into factors. Factor Analysis was found to be of a good applicability to the data, according to kmo (>0.58 and <0.76) and Bartlett test of sphericity ($p<0.05$). In fact, the data suggest that for each recording the best solution results from the extraction of one factor only (eigenvalues >1.00 and significant loadings >0.50). The total percentage of variance explained by each one of the factors extracted in each recording was good (>69%, <86%). Internal consistency/reliability of each extracted factor was tested using Cronbach's α and proved to be very good (>0.77, <0.92). Once verified, the internal consistency of each factor and index for each recording was arrived at corresponding to the arithmetic average (unweighted) of the scores for each recording (between 1 and 7) (see Table 1).

Study 1

Regarding the rating of recordings in which the existence or inexistence of correlations of expressive deviations to music structure (Lerdahl's tension and attraction) was the case, results turned out inconclusive when individually comparing the recordings. Although three of the four in which such correlations existed (Recordings B, E, and F) received higher scores and the two recordings (Recordings A and C) in which such correlations were not the case were among the three lower scores, differences did not always reach significance (see Table 2). In order to clarify these results, an index was arrived at for each pair of recordings showing similar characteristics (see Table 3).

Table 2. Principal Components Analysis.

Recording	*N*	*Mean (SD)*	*Mode*	*Minimum*	*Maximum*
E**	76	4.40 (1.05)	5.0	2.0	6.6
F*	76	4.05 (1.24)	3.0,4.0	1.0	7.0
B*	76	3.82 (0.99)	4.0	1.7	5.7
C	76	3.80 (1.14)	3.0	1.6	6.3
A	76	3.24 (0.97)	3.0	1.0	5.6
D**	76	3.21 (1.12)	3.0	1.0	6.0

Note. *Significant correlation between dynamics and structural factors, **Significant between timing and structural factors. A and C are not significant.

Table 3. Scores for homogeneous pairs of recordings.

Int	*N*	*Mean (SD)*	*Minimum*	*Maximum*
BF*	76	3.93(0.92)	1.7	5.8
DE**	76	3.81(0.83)	1.8	5.5
AC	76	3.52(0.82)	1.5	5.7

Note. *Significant correlation between dynamics and structural factors, **Significant between timing and structural factors. AC is not significant.

Table 4. Scores for homogeneous groups of recordings.

Int	*N*	*Mean (SD)*	*Minimum*	*Maximum*
AC	76	3.52(0.82)	1.5	5.7
BFDE*	76	3.87(0.79)	1.7	5.5

Note. *Significant correlation between expressive deviations and structural factors. AC is not significant.

Namely, scores of 3.93 for the pair B-F (showing significant correlations between agogics and/or tension and attraction); 3.81 for the pair D-E (showing significant correlations between dynamics and/or tension and attraction); and 3.52 for the pair A-C (showing no significant correlations between expressive deviations and music structure), with significant differences between pair A-C and all the others, but not between pairs D-E and B-F (see Table 3). Unsurprisingly, when a global score is calculated for the recordings with significant correlations between expressive deviations and music structure (Recordings B, D, E, and F) and for the recordings in which such is not the case (Recordings A and C), significantly different scores are obtained for the former (3.87) and for the latter (3.52) (see Table 4).

Table 5. Scores for Recordings AA-CC.

Rec.	*N*	*Mean (SD)*	*Mode*	*Minimum*	*Maximum*
CC*	76	4.66 (1.06)	5.0	2.32	7.0
BB	76	4.54 (1.21)	5.0,5.3	1.0	7.0
AA**	76	4.12 (1.17)	4.0	1.0	7.0

Note. *Negative significant correlation between agogics and dynamics; **Positive significant correlation between agogics and dynamics. BB is not significant.

At that level of analysis, the scores of recordings in which either agogics or dynamics correlate to tension and/or attraction showed significantly higher scores than recordings in which such was not the case. Regarding the comparison between Recordings F and G, in which repetition as a preference factor was tested, although the Barenboïm's recording received higher ratings the second time (presented as Recording G) than the first (Recording F), Wilcoxon test showed no significant difference between the scores.

Study 2

Results were inconclusive regarding the rating of recordings in which significant correlations between agogics and dynamics were, or were not, the case. Although the rating of Recording AA (bearing a negative significant correlation between agogics and dynamics) was found to be significantly lower than all the others, Recordings CC (bearing a positive significant correlation between agogics and dynamics) and BB (bearing no correlation between agogics and dynamics) are significantly higher than AA, but not significantly different in relation to each other (see Table 5).

DISCUSSION

Using Lerdahl's (2001) theorization of music structure, the research now reported aimed at ascertaining whether preference factors identified in prior research in musically literate subjects (Martingo 2007a, 2007b, 2008), were also pertinent in subjects with no musical instruction. The Factor Analysis suggests that participants do not discriminate among factors (expressivity, fluency, global assessment), rating similarly all three parameters, a fact that was also the case in musically literate subjects (Martingo 2007a). Regarding the rating of recordings in which significant correlations between expressive deviations and music structure were, or were not, the case, the higher scores assigned to recordings bearing such correlations observed in prior research among music expert listeners (Martingo 2007a, 2007b) were confirmed in the study now reported when a score is arrived at for each pair of recordings with homogeneous characteristics, as well as when recordings bearing no such correlation are compared with all the others. In what concerns repetition as a preference factor, the significantly higher ratings assigned to the second time a recording is heard observed in prior research with music expert listeners (Martingo 2008), was not confirmed in the present investigation (higher ratings were assigned to the second listening, but with no significant differences). In the same manner, the existence of a significant correlation between agogics and dynamics, contrarily to prior research (Martingo 2007a), was not found to be a preference factor among non-musicians. Thus, whereas the relation between agogics and dynamics, as well as repetition would seem more relevant in expert musicians' reception, the relation between expressive deviations and music structure, as theorized in Lerdahl's (2001) TPS, was shown a shared factor by expert musicians and non-musicians.

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Effects of meter and serial position on memory retrieval during music performance

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Effects of musical meter on memory retrieval in music performance were investigated. The range model, a formal model of memory retrieval in music performance, proposes that metrical similarity influences retrieval during sequence production. This assumption was tested by examining production errors in skilled pianists' performances of novel musical pieces. Pieces were practiced to a note-perfect criterion and subsequently performed at fast and medium musical tempi. The relative metrical accent strength of musical events influenced error rates. Effects of metrical accent on accuracy interacted with production rate; performance of metrically weak events was affected by tempo, but performance of the most strongly accented events was not. These findings indicate influences of higher-order event relationships on memory retrieval during production, consistent with theories of expert memory in music performance.

Keywords: music performance; musical meter; serial position; production errors; memory retrieval

Expert musicians produce complex auditory sequences with noteworthy precision. Long and technically difficult musical works can be performed from memory with low error rates (Finney and Palmer 2003). Although previous work has investigated the role of serial position of sequence events in performance accuracy (Mishra 2010), fewer studies have investigated the role of metrical structure, which may influence the memory encoding and retrieval of musical sequences (Palmer and Krumhansl 1990).

The range model of memory retrieval in music performance (Palmer and Pfordresher 2003, Pfordresher *et al.* 2007) proposes that metrical accents determine similarity relationships among events that affect retrieval. As a test of this assumption, we investigated effects of metrical accent strength and sequence position on pitch error rates in piano performance. Error rates at two performance tempi were compared to examine interactions of serial position and metrical relationships with the speed-accuracy tradeoff typically seen in music performance (Palmer and Pfordresher 2003, Pfordresher *et al.* 2007), which predicts that faster speeds yield higher error rates.

METHOD

Participants

Twenty-six adult pianists from the Montreal community (mean age=22.9 years) participated in the study. Participants had between 7 and 29 years of piano experience (mean=15.8). All participants reported playing the instrument regularly; none reported any hearing problems.

Materials

Eight musical pieces were composed for the experiment. Each piece consisted of 33 events, where an event was defined as a single or set of notated pitches to be performed simultaneously. All musical pieces were notated with the same time signature ($^4/_4$) and were isochronous; 32 sixteenth-note events followed by a whole note were scored for both hands. The composed pieces were novel and technically difficult, and short enough to be learned in a single experimental session. Pieces conformed to Western polyphonic music conventions (e.g. no parallel fifths or octaves between voices).

Procedure

At the start of the session, participants practiced the pieces until an error-free performance was achieved at a slow tempo (429 ms per sixteenth-note interonset interval [IOI] indicated by a ticking metronome). This criterion ensured that errors occurring at faster tempi were not due to sight-reading failures, errors of perception, or incorrect learning of the musical pieces.

Following practice, participants performed each of four pieces twice per block over four experimental blocks, with the musical notation in view. Two pieces were always performed at a medium tempo (225 ms per sixteenth-note IOI), and the other two always at a fast tempo (187.5 ms per sixteenth-note IOI). Tempo was established by metronome ticks at the quarter-note level. Additional unrelated pieces were performed either before or after the performances of the pieces evaluated in the study. Piece ordering and assignment of tempo to piece were counterbalanced. Thus, the design was a re-

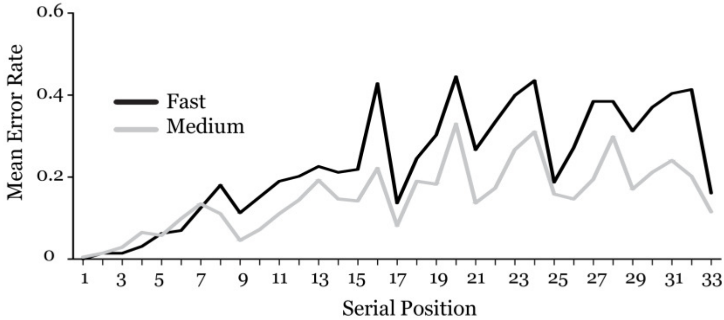

Figure 1. Mean error rates at fast and medium tempi by serial position.

peated measures design with 2 (performances) x 4 (blocks) x 2 (tempi). Pianists were instructed to perform at the tempo indicated by the metronome throughout the trial and to perform without correcting any errors.

RESULTS

Participants produced 5,131 errors across all sequences. The mean error rate per single performance was 0.11. Mean produced IOIs were 194 ms in the fast condition (compared with the prescribed 187.5 ms) and 227 ms in the medium condition (compared with the prescribed 225 ms). Figure 1 shows the mean error rates by sequence position and tempo.

A 2 (tempo) x 33 (serial position) repeated measures analysis of variance (ANOVA) on error rates indicated a significant main effect of tempo ($F_{1,25}=15.18$, $p<0.01$). Error rates at the fast tempo (mean=0.23) were significantly higher than error rates at the medium tempo (mean=0.15), consistent with speed-accuracy tradeoffs in performance. There was a significant effect of serial position on error rates ($F_{32,800}=19.58$, $p<0.001$). Also, there was a significant interaction of tempo with serial position ($F_{32,800}=2.39$, $p<0.001$), indicating that the effect of tempo on errors was modulated by sequence position. Mean error rates in Figure 1 indicate a strong primacy effect at both performance tempi, with highest accuracy for events at the beginning of the sequence, and a smaller recency effect.

Peaks in Figure 1 also suggest that higher error rates aligned with metrically weak positions (upbeats) and lower error rates with metrically strong positions (downbeats). To examine the effect of metrical strength on error rates, each event in the sequence was coded for metrical accent strength according to a 4-tier metrical grid consistent with the time signature and small-

Figure 2. One of the notated stimulus pieces with metrical accent strengths according to a 4-tier metrical grid. Events aligned with all tiers are most strongly accented.

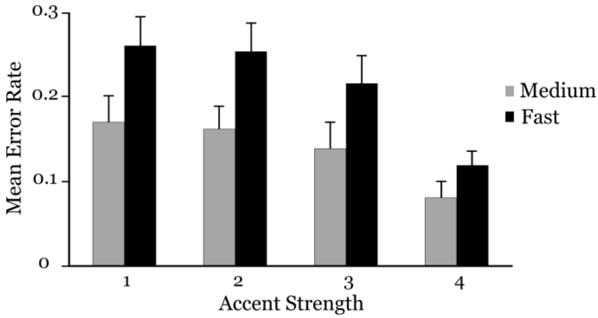

Figure 3. Mean error rate as a function of metrical accent strength and tempo.

est notated duration in the score, as shown in Figure 2 (Lerdahl and Jackendoff 1983).

A 2 (tempo) x 4 (accent strength, 1-4) repeated measures ANOVA on error rates revealed a significant main effect of metrical accent strength ($F_{3,75}$=24.84, p<0.01). As shown in Figure 3, events aligned with more tiers of the metrical hierarchy had lower error rates. Post-hoc comparisons (Tukey HSD=0.0418, α=0.05) indicated that mean error rates for events accented at level 4 were significantly lower than error rates of events accented at levels 1, 2, and 3. Mean error rates corresponding to accent strengths 1, 2, and 3 did not significantly differ from one another. On average, events aligned with the strongest metrical accents were performed most accurately. There was also a significant main effect of tempo ($F_{1,25}$=15.47, p<0.01), and a significant tempo x metrical accent interaction ($F_{3,75}$=3.37, p<0.05). The medium tempo generated lower error rates than the fast tempo, consistent with a speed-accuracy tradeoff, and metrical accent strength modulated the size of that tradeoff.

Figure 3 suggests that the influence of tempo was reduced for events aligned with the strongest metrical accent (level 4). Posthoc comparisons (Tukey HSD=0.0515, α=0.05) of the tempo x accent strength interaction confirmed that faster tempi generated higher error rates than medium tempi at positions with accent strengths 1, 2, and 3, but not at tier 4. Musical events with greater metrical accent strength were more resistant to error at both tempi.

Both primacy effects and increased metrical accent may make musical events less susceptible to error. Correlations between mean error rates and metrical accent strengths, after the effects of serial position were removed from the error rates (regressing metrical accent on the residuals of error rates), were significant and negative for both the fast condition ($r=-0.55$, $p<0.01$) and the medium condition ($r=-0.50$, $p<0.01$). Thus, error rates decreased as metrical accent strength increased, above and beyond the effects of serial position.

DISCUSSION

Accuracy of music performance was influenced by the serial position and metrical accent strength of events. Primacy effects enhanced performance of events at the beginnings of sequences, and meter enhanced performance of events in metrically strong positions. These findings are consistent with the general finding that the perceived salience of meter takes time to be established (Longuet-Higgins and Lee 1982). Accent strength modulated the effects of the speed-accuracy tradeoff; metrically accented events were resistant to effects of increased tempo that usually yielded higher error rates. This finding extends previous work that documented serial position effects across a musical piece (Mishra 2010), based on error rates averaged across metrical positions. The current study's novel focus on the contributions of metrical position to retrieval accuracy indicated that hierarchical metrical relationships transformed classic serial influences by boosting memory retrieval for accented events during production.

Memory retrieval during music performance may be simultaneously influenced by both short-term retrieval constraints and long-term knowledge of musical event relationships. This approach is taken by the range model of memory retrieval in music performance (Palmer and Pfordresher 2003, Pfordresher *et al.* 2007), which assumes long-term influences of metrical accent hierarchies on the types of errors made by performers during production. The current findings support this assumption and are consistent with theories of expert memory in music performance (Ericsson and Kintsch 1995), which propose that well-learned hierarchical frameworks provide skilled musicians with a means of quickly and accurately retrieving information from memory.

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Schenkerian analysis as generator: Stanislavski's "given circumstances"

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My model of inspired performance is based on the thesis that performers can have present in mind—although not necessarily verbalized or conscious—several "graphs" or versions of the structure of a piece, among which they can toggle, unconsciously, as inspiration compels. In my model of interaction between graph and performance, the structure you hear hangs upon the underlying structure that the performer chooses to reveal, in that notes that are subservient in a graph enter into specific relationship with the structure they immediately embellish. By using tools such as volume, color, vibrato, and tempo, a player can encourage an understanding of function for each pitch and pitch event, resulting in a hierarchy of pitch relationships that extends from the surface all the way into the deep structure of a performance. The struggles a graph faces, both within itself and within a larger network of relevant motivations such as meter, melodic contour, surface harmony, and instrumental limitations can serve to provide "given circumstances" in the manner of Constantine Stanislavski. Exploration of potential structures and their consequences can guide a performer toward mental construction of a "network of structural potentialities," which can be travelled, via portals, in and among various graphs.

Keywords: Schenker; analysis; personification; Stanislavski; metaphor

For the imaginative performer, the metaphor communicated in a Schenker graph offers a playground of creative inspiration and thus a portal to the profound heights and depths of Stanislavski's "what if?" universe (Stanislavski 1936). More than one valid structural reading is present in much music, and this plurality of interpretation affords a performer an analogous plurality of potential performances. A pitch or pitch event which functions as a point of stability in one graph might function as an embellishment in another, equally valid graph. Thus, that pitch or pitch event can validly take on very different qualities from one performance to the next. Carl Schachter presents to us in his "either/or" chapter of *Unfoldings* a number of criteria which analysts can use to obtain the "most correct" graph, or the graph which is "the truest artistically" (Schachter 1999). Whereas many analysts will use these criteria to *choose* a graph based upon a preponderance of evidence, I prefer to appreciate graphs for both their strengths and their weaknesses. For it is largely due to a graph's weaknesses, and thus the compensations they beg of the performer, that interesting and intelligent performance decisions arise.

Each graph will hold within itself an innate series of challenges and complications. By then placing the graph within a network of other relevant motivations, such as meter, melodic contour, surface harmony, external form, motivic reconciliation, and instrumental limitations, its challenges multiply (perhaps logarithmically) since often these forces do not work in tandem, but rather, in a dialogue, indeed sometimes in conflict (Agawu 1992). The obstacles a voice-leading graph faces in surmounting problems within itself (such as registral displacements, the need to regain obligatory register after prolonged sojourn into inner voice, or anxious "neighborly" foot-traffic which drives the player to disassociate via cover tone), and external to itself (in interacting with other forces within a network of relevant motivations) can render a beautiful vulnerability, or inspire a spirited adventure through that graph. Each performance of a work can potentially unveil a different set of obstacles, vulnerabilities, tragedies, and triumphs. "Graph-hopping" in and among these analytical potentialities via compatible "toggle points" can serve to provide whole sets of inspiration for a performer in the manner of Stanislavski's "given circumstances."

It is well-known that Schenker did not believe that the tones of highest structural significance in a composition should be given any special emphasis, and despite the fact that Schenker was deeply engaged with performance in many of his writings, this stance is often invoked to criticize attempts to define a relationship among graph and performance. Schenker's often-invoked stance and the problem of defining a relationship between graph and performance do not necessarily communicate, however; in some cases, structural hierarchy can be successfully projected by emphasis, but the Urlinie is a concept which comprises *two* criteria: *hierarchy* as well as *quality* of function. Addressing one without the other over-generalizes the Urlinie process, and robs it of its life.

Schenkerians erase notes, or "explain away" notes toward the end of arriving at a larger-scale understanding of a work, and many performers find this counter-intuitive, since (one can over-generalize that) many of the notes which disappear at deeper levels of graphing need the most emphasis in performance. However, the Urlinie, and all the layers of metaphorical life built upon it can provide an effective inspiration for a performer, as long as we erase notes with the express aim of putting them back, level by level, until we once again reach the surface of a piece. As we reclaim each level, we do so with an understanding of the piece's many layers of internal contrapuntal dialogue. Much work has been published regarding the interaction among graph and performance, notably by Burkhart (1983), Dodson (2008), Guck (2006), Pierce (1994), Schachter (1991), and Swinkin (2007). I would like to extend that work.

MAIN CONTRIBUTION

Imagine for a moment what a scale degree 4 accented neighbor feels or sounds like. It, in a sense, is a temporary "dissonant substitute" for scale degree 3. It will perhaps have a stronger color and/or volume than its adjacent pitches, a deeper, faster, or slower vibrato, a rich color at the start of its articulations. An unaccented neighbor may perhaps have a more floating sense to it, with a lighter color and vibrato in comparison to its adjacent pitches. It may perhaps enjoy a sense of urgency at the middle to end of its life, in an eagerness to regain stability. At the middleground level, a scale degree 4 accented neighbor pitch event region may be characterized by an overall rush of tempo, an urgency, a general mood of instability, richer generalized overtone content, more rapid vibrato, or more sudden or severe changes in color, vibrato, and/or dynamic. An unaccented neighbor region may project a sense of groundlessness, characterized by a lighter color, a relaxation of tempo, a vibrato that lingers nearer the top of the pitch. It may also be characterized by a slight increase in tempo as we approach its resolution.

Like a neighbor, an arpeggiation or arpeggiation region might also take on a sense of floating—but that of a floating "consonance" as opposed to floating "dissonance." This sense might be projected by diminuendo into inner voice, or (equally) by crescendo, in attempt to "increase" the object of its affection, via register and temporal prominence.

In general, a slur or a beam on a graph indicates an allegiance to the more structurally important pitch or pitch event to which it is connected. Not all allegiances are equal: some are more remotely allegiant than others. Thus foreground voice-leading decisions must be tempered according to their location within the overall hierarchy. A "neighbor region" which is a neighbor to an Urlinie pitch will come with a set of definitions: a set of finite but flexible potentialities, since everything within that region should serve to embellish the neighbor—at the appropriate "neighbor level" and thus in the appropriate "neighbor mood." A middleground Anstieg region climbing toward a structural node will come with a different set of finite but flexible potentialities.

BWV 1034, Andante, bars 7-13: Two adventures

Figure 1 presents two different contrapuntal interpretations of bars 7-13 of BWV 1034, Andante. The graphs are highly foreground-oriented, and there is minimal abstraction, since, as a performer, I choose to coordinate the foreground temporally with the middleground to a high degree. The general guideline wherein things which "sound alike" should look alike is not observed, since things which sound alike in abstraction need not sound alike in performance, nor do they function perceptually in the same way.

The common thread which supports the top panel of Figure 1 is a long Zug from D to B. An interesting feature of this graph is something I like to call a "magic slur": the magical change of function of pitch G, which begins its life as the local fundamental of an unstable first inversion G Major triad, and transforms, via E F# G into the fifth degree of a root position C Major triad. The magical G is placed (in bar 10) in a metrically weak position: a problem which will require a negotiation among metrical and pitch-functional information: by strengthening all three pitches D B G, D and B can act as surrogate nodes for the misplaced G. This will help move the Zug upward while simultaneously revealing the rhythmic rhyme among bars 9 and 10. The magic slur, combined with mismatched rhythmic rhyme and registral displacement, will cause a tension of structural haze, which will not be relieved until the dramatic climb to A and subsequent retreat to inner voice which allows the Zug to stretch upward toward the stability of B.

The bottom panel of Figure 1 depicts the same excerpt as a five-line descent. In this reading, the E is marked as an incomplete neighbor to D. A matching of color and dynamic helps guide the ear to believe that E accomplishes the task of embellishing D, despite being separated from it by motion to inner voice. The neighbor E is embellished by a double-neighbor motion, resolving to a re-interpreted E, which now functions as arpeggiation of C. As a result of this magic transformation slur, the music will appear to have released a great deal of tension when the C materializes. Run-off energy from the release inspires the C to unfold into A, which relaxes us down the Zug into G. Because the G which completes our descending five-line is in fact substituted by a cover tone B, the music cadences tentatively (in IAC), causing subsequent music to move urgently toward its misplaced stability.

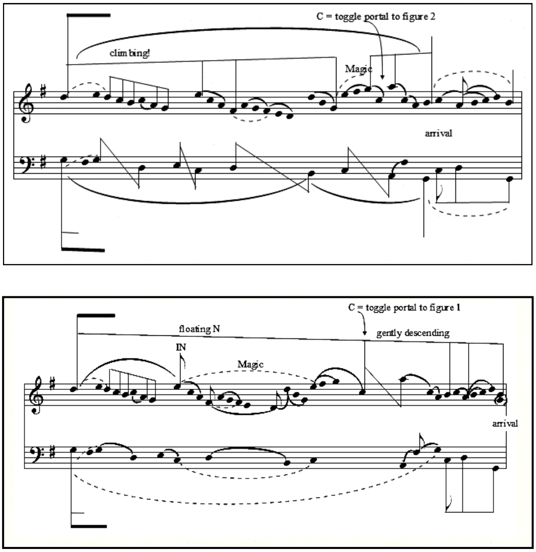

Figure 1. Two different contrapuntal interpretations of bars 7-13 of BWV 1034, Andante.

Both of these graphs have their struggles and high points. A performer might prefer the top on a particularly adventurous day, while on a more melancholy or a more self-assured day, they might prefer the bottom. The toggle point indicated in each graph marks a carefully chosen portal opportunity, wherein the player can "switch" graphs without collapsing the structure. This "toggle move" contains within itself a whole new set of consequences and thus adventures for revelation.

IMPLICATIONS

Berry (1989) states frankly that there are times when a player need only produce the text of a piece and allow it to speak for itself, and Schmalfeldt (1985) acquiesces to this position. However, by pursuing a vivid structure, a performer not only reveals an interesting "dialogue" within their own interpretation, they simultaneously place that interpretation into a higher-level dialogue with a network of all possible structural potentialities, in a similar way that Hepakoski and Darcy (2006) demonstrate a sonata to be simultaneously "in dialogue" with itself and a variable prototype. At an external level, the player who reveals a distinct structure engages in dialogue with a listener's expectations, adding an additional dimension of complexity to the concept of "structural experience." When the process of structural revelation takes the form of personification, a performance gains access to that most transient and priceless height of experience we call "inspiration."

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Pansonic coordination on the drum set: The synthesis of the essential components in groove-based improvisation

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Due to the development of the instrument over the last three decades, drummers have gained access to a wider range of functions within the music making ensemble. One of the most innovative areas in the expansion of the drumset has been *pansonic coordination* created by Kenwood Dennard in the mid 1970s. This approach to drumming consists of adding other sound sources to the drum set such as keyboards and pedal boards in order to realize harmonic and bass-line functions along with the drumming. Since the drummer performs two, three, or four instruments simultaneously, pansonic coordination is possible when each texture is synthesized to its essential components. This poster presentation introduces the principles of pansonic coordination and illustrates some of its applications in groove-based, improvised performance. Drawing from notions of cognitive science, the poster also shows a pedagogical approach to learning this multi-instrumental technique.

Keywords: improvisation; drums; bass pedal-board; multi-instrumentalist; groove

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Performance implications of instructional material in instrumental music education: A case study

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This paper discusses the impact of teaching on instrumental music performance as seen and shaped through a piece of instructional material. A part of Ševčík's violin methodology is analyzed, using an established framework of teaching models. Findings show that there is an active imprint of teaching models inherent in the particular violin methodology, suggesting in conclusion that instructional material could play an active role in shaping cognitive performance practice, as it could dynamically affect students' and teachers' learning and teaching aspects according to its instructional dispositions and balances.

Keywords: teaching; performance; Ševčík; instructional material

It has been generally suggested that whether the *praxis* and "product" of teaching is "correct" is not defined by the use or non-use of a particular technique or strategy, but rather by the praxis's impact on the learner. Based on this, most of us would agree that teaching is a wide process of learning facilitation (McIntyre and Byrd 2000) which should incorporate both planning and delivering of instruction (Gagné 1976) in order to cover most of the "loose" needs and *desiderata* its final product represents.

The teaching "product," in our case, is the final music performance, which, encapsulating variable sets of musical and technical approaches and constituents, indirectly "asks" from the teacher to "…make a host of individual decisions concerning what kinds of stimulation to present to the learner, what communications to make, what questions to ask, what sorts of confirmation of the learner's productions to provide…" (Gagné 1976, p. 21).

Unfortunately, these decisions are not something explicit in the teaching and learning process; and most of all they are not straightforwardly based on the final musical performance itself, even if they so strongly and directly refer to it. Considering the gamut of performing parameters as well as the cultural, psychological or contextual extensions in place, these decisions seem to be influenced from the teacher's understanding on the student's learning approach and capabilities and the teacher's concept relevant to learning and perceptual deduction of the instructional material into the individual's learning process (Biggs and Tang 2007, Gagné 1985, Jones 2005).

Music research, focusing on performance issues, has widely debated the interpersonal links of education between teacher and student (i.e. Creech and Hallam 2010, Gaunt 2008) as well as the teacher's conceptual premises onto the learning process (i.e. Butler 2001, Laukka 2004) so as to facilitate and improve performance's final outcome. Strangely, fewer research efforts have been focused on this important link permeating teaching practice, instructional material, and final music performance, especially when it is widely accepted that "there is no one correct way to 'do it by the book', but…an interpretation, a way of reading and acting upon the book" (Lefstein 2005, p. 348). Should it not be functional to at least try to explore and understand this path of teacher's interpretation of the instructional material, improving the course of learning and the final result of performance too? Following the latter question, the aim of this study was to analyze and pinpoint the teaching approach of an instructional material of violin performance. Its main contribution is to bring to the fore findings of the relevant process, and further discuss implications referring to performance of instrumental music.

MAIN CONTRIBUTION

For this study, Ševcík's Opus 6 (2000), from his violin teaching and learning methodology, was chosen as the instructional material to be analyzed. Following a linear deployment of exercises, the particular Opus refers to the violin's first stages of musical and technical advancement, while it presents its developmental process of learning and performance almost in an explicitly inductive manner (Papatzikis 2008).

Analysis-wise, a particular framework was employed, in order to describe at a cognitive level—naming and explaining—the teaching representations and activities inherent in the above Opus. This framework was directly deducted from Joyce *et al.*'s (2009) *Models of Learning–Tools for Teaching* research study, while it was adapted to fit the purposes of this study.

Tables 1 presents an example of this set of models, as well as their "adaptation" (for the whole set, see Papatzikis 2008). Only those models potentially or directly referring to one-to-one teaching episodes were used during the

Table 1. Examples of teaching models and adaptation.

Model	*Adaptation*
Inductive thinking	Development of musical and technical reasoning on violin performance; the conceptual building, testing, and understanding of violin performance content.
Concept attainment	Learn concepts and studying strategies relevant to violin performance.
Scientific inquiry	-
Inquiry training	Casual reasoning and understanding of how to collect information and build concepts relevant to violin performance.
Cognitive growth	Increase musical and technical development and adjust instruction to facilitate intellectual growth.
Advance organizers	-
Mnemonics	-
Picture-word inductive	-

Table 2. Rates of the models' appearance.

Model	*Rate*	*Model*	*Rate*
Awareness training	4.32%	Conceptual systems	4.32%
Structured social inquiry	2.16%	Concept attainment	18.36%
Non-directive teaching	3.24%	Programmed learning	18.36%
Cognitive growth	57.24%	Simulation	5.4%
Positive interdependence	9.72%	Inquiry training	2.16%
Inductive thinking	15.12%	Self-actualization	1.08%
Role playing	3.24%	Social learning	1.08%
Scientific inquiry	2.16%	Mastery learning	24.0%
Direct teaching	1.08%		

analysis of the 108 exercises included in Opus 6. A link of content and instructional approach was issued for each one of the exercises, taking into consideration the intended teaching and learning results, as proposed either by Ševcík or other teaching and learning parameters found and established in a previous research stage referring to Ševcík's work (Papatzikis 2008). The results from all 108 exercises were gathered, reviewed, and appraised.

Findings

A consistent application of the aforementioned teaching models seems to permeate the work's structure in its entirety, resulting in a decisive correlation of the two elements. For every single exercise of Opus 6, a match with one or more teaching models was found, while the rates of the models' appearance shown in Table 2 sum up to the content of the 108 exercises.

According to Table 2, a 5:5:4:3 ratio of the behavioural, information processing, personal, and social families of teaching models occurs in Ševčík's work. Additionally, it seems that a cognition-related educational mentality (the cognitive growth model) is inherent, simultaneously embodying important characteristics of a combinational-like system of information delivery (the mastery learning model), and an inductive frame of knowledge-production basis (the inductive thinking model). This means that Ševčík's work appears to be a systematic and logically structured educational construct.

It might also be suggested that there is a "determinate meaning" (Meyer 1994) in the way exercises are offered, shaping consequently a "determinate" instructional approach. The element of the determinate meaning potentially presents a productive, stable, and secure educational-performing environment, which in essence agrees with an important principle of instrumental tuition and its performance practice: that acquisition of the physical skills will best be achieved when knowledge of the music being studied is in its most secure form (Cope 1998, p. 267).

The findings also revealed that teaching models belonging to the information processing family, like the cognitive growth (57.24%), concept attainment (18.36%), and inductive thinking (15.12%) approaches, are dominant in the work. This suggests strongly that Ševčík's work favors a student-centered teaching approach, as it addresses knowledge from the point of facilitation, processing, and exploration, and not that of "conduction." It deploys a design "for the development of creativity and discovery of alternatives and new concepts" (Mosston and Ashworth 1994, p. 5) and thus comes closer to a more personal approach of performance handling.

Finally, according to the above findings, Opus 6 seems to be permeated by an inner system of "sequential patterns of instruction" (Yarbrough and Price 1989). Different and seemingly unconnected parts of the work's content follow a certain path to the teaching models' deployment and usage, thus embodying in effect what Yarbrough and Price (1989) presented in their study in three stages as (1) attention-grabbing before presenting the task, (2) presenting the task to be learned and requiring the students to interact with the task and the teacher, and (3) reinforcing by immediate praise or corrective feedback the student's right or wrong responses.

The content leads the student to get involved in a task in variable and differentiated levels when for instance the concept attainment, inductive thinking, and mastery learning teaching models come into effect for the same technical or musical issue across the span of the content (1); a direct pursuit and interaction with both the task and the teacher takes place when for instance the non-directive or the structured social inquiry teaching models are involved in the teaching process (2), while a direct reinforcement and "calibration" of the student's self-esteem and personal development becomes evident when, for instance, the positive interdependence and the role-playing teaching models are connected to the content (3).

IMPLICATIONS

According to the above, it seems that Ševcík's Opus 6 could play an active role in shaping cognitive performance practice, as it indirectly "conducts" students' and teachers' learning and teaching aspects according to its instructional dispositions and balances.

As the instructional material's content seems to be able to project to both the learner and the teacher an active framework of instructive line of how to control better, refine, or even develop anew extensions of cognitive performance, it is important for the teacher to understand the proportions of instructional "ingredients" each educational construct represents. Therefore, it could be said that it is not only about using the right instructional material to achieve an effective level of performance, but it is also about "challenging'" the material's content in relation to what it provides or could provide, in terms of performing concepts, through the instructional process it offers.

Considering the extensiveness of instructional points of view and their active handling through the content of an educational construct—as this study suggests—opportunities to achieve faster a desired level of performance may increase on behalf of the student-performer, providing *in finale* a decisive advantage on the way s/he develops his/her cognitive and metacognitive performing structures.

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The effects of music tuition on academic achievement in Portuguese 8th year students

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The positive association between music lessons and academic achievement is well documented in the literature. Students who learn music show better academic achievements than those who are not involved in musical activities. However, this is a multifaceted association that can only be explained if several dimensions are taken into account, such as socioeconomic status (SES) or general intelligence (*g*). Significant differences in academic achievement were found between 8th year students who studied music (n=60) and those who did not (n=50) in five out of seven subjects analysed: natural sciences, physics and chemistry, Portuguese language, history, and geography. In addition, a multiple linear regression analysis was conducted in order to assess the role played by other potential dimensions (SES and general intelligence) in academic achievement. After including SES in the analysis, the results indicated that music tuition still contributed significantly to the given variance in academic achievement. However, in combination with all the factors (music tuition, SES, and general intelligence), music learning lost its statistical significance. Moreover, contrary to the majority of studies, one noteworthy finding was that SES had no significant impact on academic achievement. In conclusion, the results suggest that musical tuition does have a positive relationship to academic achievement.

Keywords: music tuition; academic achievement; marks; socioeconomic status; general intelligence (g)

A growing body of literature focusing on the effects of musical tuition on academic achievement reports a positive relationship between music lessons/music participation and academic achievement (Catterall *et al.* 1999, Babo 2004, Johnson and Memmott 2006, Fitzpatrick 2006, Kinney 2008, Southgate and Roscigno 2009, Wetter *et al.* 2009). These studies document higher performance in school subjects such as mathematics (Catterall *et al.* 1999, Johnson and Memmott 2006, Fitzpatrick 2006, Kinney 2008, Southgate and Roscigno 2009, Wetter *et al.* 2009), reading (Babo 2004, Fitzpatrick 2006, Kinney 2008, Southgate and Roscigno 2009, Wetter *et al.* 2009), language arts (Babo 2004, Kinney 2008), English (Johnson and Memmott 2006), German (Wetter *et al.* 2009), French (Wetter *et al.* 2009), science (Fitzpatrick 2006, Kinney 2008), history and geography (Wetter *et al.* 2009), citizenship (Fitzpatrick 2006, Kinney 2008), sports (Wetter *et al.* 2009), and handicrafts (Wetter *et al.* 2009).

Despite the fact that the relationship between music tuition and academic achievement is well documented, in literature on the subject the aspects that may account for this vary. Several researchers have attempted to clarify this relationship by controlling the effects of the variables identified in the relevant literature that traditionally have had a significant effect on academic achievement (e.g. socioeconomic status [SES] and IQ). The results indicate that when the aforementioned aspects are controlled, music tuition still has an impact on academic achievement (Babo 2004, Fitzpatrick 2006), while in other results, the effects of music participation became *non* significant (Robitaille and O'Neil 1981) or less significant when variables intervene (Kinney 2008, Southgate and Roscigno 2009, Wetter *et al.* 2009). Research by Babo (2004) reported that participation in a musical instrument learning programme was a significant variable that accounted for the overall variance in language and arts scores when SES, gender, and IQ were controlled. Kinney (2008) reported that students from two cohorts (6^{th} year and 8^{th} year) who were classified as having a high SES performed significantly better in maths, science, and citizenship subtests (6^{th} year cohort) and language arts, maths, science, and social studies subtests (8^{th} year cohort). Robitaille and O'Neil (1981) attempted to answer the causal/correlational question by comparing musical instrument students in the 5^{th} grade with students who did not study music in terms of IQ and concluded that this match eliminated any differences in academic performance between the two groups. The results showed that any differences in academic achievement between the two were eliminated.

In fact, general intelligence (the *g* factor) represents the best predictor of academic achievement (Deary *et al.* 2007, Chamorro-Premuzic and Arteche 2008). Moreover, Undheim and Gustafsoon (1987) claim that *g* and *gf* (fluid intelligence) are conceptually equivalent.

This study aimed to analyze the relationship between music tuition and academic achievement, including effects of SES and general intelligence.

METHOD

Participants

The sample was composed of 8th year students (n=110, mean age=13 years, 62% girls and 38% boys). Students were recruited from ten Portuguese secondary schools during the academic year 2008-09. The students were divided into two groups: (A) students without music lessons (n=50) and (B) students with 6 to 8 years of formal music tuition (n=60). In Group B, 66.7% of the children had taken musical aptitude tests before they started learning music. The parents' level of education was significantly higher for the students in Group B in comparison with Group A (5.30 versus 4.23, $p<0.001$).

Materials

Data collection involved researching the education system databases, specifically to determine (1) marks for subjects included in the 8th year curriculum, in order to assess academic achievement, and (2) students' socioeconomic status (SES), including parents' education levels.

A Battery of Reasoning Tests adapted for the Portuguese population (BPR/7-9) was used to assess general intelligence. A global score of BPR/7-9 is a measure of general, or fluid, intelligence (g).

Procedure

Students were tested individually using the BPR/7-9 at the beginning of the 7th year of the Portuguese education system. Academic achievement in seven subjects—mathematics, natural sciences, physics and chemistry, Portuguese language, English, history, and geography—was compared in the two groups, using a t-test (two-tailed).

A hierarchical regression was carried out in order to analyze the effects of SES and general intelligence, together with music tuition, on academic achievement. Independent variables were entered in block to clarify the relationship between musical training and academic achievement.

RESULTS

The t-test showed significant differences in the global average marks for the groups, with group B scoring higher than group A ($t_{108}=-3.69$, $p<0.001$). They also revealed significant differences in the marks for individual subjects. Group B had higher marks than group A in five subjects: natural sciences ($t_{108}=-5.11$, $p<0.001$), physics and chemistry ($t_{108}=-3.57$, $p<0.001$), Portuguese language (t_{108}=-2.69, $p<0.008$), history (t_{108}=-1.99, $p<0.05$), and geography (t_{108}=-5.908, $p<0.001$).

In the regression analysis each variable was entered into the model as follows: (1) music tuition, (2) music tuition and SES, and (3) music tuition, SES, and general intelligence. Music tuition was found to be a significant contributor to models 1 and 2 but not to model 3 when general intelligence was entered. SES was not found to be a significant variable in all models. The combined effect for all variables, model 3, accounted for 27.1% of the variance (R^2=0.271, p=0.000). General intelligence was the main predictor (β=0.46) for academic achievement, with music tuition losing its significant contribution to the given variance in academic achievement.

DISCUSSION

In line with previous research, the results showed that music tuition is significantly related to academic achievement. In fact, the students in the music tuition group scored higher in five out of seven of the subjects analyzed. It should be noted that the groups did not differ significantly in mathematics and English, a result that is not in line with other studies, which report differences for these two subjects as well. However, they did have higher scores, reflecting the trend in other research findings. Our findings also showed that general intelligence had the strongest predictive power in terms of academic achievement.

The research indicated that being involved in learning music can improve intellectual development (Schellenberg 2004). Moreover, musical aptitude is related to general intelligence (Lynn *et al.* 1989). Thus, it can be argued that learning music can probably improve musical aptitude as well as non-musical abilities (Schellenberg 2004). This assumption is in line with the concept of "musical aptitude in development," since musical potential is affected by the quality of environmental aspects. According to Gordon (2000), this occurs at an early age and continues until the child is 9 years old. Additionally, musical aptitude is also related to better academic achievement (Young 1971, Johnson 2000). Music lessons produce a small increase in IQ (Schellenberg 2004) and have slight positive associations with measures of intelligence (Schellenberg 2006). Schellenberg (2006) reported that music lessons were also positively associated with academic performance even after individual differences in general intelligence were established.

Another important dimension to be taken into account is that parents with higher levels of education tend to be more actively involved in their children's educational achievement (Baker and Stevenson 1986). Our results did not show that the parents' level of education was a significant variable in explaining the children's academic achievement. Despite the fact that this result is not consistent with what has been claimed by other authors, it can be argued, in line with Catterall *et al.* (1999), that regardless of the socioeconomic background of the students, those who were involved in learning music had higher scores than those who did not learn music. This result, in our opinion, is particularly interesting since it seems to support the idea that it is music tuition that has a significant impact on the students' academic achievement. Thus, further research should attempt to clarify the consistency of these results, using student samples from other years, namely 9th year students.

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Repetition and judgment of learning in wind instrument practice

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This study draws on two existing lines of research: blocked and random practice orders and judgment of learning. University wind and brass students practiced three short technical tasks in either a repetitive order or a random order during two practice sessions. Retention testing occurred 24 hours and 1 week after the second practice session. Performances were evaluated for accuracy, speed, and evenness. Woodwind players benefited from a random practice order. A secondary research question was drawn from judgment of learning research in motor learning and metacognition. At the end of the second practice session, participants predicted the metronome marking at which they would play each music task. Predictions were compared with the actual tempos performed at 24-hour retention. All instruments had low to moderate correlations between predicted and performed tempos.

Keywords: practice; contextual interference; judgment of learning; music cognition; learning

While repetition is a common practice strategy in wind instrument practice, previous research suggests blocked practice orders (AAA BBB CCC) are not always as effective as random practice orders (ABC CBA BAC) (Shea and Morgan 1979) for learning brief technical tasks (Rose 2006, Stambaugh 2011). This phenomenon has not been studied with university-level wind players, only at the beginning level. Because this effect is related to cognition, it is possible that more experienced and older musicians may not be affected by practice orders in the same way as young musicians. In addition, it is possible that brass instruments require a higher cognitive load than woodwind instruments, and this could interact with practice orders.

A secondary research question was drawn from "judgment of learning" research in motor learning and metacognition (Simon and Bjork 2001). The judgment of learning construct represents how well an individual believes he has learned a task. This is highly relevant to self-regulated practice. When judgment of learning interacts with blocked and random practice orders, this construct reveals repetitive practice orders lead a learner to be overconfident in how well they have learned a task. Conversely, learners who have practiced in a random order underestimate their level of learning. The purpose of this study is to examine the following research questions:

- Will blocked and random practice orders affect university woodwind and brass players' learning in a similar manner?
- Will blocked and random practice orders affect university woodwind players in the same way as beginning woodwind players?
- How accurately can university wind players predict their level of learning?

METHOD

Participants

Undergraduate participants (N=46; mean age=19.9 years) were members of concert bands at two universities in the USA. Instruments were represented as follows: flute n=10, oboe n=2, clarinet n=9, saxophone n=4, trumpet n=14, French horn n=5, and tuba n=2. Twenty-three students were randomly assigned to a blocked practice group (n=12 woodwind, n=11 brass), and 23 students were randomly assigned to a random practice group (n=13 woodwind, n=10 brass). At retention testing, the practice groups were divided into blocked and random retention testing orders.

Materials

One practice task was composed and then transposed into two additional keys (see Figure 1). With seven pitches, the tasks were designed to represent one motor unit. The transfer tasks were composed to present some of the same intervals as the practice tasks, but in different contexts.

Procedure

All sessions took place in a small room with the researcher present. Participants were recorded at 16 bit 44.1 kHz sampling rate with a Nady CM-60 miniature condenser lavalier microphone. This was connected to a PreSonus FireStudio interface into a MacBook Pro laptop running Cubase LE4 software.

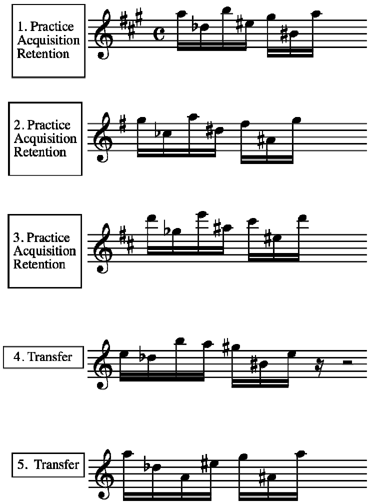

Figure 1. Musical tasks as presented to the flutists.

Each practice task was printed on a separate piece of paper. The music stand had a sheet of paper that listed the order of the practice trials. Participants were told to check off each practice trial as they completed it, to ensure they practiced the tasks in their assigned blocked or random practice order. In the blocked (repetitive) order, participants played nine trials of one task, then nine trials of another task, and finally nine trials of the third task. In the random order, participants played nine trials of each task but in a mixed up order (2 3 1 3 1 2 1 2 3…). A pencil and metronome were also available for use on the music stand.

The second practice trial occurred approximately 24 hours after the first practice session. After completing the practice trials on day 2, participants were told to write down the metronome marking they expected to play each of the three practice tasks when they started the research session on day 3.

On day 3, participants played three trials of each practice task in either a blocked or random order. Then they played the two transfer tasks in an alternating order. One week later participants again performed the retention and transfer trials. The research design was fully counterbalanced.

The trials of interest were each participant's final practice trials, termed "acquisition," the retention trials, and the transfer trials (1,863 trials). The trials were prepared for scoring by first creating master audio files with all the trials of each task placed in a random order. To score for accuracy, I listened to each trial repeatedly and employed a point-deduction system used in previous research (Stambaugh 2011; Stambaugh and Demorest 2009). To score the speed of each trial, the trials were imported into Audacity. I highlighted the onset of the first pitch to the onset of the last pitch and recorded the time generated by Audacity, to the hundredth of a second. To determine evenness for each trial, the average interonset interval (IOI) of the six intervals was determined (IOI_m) and subtracted from the IOI of each individual interval (IOI_x) in the trial. This produced six scores for the differences between individual IOIs and the mean within the trial. The sum of all difference scores ($\sum IOI\Delta$) was divided by the sum of the IOIs for the trial ($\sum IOI$).

RESULTS

The preliminary analysis examined retention order: within the blocked woodwinds, for example, did it matter if they played their retention trials in a blocked or random order? Four sets of t-tests for independent groups compared the retention order within blocked woodwinds, random woodwinds, blocked brass, and random brass for speed and accuracy. The *a priori* alpha level was set at 0.025 for each t-test. Only one within-group comparison was significant: woodwind blocked practice/blocked retention (M=2.24, SD=0.33) versus blocked practice/random retention (M=1.42, SD=0.22), $t_{10}=2.07$, $p=0.019$, for speed. Therefore, the practice-retention groups were collapsed to just practice groups for the remaining analyses.

Blocked versus random practice

Two covariate scores were used to control for individual abilities in playing: the accuracy and speed scores for the first practice trials. Analyses of covariance (ANCOVAs) examined within-practice group changes from acquisition to 24-hour retention and 1-week retention, as well as 24-hour transfer to 1-week transfer, for accuracy, speed, and evenness. The *a priori* alpha level was set at 0.016 per comparison. Table 1 presents the means and standard deviations for these comparisons. No main effects or interactions were found for accuracy for woodwinds, but a significant practice group by speed interaction was found, $F_{4,17}=4.232$, $p=0.015$. Woodwinds who used random practice were able to play significantly faster than woodwinds who used blocked practice. For accuracy by brass players, ANCOVAs indicated no significant differences for accuracy, but the blocked group approached a significant learning advantage for speed, $F_{4,13}=3.663$, $p=0.03$.

Table 1. Means (and standard deviations) for groups (woodwind [WW] and brass) at acquisition, 24-hour retention, and 1-week retention.

	Acquisition		*24-hour retention*		*1-week retention*	
	Accuracy	*Speed*	*Accuracy*	*Speed*	*Accuracy*	*Speed*
Blocked WW	6.06 (0.77)	1.52 (0.67)	5.62 (1.01)	1.94 (0.83)	5.94 (0.86)	1.87 (0.82)
Random WW	6.32 (0.52)	1.41 (0.43)	6.29 (0.72)	1.44 (0.33)	6.09 (0.64)	1.50 (0.44)
Blocked Brass	5.50 (0.65)	1.61 (0.32)	5.04 (0.68)	1.95 (0.35)	5.40 (0.72)	2.06 (0.55)
Random Brass	4.36 (1.22)	2.28 (0.96)	4.16 (1.26)	2.35 (0.76)	4.68 (1.44)	2.02 (0.56)

Table 2. Difference between predicted tempo and performed tempo (in beats per minute). Positive numbers indicate having predicted a faster tempo than having played. Negative numbers indicate having predicted a slower tempo than having played.

	Song 1	*Song 2*	*Song3*
Blocked WW	0.56	-2.47	5.87
Random WW	3.70	4.61	7.61
Blocked Brass	25.54	25.64	27.81
Random Brass	25.20	24.00	27.70

Judgment of learning

Pearson correlations were examined between musicians' predicted tempos and their actual performed tempos. Table 2 shows the mean difference between the predicted tempos and the actual tempos. Brass players consistently predicted faster tempos than they actually played, regardless of practice condition.

DISCUSSION

Previous research found that for beginning clarinet students learning short technical tasks, random practice was more effective than repetitive practice. These results were replicated with university-level clarinet players. However, blocked practice may be more effective for university brass players. This may be related to the greater cognitive demands already present in playing a brass instrument. Often, practice strategies are generalized for use with all instruments. Evidence from this research suggests it is important to validate the use of specific practice strategies with a variety of instruments. In addition, it is clear that brass students were highly inaccurate when assessing their own learning. Future research should investigate how brass students can become more reliable in assessing their learning.

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The musician doctor: A musical evaluation of treatments for movement disorders

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Various therapeutic approaches have been established for the treatment of movement disorders such as Parkinson's disease, dystonia, or essential tremor. However, the effects of such therapies on fine, more sophisticated motor movements relevant to musicians are not well known. The aim of this study was to develop a reliable tool that would allow assessment of treatment effects on fine motor movements through measures of musical performance. The playing of a professional violinist suffering from Parkinson's disease was recorded during different treatment conditions. In each recording, a scale and two themes from violin concertos were played. These were presented (audio only) to 11 violin students who, unaware of the medical history of the player, rated the extracts along various musical dimensions (e.g. intonation, timing, and emotion). We thus employed the highly trained musician's ear to detect fine differences of various treatments on instrumental playing. The ratings allowed striking differentiation between the different treatment conditions. Our study provides an innovative way of evaluating the impact of movement disorders and of different treatment modalities on sophisticated motor functions. Our paradigm can readily be extended to other movement disorders, as well as to other instruments.

Keywords: musical rating; Parkinson; therapy; violin; treatment evaluation

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Tuning movement: Body education in teaching music instruments

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Performance related musculoskeletal disorders are highly prevalent among instrumentalists and have led to an increase in health, wellbeing, and prevention actions in countries around the world. Researchers on prevention of occupational musculoskeletal disorders propose that an effective way of reducing their prevalence and gravity is to intervene during training periods, using professional know how of more experienced workers—the *savoirs de métier/savoirs de prudence*—that allows them to keep safe. Learning a musical instrument involves not only the acquisition of very complex motor skills and language symbols but also represents the initiation to a social group with very structured mores and rules of conduct that may interfere with health behaviors. This article presents ongoing research that investigates the training of beginners and intermediate students at a public music school in São Paulo, Brazil, particularly regarding the way teachers approach the body and movement. Preliminary results indicate that teachers' verbal abilities for describing sound, movement, and sensation can be described as part of the *savoirs de métier* that interfere with students easiness of learning and performing. This could be used in health promotion contexts on the activity of performing an instrument.

Keywords: instrumental learning; teaching approaches; ethnography; motor skills; health promotion

High prevalence of performance-related musculoskeletal disorders (PRMD) among instrumentalists and instrument students has determined the inclusion of health and wellbeing programs in many schools around the world (Manchester 2009, Kenny *et al.* 2009a, Atkins 2009). In Brazil, only a few music schools and conservatoires have included these contents, and the ones who did offer them as elective courses. One of the recognized forms of prevention of painful musculoskeletal disorders related to repetitive motion is action during the learning period, through training that incorporates elements of the *savoir faire (*know-how), a professionally developed knowledge that can protect workers (Ouellet and Vézina 2008). To play a music instrument is a highly complex body technique (Mauss 2003), which establishes movement patterns capable of modifying the brain's substratum (Altenmüller 2007). The training of a musician is a particular type of body education which goes beyond motor skill and language acquisition. It is a novitiate into a particular social group, which influences modeling of individual practices through group current customs, traditions, and social relations (including work relations) (Fortin 2009, Wacquant 2002). To verbalize and turn into formal knowledge the *savoirs de métier* during student training could allow that prudence knowledge to be developed, in a way that enables novices to keep healthy and safe while facing the burden of a repetitive practice in an inadequate environment. This article presents the preliminary results of ongoing doctoral research that investigates the way teachers approach the body during early years of instrument training, with the aim of identifying relevant themes and moments for health promotion actions.

METHOD

Participants

Twenty teachers of orchestral string instruments at a public music school in São Paulo took part in the study.

Procedure

Ethnographic observations of beginners' and intermediate students' classes were carried out and followed by in-depth, semi-structured interviews of instrument teachers exploring themes revealed by observations and arising from the researchers' previous knowledge. These themes refer to students' performance features that are relevant to the teacher, resources for instructing—including oratory, demonstration, and studying strategies—and *savoirs de métier* that are mobilized during classes. The project was submitted to and approved by the faculty's research ethics committee.

RESULTS

Initial observations of classes suggest the existence of different categories of body-related instructions given by the teachers, as shown in Table 1. Observations also revealed teaching resources used by the teachers to favor learn-

Table 1. Categories of body-related instructions observed at beginner and intermediary classes.

Category	*Type of instruction*	*Contents of instruction*
Positioning movements	Relationship between body and instrument	How and where to hold the instrument; general body alignment….
Technical movements	Basic	How to produce sound; tuning instructions; format and position of hands; separate hands studying strategies; instructions to point out correct coupling of movement and sound….
	Intermediary	Fingering, tuning, intensity variations (dynamics); sound characteristics (legato, staccato); interpretative/reading aspects, such as phrasing, pauses, rhythmic elements….
	Advanced	Performance preparation strategies; mental studying; anticipatory movements to ease performance accuracy; emblematic gestures to communicate with the public or fellow performers; mental imagery to help rendering of composers' intentions…. *Savoirs de métier*: cheats and tricks to ease performance, reduce stress….

ing and sound production, like verbal instructions, demonstrations, and eventually physical guidance of students' gestures. Their use is a function of teachers' personal characteristics and students' level.

Physical guidance was the least used type of instruction, seen mainly with younger, beginning students. *Demonstration* of sound results expected, at the instrument or through teachers' vocalizing, was observed in almost all of the classes.

Verbal instructions are the prevailing resource and, adapted to the age and knowledge of the student, address a variety of themes: the instrument, correct grip and sensation of force, tension or body alignment, musical play, and others. Features of teachers' speech about the body and movement are highlighted in the following sections.

Use of figures of speech

Metaphors, resource to non bodily movement images, expressive or affective allegories of the sound/movement of play, and anecdotes were used to describe or enhance the kinesthetic of position, sound and movement required, or even sensations that the student should feel.

Emphasis on control of performance and speed

Teachers instructed students on tempo increase or decrease, rhythm variations to clean reading, fingering, or tuning imperfections. This contributes to a clearer verbalization about the play or its performance.

Resource to personal experience

Teachers pointed out to students strategies used during professional or study practice, weaving relationships between what the students face at that particular moment and what s/he did or does to overcome a similar situation.

DISCUSSION

Playing music is a skill that requires as much physical craft as it does cognitive and emotional skills. These capacities develop together, and teachers—particularly those of beginning students—set the track that will guide music production. This means not only how to move, but how to move to produce a particular type of sound. The nature of this movement is repetitive, since the same elements will always be necessary to play, but repetition during daily practice does not necessarily result in PRMD, although mild aches or pains may be common (Kenny *et al.* 2009b). This can mean that pain should be seen as a parameter of *DO's* and *DON'Ts* in the process of taming the body, not to be disregarded but to be worked out as a part of apprenticeship.

Health professionals have been informing musicians about diseases, what are their symptoms, and what to do in order to prevent or cure them. Although this may be a necessary content at some point of the musician's career, it is an action focused on illness, not on health. If one is to promote health, one should discuss health, and not the lack of it. Health is a much more difficult subject than disease. To deal with this subject, instrument teachers may be far more prepared than health professionals, as they would be discussing health within the sphere of activity, betaking of a body of knowledge that gathers coping strategies to face potentially harmful environment and tasks—the *savoirs de prudence*. In the case of painful disorders of the musculoskeletal system, decreasing the effort and increasing the easiness of playing can be a way of preserving health.

The craft of teaching, although strongly dependent on personal instrument abilities, is different to playing. It asks for resources either learned when a student or created *ad hoc*. Demonstration of expected sound seems to be an example of the first: the teacher tries to establish a stronger aural and bodily landmark that furthers multisensory coupling—the kinesthetic of body positioning and moving in relation to sound production. Verbal instruction is one of the main resources for teaching. It is a speech that faces particular difficulties of wording and describing, due to the nature of the facts that it refers to and to the relational aspect of the class. It will demand of the teacher the development of strategies adequate to the instruction s/he wants to convey—the *savoirs de métier*—adequate to the student and moment.

Our preliminary results reveal certain characteristics of teaching language that may be classified as *savoirs de métier*, directed to facilitate learning and motor skill acquisition. Resourcing to figures of speech in particular appears as such, as it allows a finer description of movement and, at the same time, gives it emotional coloring. The teacher speaks trying to unveil to his/her student what is obscure, intricate, or unvoiced (Barthes 1982)—the way the body should move and feel when playing. This should be a two-way route: at the same time that s/he teaches, there is learning with students and with his/her own body, improving performance skills, as recommended Menuhin and Primrose (1991).

The contents of these s*avoirs de métier/savoirs de prudence* identified up to now refer to acquiring/improving fitness, relaxation when playing, description of affective colorings that contribute to singularity in performance—unity of movement, feeling, context, explicitation of expression, or communication gestures (with co-performers or the audience). The fact that many times the teacher must refer to non-verbal knowledge represents a particular obstacle to the development of his/her craft. Therefore, it seems to us that it could be useful both to teachers as to students to unveil this discussion and to formalize such a body of knowledge, which will develop the findings of observations.

Finally, if health is to be considered under a new light, the adequate methodology to investigate it also has to incorporate new ways of searching. It seems to us that ethnographic observations have yielded explicit features of the teaching situation with potential to advance not only in developing topics of interest that should be approached in continuing education of instrument teachers but also in raising relevant questions that should be addressed in the field of health promotion.

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A comparison of music performance anxiety to a laboratory stressor

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This study extends previous work investigating the cardiovascular reactivity to stress obtained in response to laboratory-based tasks to cardiovascular reactivity measured in response to a musical performance. Heart rate (HR) reactivity and psychological responses were measured in 52 female and 18 male healthy classically trained graduate students in two settings: during a standardized laboratory stressor (Stroop) and prior to a jury assessed musical performance of two pieces. HR and state anxiety (SAI) were assessed. Results indicate that while both conditions increased HR significantly, there was no difference in the magnitude of change in response to the musical performance and the laboratory stressors. However, the musical performance produced significantly higher levels of perceived anxiety between conditions. A greater correlation was observed for HR in between conditions compared with the relationship observed in the SAI responses. Some support is provided for the view that the Stroop could be used to identify higher HR responders to musical performance, although its efficacy to self perceptions of anxiety are less compelling.

Keywords: performance; stress; cardiovascular; laboratory; prediction

Musicians experience anxiety as part of an occupational hazard, and to some extent this, can facilitate the quality of performance to which they aspire (Valentine *et al.* 1995). However, it is recognized that prolonged anxiety and stress can lead to psychological and physiological adjustments that may be detrimental to health. For example, excessive psychological stress is associated with lifestyle behaviors such as smoking and excessive alcohol consumption (Kreutz *et al.* 2009), while other, less injurious stress coping methods exist (Hull *et al.* 1984). Immediate and long-term effects of stress include altered hormonal and cardiovascular status that over time are linked with increased risk of hypertension, diabetes, and a range of other chronic conditions (Cohen *et al.* 2007, Wiebner *et al.* 1996, Wiebe and McCallum 1986).

Research into stress response predominantly utilizes laboratory tasks that, while standardized, lack relevance to the everyday experience of the individual, and there is also some difference in responses across stressors (Mason 1975). Some studies have used more applied stressors, for example Abel and Larkin (1991) investigated the cardiovascular response of musicians to two laboratory tests and a jury performance, although the study lacked psychological measures. This study had two aims, firstly to compare the psychological and cardiovascular response of musicians prior to an assessed performance and a common laboratory stressor—the Stroop Word Colour conflict test (SWC)—and secondly to identify whether the SWC could be used to identify high responders prior to the musical performance.

METHOD

Participants

Seventy classical musicians (52 female, mean age=22±2.96 years; 18 male, mean age=21±1.94 years) representing a wide range of instrument types with an average of 12 years experience took part in the study.

Materials

State anxiety was assessed using the short version (10 items) of the original 20-item State Anxiety Inventory (SAI; Spielberger *et al.* 1983) due its suitability for repeat-measures. The SAI is a widely used assessment tool of state anxiety and has acceptable reliability and predictive validity (Barnes *et al.* 2002) and has been used widely in this area (e.g. Knyazev *et al.* 2002, Raikkonen *et al.* 1999).

The Stroop Word Color conflict test (SWC) “is a widely known and robust measure of selective attention and interference” (Atkinson *et al.* 2003, p. 1) and is commonly used to illicit cardiovascular challenge (Hamer *et al.* 2005). The task involves the use of a sequence of slides shown on a computer screen at a rate of one slide per second. Each slide contains a word describing a color written in an alternative color termed the incongruent condition. The process of word impacting the processing of color is the so-called “Stroop effect.” Participants responded verbally with the color in which the word is written and errors are recorded. There are 11 color nouns colored in 10 different colors in this test, of which some were chosen specifically because they were ambiguous.

Procedure

Participants completed two assessments: an assessed, two piece musical performance of about 10 minutes and a 3-minute Stroop word-color conflict test on separate occasions at the same time of day one week apart. Heart rate (HR) was assessed at baseline after 15 minutes rest, during 3 minutes pre-musical performance (PMP) after 15 minutes rest, and during the 3-minute Stroop. State anxiety was assessed pre- and post-Stroop and pre-performance. All data met the criteria for conducting parametric statistics.

RESULTS

The data showed that HR was significantly elevated from rest (M=74±11.31 beats per minute [bpm]) to PMP (M=85±11.26 bpm, t_{69}=8.83, $p<0.001$) and during SWC (M=83±11.73 bpm, t_{69}=8.91, $p<0.001$). The spread of data was consistent across the three data points. Repeat measures t-test revealed no significant difference between PMP HR and SWC HR responses. The HR PMP was significantly correlated with SWC HR (r=0.50, $p<0.001$, R^2=0.25).

SAI was significantly elevated PMP (M=21.51±5.21; t_{69}=10.18, $p<0.001$) and post-SWC (M=18.66±4.97; t_{69}=7.12, $p<0.001$) compared with rest (M=14.91±4.55) The SAI PMP was significantly greater than the SAI response to the SWC (t_{69}=4.19, $p<0.001$). The SAI PMP was significantly correlated with SAI SWC (r=0.37, $p<0.01$, R^2=0.14).

No differences were observed between genders for HR PMP and during SWC or for SAI values. There was a trend for female musicians to have higher SAI PMP than males (p=0.051).

DISCUSSION

This study demonstrates increased cardiovascular responses to musical performance, which concurs with the findings of Abel and Larkin (1991), and increased anxiety above baseline, in agreement with LeBlanc *et al.* (1997). The SWC also produced increased cardiovascular and anxiety as previously demonstrated (Hamer *et al.* 2005). The results show that a 3-minute laboratory stressor elicits a similar magnitude of HR response to those observed pre-musical performance. This is in contrast to Davig *et al.* (2000) who showed that HR responses to a “natural stressor” was more elevated than a battery of laboratory stressors. These data also showed that HR between conditions had a shared variance of 25% indicating some, although not strong, predictive power. Kamarck *et al.* (2000) demonstrated similar results with those who showed larger responses to laboratory stressors, demonstrating greater HR responses to classroom speeches. The absence of differences between men and women is in contrast to van Doornen (1987), but it is recognized that the sample is heavily weighted toward female participants (52 versus 18). Hence, care is required when interpreting this absence of difference.

In contrast to the cardiovascular response, while SAI also increased in both conditions above baseline, musical performance produced a significantly greater SAI response than the Stroop test. One explanation for this may be the greater psychological engagement in the task and salience of the performance against the more abstract task. Dickerson and Kemeny (2004) report that stressors characterized by social-evaluative threat demonstrate greater cortisol responses. There appears to be no previous comparison of SAI between the Stroop Word Color test and music performance anxiety.

This work suggests that the Stroop Word Color test could be useful in identifying high music performance anxiety cardiovascular responders, but not high self-perceived music performance anxiety.

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John Dewey and F. M. Alexander: Habit and performance skills

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In a PhD thesis by McCormack, *John Dewey and F. Matthias Alexander: A Neglected Influence*, Alexander is identified as a significant influence on Dewey's philosophical thought. The 25-year association is re-examined in the light of what the two men say about the nature of habit, and its relevance to performing artists and skill development.

Keywords: Dewey; Alexander; habit; change; skills

Many promising students enter music colleges with long-standing habits of undue effort and muscular tension that have become part of their practice routine. When these habits are not recognized and addressed they remain obstacles to optimal technical and artistic achievement and are likely to curtail what might otherwise have been a successful and fulfilling career.

The fact that musculoskeletal and anxiety-related problems are suffered by some musicians and not by others indicates that there are personal predisposing and causal factors at work (Ballard *et al.* 1997). Here, I propose that these factors are certain acquired patterns of habit involving inappropriate muscular tension and associated attitudes of mind that disturb the natural functioning of the individual as an integrated whole.

It may seem odd to include both physical and mental problems that are usually considered separately. However, the continuum between mental-physical is a feature of this paper that re-examines a 25-year association between John Dewey, America's pre-eminent philosopher and educationist, and F. Matthias Alexander, writer and originator of the Alexander technique (see Figure 1).

In a remarkable PhD thesis by Eric McCormack (1958), *John Dewey and F. Matthias Alexander: A Neglected Influence*, Alexander is identified as a significant influence on Dewey's philosophical thought. When asked by his daughter to identify highlights in his career for a biography, Dewey wrote:

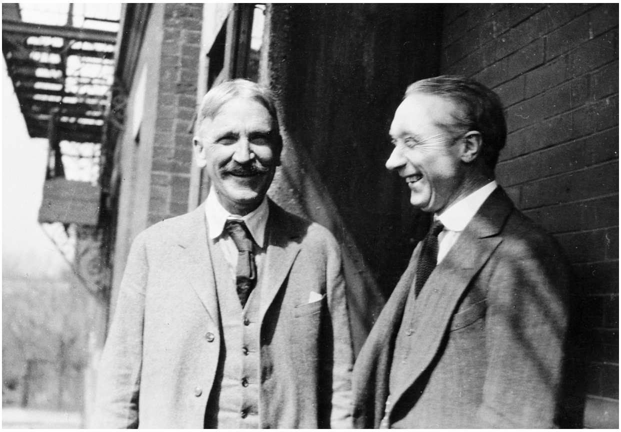

Figure 1. John Dewey and F. M. Alexander (© Walter Carrington Archive, used by permission).

> My theories of mind-body, of the co-ordination of the active elements of the self and of the place of ideas in inhibition and control of overt action required [for confirmation] contact with the work of F. M. Alexander and in later years his brother, A. R., to transform them into realities" (cited in Martin 2002, p. 286).

MAIN CONTRIBUTION

From his experiences in lessons with Alexander, Dewey became aware of how thinking could usefully be applied in the performance of everyday activities and bring about positive changes to unwanted habitual patterns of behavior. As the vehicle of his instruction, Alexander focused on habits of the way we carry ourselves and move (Mixon 1980). Acts such as sit-stand are discretionary (we can perform them at will), but how they are performed is governed by an individual's capacity, skill, and habit.

In his masterful discussion of habit in *Human Nature and Conduct* (1922), Dewey puts the case for habit as the unit of analysis in the control of action and as the key to reliable skill learning:

> The essence of habit is an acquired predisposition to ways or modes of response, not to particular acts except as, under special conditions, these express a way of behaving. (pp. 40-41).

Dewey's meaning is close to its primary sense of the way something is done: "a tendency or disposition to act in a particular way…" (Collins English Dictionary 2000).

Dewey discovered that, when it came to ways of moving, he could not carry out aims or intentions contrary to his habit without further training and practice. Habits are analogous to skills, particularly, in the context of what Alexander dealt with. Dewey wrote of:

> the most humiliating experience of my life, intellectually speaking. For to find that one is unable to execute directions, including inhibitory ones, in doing such a seemingly simple act as to sit down, when one is using all the mental capacity which one prides himself upon possessing, is not an experience congenial to one's vanity (Alexander 1985, p. 10).

Fixed and adaptable habits

Alexander and others identify two kinds of habit: (1) *fixed habits* acquired without thought or planning and (2) *adaptable habits* that are consciously controlled and can be altered at will—what Dewey called "intelligently controlled" habits (cf. Alexander 1910, pp. 74-75, and Alexander 1996, p. 54). Mechanization and propulsive power are properties of all habit, but it does not follow that habit must be mindless. Musicians needs to avoid thoughtless, mechanical, and fixed habits that create strain and lead to impoverished technical and artistic outcomes for the artist (Leiberman 1991).

The interpenetration of habits

A reason why habits are so persistent and difficult to change is because of what Dewey calls their "interpenetration." Mixon (1980) writes:

> This is especially true of the habits Alexander worked with. The way we carry ourselves and move is something that enters into everything we do, that is involved in every waking and sleeping moment (p. 182).

We are the totality of our habits: our habits are us. Alexander (1985) was aware of this when investigating the cause of his own vocal problems:

> …I came to see that any attempt to [prevent my harmful vocal habits]…involved my bringing into play the use of all those parts of the organism required for *the activities incident to the act of reciting*, such as

> standing, walking, using the arms and hands for gesture, interpretation, etc. (p. 32, italics added).

Conscious inhibition

Dewey (1922) writes that without reliable control of habits, simply wishing to do something differently is on a par with primitive magic or superstition in its neglect of attention to the means that are involved in reaching an end. Habit cannot be changed directly, simply by an act of will for this "puts into operation the very conditions that are the source of the experienced trouble, thereby strengthening them and at most [merely] changing the outward form in which they manifest themselves..." (cited in McCormack 1958, p. 129).

The principle of inhibition ("withholding consent") forms the cornerstone of Alexander's technique. It might be compared to John Locke's notion of "the power to forbear" or Benjamin Libet's "power of veto," but Alexander was the first to demonstrate its practical significance (c. 1894) as a fundamental principle in the control of human behavior. It verified something that Dewey (1938) considered of primary importance on the intellectual level: "the old phrase 'stop and think' is sound psychology" (p. 74). Old habits must be prevented (inhibited) and time given to refashion the underlying preconditions in accordance with the expression of the new adaptable habit.

Habits are complex organizations of the self, tools, and materials. Alexander's technique deals initially with the self, restoring functional integrity and bringing about the "harmonious relationing" of the parts of the body. Both physical and mental changes are necessary in order for a change of habit, and as reliable sensory experiences are necessary to form new mental concepts, the individual is often unable to accomplish the changes without assistance.

The Alexander technique has been taught as a foundation skill in music and drama conservatoires since the 1950s. It is usually regarded as a way of improving posture, but this is just what can be seen. By applying the technique in daily activities a particular plane of awareness is reached. Alexander (2000, 2004) called this "conscious control." Dewey referred to it as "thinking in activity," a sort of in-the-moment impartial monitoring of one's own activity (Alexander 1985).

Many authors other than Alexander and Dewey have suggested that enhanced self-awareness is essential if we are to be able to do as we intend. These include Todd (1937) and Shusterman (2008), for example. Without reliable control of adaptable habit (i.e. the "means"), it is impossible to reach one's goals consistently and with certainty. Dewey (1922) used the example of a man who is told to "stand straight" to illustrate his general law of habit:

> A man who can stand properly does so, and only a man who can, does (p. 29).

In fact, this is a reworking of Alexander's arguments for "a boy who stoops…[and] is told to 'stand up straight'" (Alexander 1910, p. 191, and Alexander 1996, pp. 90-91.) Dewey (1922) continues:

> Only when a man can already perform an act of standing straight does he know what it is like to have a right posture and only then can he summon the idea required for proper execution. The act must come before the thought, and a habit before an ability to evoke the thought at will. Ordinary psychology reverses the actual state of affairs (pp. 30-31).

Musicians ideally should be taught from first principles how to cultivate and develop the transferable skills of impartial self monitoring, inhibition of unwanted habits, and how to restore and continually develop better use of the self. The promise of cure often holds more immediate appeal than this slower but surer educational process. Those who rely on quick fixes, seeking palliatives that deal with symptoms and not root causes, often side-track their attention and delay investigation of the intelligent control of means.

When the Alexander technique was first introduced into a music college in the 1950s, Royal College of Music singing professors recorded their conclusions as follows (Barlow 1978):

> In each case [following a course of Alexander lessons] there has been a marked physical improvement, which was usually reflected vocally and dramatically. It was a revelation to discover that tricks of behaviour could be eliminated in a comparatively short space of time once the student learned to control his tensional balance from the head-neck region…. In all cases students since re-education are easier to teach, and can take and carry out stage directions with greater ease. The students seem to become aware of themselves in a new way. Each student reacted in a different characteristic way. For example, those who had been over-anxious to please authority discovered that they could be themselves with impunity, ceasing to be such model students, but becoming better performers… In our opinion, this approach is the best means we have yet encountered for solving the artist's problem of communication and should form the basis of his training (p. 195).

IMPLICATIONS

Until teachers and members of the caring professions recognize the influence of unwanted habit and that individuals can be taught and learn how to change it, then their methods will be incomplete and less effective than they might otherwise be.

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Investigating time relations in musical instrument's masterclasses

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Even though musical instrument's individual classes in conservatoires and schools of music have been investigated by many authors, there is still demand for specific studies regarding the unique characteristics of masterclasses. The present work analyzes two of these characteristics: masterclass durations and the time spent by both professor and student in the context of music festivals. One hundred and thirty masterclasses that took place in Brazil and Portugal were analyzed by the researchers. All masterclasses had their durations measured according to the following parameters: total duration, student speaking time, student performance, instructor speaking time, and instructor performance. The average masterclass duration was 34 min 37 s, with a standard deviation (SD) of 26 min 46 s. This high variability seems to be related to the challenges of predicting the duration of a masterclass, which depends on a multitude of factors, such as the instructor's individual teaching strategies, time limits defined by festival organization, and the student's performance level. Time spent between student and instructor shows that masterclasses often do not focus on verbal dialogue. A longitudinal study becomes necessary to investigate if there is musical learning in fact or just the momentary reproduction of interpretative ideas suggested by the instructor.

Keywords: masterclass; musical instrument; duration; verbal strategies; performance

A masterclass is a kind of teaching which holds a large variety of purposes that places it into the list of the significant methodologies of pedagogy of the musical instrument (Swanwick 1994, Tourinho 2006). Side by side with the tutorial class, the masterclass has been effectively put in practice into the teaching of students in advanced traineeships of instrumental practice (Schon

2000, Zorzal 2010). However, while the tutorial class which takes place in conservatoires and music schools has been studied (Gaunt 2008, Karlsson and Juslin 2008, Kurkul 2007, Nerland 2007, Presland 2005, Purser 2005), the masterclasses occurring in music festivals bring along some peculiarities that distinguish themselves from the former teaching approach and were not worthy of the same attention (e.g. Iglesias *et al.* 2006).

Generally speaking, a masterclass is a teaching method where a musical instrument student performs, with prior preparation, a work for a well-known and esteemed teacher of the same instrument. This performance has an audience, which does not interfere actively while the performance takes place, and no previous contact between student and teacher before the masterclass is held (Zorzal 2010).

Given this context, we have set a goal to trace the time relationships in masterclasses with the following aims: identifying the timeframe average of a masterclass and disclosing the time relationships between teacher and student over the variables of musical performance and verbal dialogue.

METHOD

Participants

One hundred and thirty masterclasses were analyzed, comprising 35 teachers and 100 guitar students.

Materials

We have analyzed 82 masterclasses from the School of Music and Performing Arts (ESMAE) collection, from Porto, Portugal, and 8 masterclasses from first author's private collection. The remaining masterclasses were recorded *in loco* during music festivals in Brazil and Portugal, employing passive observation and using a recording camera (JVC model GZ-MG130).

Procedure

The research adopted a descriptive and an exploratory nature. Thus, we were able to specify the properties, features, and profiles of the analyzed phenomena without the need for explanations for the given graphic representations (Beran 2004, Sampieri *et al.* 2006). Hence, according the following variables, the 130 masterclasses were analyzed concerning the total duration, speaking time per student, student performing time, teacher speaking time, and teacher performance time.

The total duration was analyzed using SPSS and with the statistics resources of the normal curve and box-plot. The results were organized together with the other variables in a histogram in order to visualize the percentage of each of them.

RESULTS

We have organized by crescent order the 130 masterclasses, and we have got, employing the descriptive analysis, the following statistical values: n=130, M=34 min 37 s, and SD= 26 min 46 s, with a confidence interval of 95%. Figure 1 presents the performed analysis displaying the masterclasses' concentration with time durations between 20-45 minutes. Thus, we have acknowledged an asymmetry to the normal curve.

A normal curve representation which displays an asymmetry means that the values of mean and of median are different. The median presents an analytical advantage over the mean, as it is not so sensitive to data with values so different from the central tendency. For instance in Figure 1, it seems that some time durations, such as 1.5-hour masterclasses, are not in harmony with most of the data.

A box plot is a convenient graphic form to present a data central tendency through the median. Through this analysis we could reach to a value of 30 min 29 s for the median and we have observed that, indeed, time durations around 1.5 hours represent outliers (see Figure 2).

The mean and median analyses suggest that masterclasses have time durations around 30 minutes, although this time duration must be seen carefully, as the large standard deviation presented by gathered data (SD=26 min 46 s) shows that values can be very different.

The analysis of speaking time duration and performance presents a balance between student and teacher, who have had on average, adding up the time spent with speaking and performance, 47.9% and 52.1% of masterclass time, respectively. When fully detailing the time spent with the speaking and with the performance we realize that the student spends most of the time performing while the teacher spends a great amount of time speaking (see Figure 3).

DISCUSSION

The duration time of a masterclass seems to be the result of a number of elements. Between these elements may be the individual features of teacher's teaching, scheduling limits demanded by the festival in which the masterclass

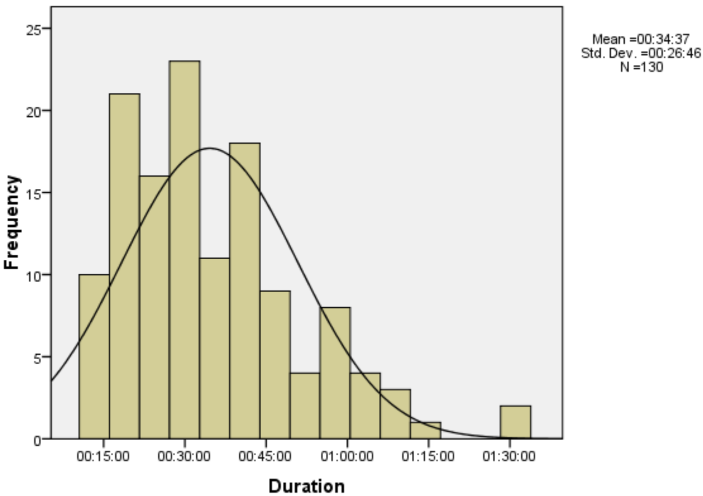

Figure 1. Duration's representation through the mean.

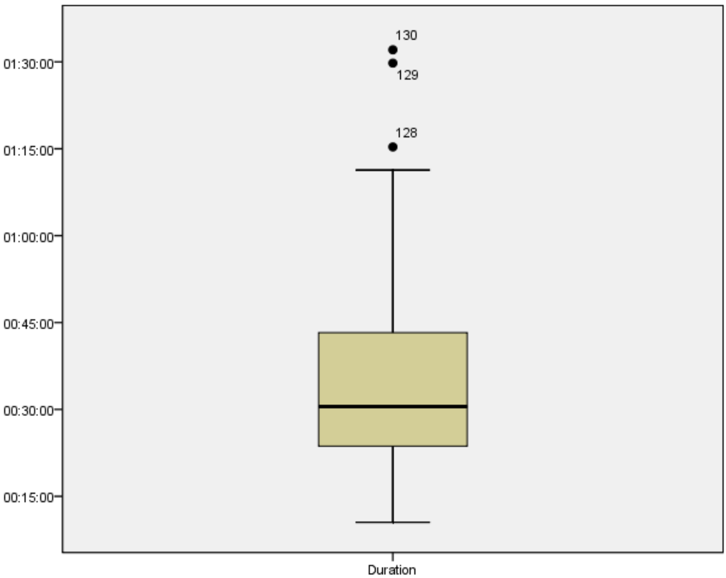

Figure 2. Representation of time duration through the median.

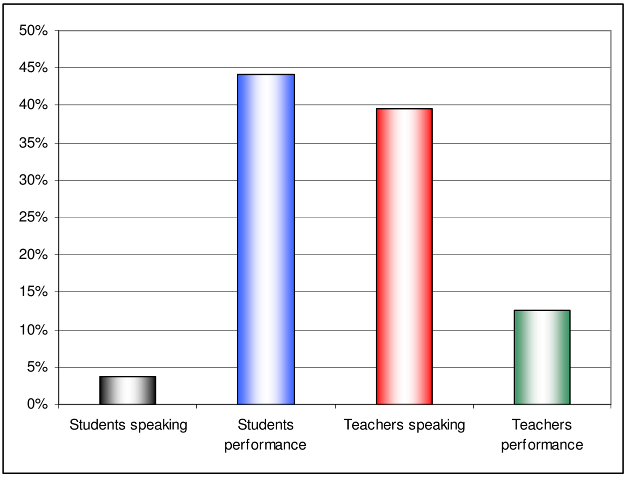

Figure 3. Mean percentage of time spent between students and teachers. (See full color version at www.performancescience.org.)

is taking place, the student's performance level, the performed work difficulty level, and duration of the work performed by the student.

We have come to the conclusion that a masterclass is dominated by the student's performance and the teacher's speaking, which have led us to conclude that a masterclass is a kind of musical instrument teaching where discussions scarcely take place. This suggests to us that the teacher's speaking is followed by the student's musical answer attempting to pay attention to the given instructions, which do not mean that the student accepts uncritically the teacher's suggestions. An explanation may be that a masterclass is a short moment of interaction between teacher and student. The student's attitude in a masterclass may be of receiving the teacher's information and then assessing it after class. In fact, a longitudinal study would be necessary to determine whether there is musical learning or only a temporary reproduction of interpretative ideas suggested by the teacher.

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Symposium:
Empirical approaches to the study of expressive strategies and aesthetic responses in harpsichord performance

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Disentangling performer- and piece-specific influences on interpretative choices: A comparison across three harpsichord pieces

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This study aims to identify the markers of artistic individuality in music performance by discriminating between piece-specific stylistic influences and commonalities in performers' expressive patterns across pieces, using a robust statistical approach. Twelve professional harpsichordists from the Montreal area recorded three pieces on a harpsichord equipped with a MIDI console. Each piece was recorded at least twice. Performances were matched to the scores of the pieces using an algorithm developed by the authors. Four expressive parameters were analyzed: velocity, note onset asynchrony, timing deviations, and articulation. Analyses of variance using linear mixed models were used to estimate effects related to individual performers and specific pieces. Mantel correlograms, which allow comparisons between two similarity matrices, were used to compare expressive strategies on a note-by-note basis across pieces. Comparisons across pieces revealed significant differences in the amount of overlap and velocity employed for specific pieces. Some performers consistently deviated from the mean values for specific expressive parameters, indicating that some broad markers of artistic individuality may transcend pieces and genres. Correlational analyses revealed unexpected dissimilarities between pieces in the performers' note-by-note expressive profiles. Musicological considerations and stylistic issues are advanced to explain these observations.

Keywords: artistic individuality; expressive strategies; harpsichord; style; piece-specific influences

Over the last few decades, a growing body of research has examined issues related to individuality in musical performance (Repp 1992, Sloboda 2000).

Computational methods have led to the development of higher-level descriptors to capture and identify recurrent expressive gestures associated with a given performer (Widmer and Goebl 2004). However, few studies have attempted to quantify markers of individuality that transcend specific pieces and musical styles. Indeed, among the factors which influence a performer's interpretative choices, some derive from performer-specific tendencies and others from stylistic considerations related to the piece being performed. In order to identify which performance characteristics are reliable markers of a performer's artistic individuality across genres and styles, it is necessary, as a first step, to disentangle these two contributions. Nevertheless, it has proven difficult, for several reasons, to untangle these factors. One obvious issue is that pieces vary in length, texture, and meter. Another is that different expressive parameters, such as articulation, velocity, or tempo, are measured in different units and cannot be directly compared. Thus, there is a need for a robust methodological approach that allows us to obtain valid statistical inferences even when comparing across pieces and expressive parameters.

Stamatatos and Widmer (2005) showed, by developing a computer algorithm which can recognize individual performers playing two different pieces by Chopin, that performer-specific characteristics could be reliably identified across pieces. This study focused on methodological issues related to machine-learning algorithms rather than on musicological aspects. The present article aims to expand on this previous work by presenting a quantitative approach for discriminating between piece-specific stylistic influences and commonalities in performers' expressive patterns across pieces. A related goal is the development of a reliable method for evaluating and comparing expressive strategies across pieces.

METHOD

Participants

Twelve professional harpsichordists, five female and seven male, from the Montreal area were invited to participate in the experiment. Their average age was 39 years (range=21-61). They had played the harpsichord for a mean duration of 22 years (range=6-40). Seven of them had previously won prizes in regional, national, or international harpsichord competitions.

Materials

The following three pieces were selected for this experiment: the third variation from the *Partita No. 12 sopra l'aria di Ruggiero* by Girolamo

Frescobaldi (1583-1643), the *Prélude non mesuré No.7*, an unmeasured prelude by Louis Couperin (1626-1661), and *Les Bergeries*, a rondo by François Couperin (1668-1733).

Procedure

Performances took place in an acoustically treated studio, on an Italian-style Bigaud harpsichord (Paris, Heugel) with two 8-foot stops. Only the back stop was used for the experiment. This harpsichord was equipped with a MIDI console, allowing precise measurement of performance parameters. MIDI velocity values for each note event were coded in a range between 16 (slowest) and 100 (fastest). The audio signal was recorded through two omnidirectional microphones MKH 8020. The microphones were located 1 m above the resonance board and were placed 25 cm apart. The audio and MIDI signals were sent to a PC computer through a RME Fireface audio interface. Audio and MIDI data were then recorded using Cakewalk's SONAR software and stored on a hard disk. Each piece was recorded at least twice. Performances were matched to the scores of the pieces using an algorithm developed by the authors (Gingras and McAdams 2011). Four expressive parameters were analyzed: velocity, note onset asynchrony, timing deviations, and articulation.

RESULTS

Two statistical approaches were used to quantify performance features. The first approach involved the examination of global trends at the levels of pieces or performers, grouping all notes together instead of focusing on note-by-note comparisons, using analyses of variance (ANOVAs). This statistical method was used to determine whether, for instance, there were significant differences in the mean velocity between performers and to isolate the contribution of specific pieces from the unique characteristics of performers. One drawback of this method is that it is not suitable for analyzing differences in expressive profiles that are only manifest on a note-by-note level. Thus, a second approach was necessary to compare the note-by-note correlations between different performances and to use these correlations as a measure of similarity between performers' profiles. This procedure was used, for instance, to evaluate whether the articulation profiles of different performers were more similar between certain pieces than between others.

Table 1 summarizes the results of a series of repeated-measures mixed-models ANOVAs conducted on each expressive parameter, with individual performers ($n=12$) treated as a random effect and pieces ($n=3$) treated as a fixed effect, with two recordings per piece. Post-hoc comparisons between

Table 1. Comparisons of performers and pieces.

Parameter	*Pieces*	*Performers*
Tempo	n/a	Not significant
Overlap	Bergeries>Frescobaldi***	More detached: 7**, 10*
	Prélude>Frescobaldi***	More legato: 3***, 5**
	Prélude>Bergeries***	
Asynchrony (only Bergeries and Frescobaldi)	Not significant	Larger asynchronies: 3***, 7*
Velocity	Frescobaldi>Prélude***	Less velocity: 12***
	Bergeries>Prélude***	More velocity: 10***
Error rate	Not significant	Not significant

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

pieces were computed using Tukey's HSD correction. Comparisons across pieces revealed that the *Prélude* tended to be played with a significantly more legato articulation and with less velocity than the *Partita* or the *Bergeries*. Comparison across performers showed that a few performers either played with a consistently more detached (performers 7 and 10) or more legato (performers 3 and 5) articulation. Similar individual variations were observed for the magnitude of the chord onset asynchronies and for the attack velocity.

Correlations were also computed on a note-by-note basis between all pairs of performances for each expressive performance. Standardized values (Z-scores) were used to obtain dimensionless units, allowing for comparisons across expressive parameters and across pieces. These correlations were then used to obtain similarity matrices for each expressive parameter. Mantel tests, a non-parametric permutation test which evaluates the degree of correlation between two similarity matrices (Mantel 1967), were used to determine the distance between two matrices. Ten thousand permutations were conducted. Intriguingly, the Mantel correlograms (see Table 2) suggest that, for all expressive parameters analyzed here, there was a greater similarity in the expressive strategies employed between the *Partita* and the *Prélude non mesuré* than between the *Partita* and the *Bergeries*. In fact, R values between the *Bergeries* and the *Partita* were significantly negative, suggesting that performers who used a similar strategy for one piece tended to use contrasting strategies for the other, indicating a lack of agreement between performers. In contrast, performers who employed similar strategies for the *Partita*

Table 2. Mantel tests on the correlograms reflecting note-by-note expressive profiles.

Parameter	*Bergeries Partita*	*Bergeries Prélude*	*Partita Prélude*
Tempo	R=-0.159 p<0.001	R=0.012 p=0.399	R=0.188 p<0.001
Overlap	R=-0.180 p<0.001	R=-0.014 p=0.363	R=0.164 p<0.001
Asynchrony (only Bergeries and Frescobaldi)	R=-0.114 p=0.005	n/a	n/a
Velocity	R=-0.201 p<0.001	R=0.021 p=0.317	R=0.228 p<0.001

were more likely to use similar strategies for the *Prélude*. The fact that the agreement between performers was higher between the *Partita* and the *Prélude* than between the *Partita* and the *Bergeries* was somewhat unexpected given that the *Prélude* is markedly different from the other two pieces due to its unmeasured character.

DISCUSSION

In this article, we presented two statistical approaches used for discriminating between performer-specific interpretive features and piece-specific influences. ANOVAs showed significant differences in the amount of overlap and velocity between specific pieces. Our results also indicate that some individual performers consistently deviated (across all three pieces) from the mean values for specific expressive parameters, suggesting that some broad markers of artistic individuality, such as the amount of overlap or the magnitude of chord onset asynchronies, may transcend pieces and genres.

Correlational analyses revealed that similarities between the expressive strategies applied by performers on a note-by-note level were greater between the *Partita* and the *Prélude* than between the *Bergeries* and the *Partita*, an unexpected result given that the *Prélude* is an unmeasured piece written in a markedly different style from the other two pieces. Although the *Bergeries* and the *Partita* seem much closer to each other than to the *Prélude* from a musicological perspective, it is possible that other stylistic features, related for instance to the date of composition, the meter (the *Bergeries* is written in $^6/_8$) or the texture (homophony versus polyphony) played a role in performers' choice of expressive strategies. Further musicological analysis is necessary in order to better understand this result.

Besides proposing a novel methodological framework for quantifying performer- and piece-related influences on interpretative choices, this study provides a complementary approach to empirical research examining the perception of artistic individuality in music performance (Koren and Gingras 2011). Future research should include the analysis of other expressive strategies, such as durational contrasts (for instance, eighth versus quarter notes) or metrical emphasis (strong versus weak beats).

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Exploring interrelationships between melodic expectations, tempo variations, and perceived tension in performances of an unmeasured prelude for harpsichord

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Studies comparing the influences of different performances of a piece on the listeners' aesthetic responses are constrained by the fact that, in most pieces, the metrical and formal structure provided by the score limits the performer's interpretative freedom. As a semi-improvisatory genre which does not specify a rigid metrical structure, the unmeasured prelude provides an ideal repertoire for investigating the links between musical structure, expressive strategies in performance, and listener's responses. Twelve professional harpsichordists recorded two interpretations of the *Prélude non mesuré No. 7* by Louis Couperin on a harpsichord equipped with a MIDI console. The MIDI data were analyzed using a score-performance matching algorithm. Subsequently, 20 non-musicians, 20 musicians, and 10 harpsichordists listened to these performances and rated the perceived tension in a continuous manner using a slider. Melodic expectation was assessed using a probabilistic model (IDyOM) whose expectations have been shown to match closely those of human listeners in previous research. Time series analysis techniques were used to investigate predictive relationships between melodic expectations and the performance and perceptual parameters. Results show that, in a semi-improvisatory genre such as the unmeasured prelude, predictability of expectation based on melodic structure has a measurable influence on local tempo variations.

Keywords: performance; aesthetic perception; expectations; communication; information content

Acknowledgments

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Perceiving individuality in musical performance: Recognizing harpsichordists playing different pieces

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The present study aimed to test whether listeners are able to distinguish between unfamiliar performers playing two different, unfamiliar pieces on the harpsichord. Recordings of two different Baroque pieces by six professional harpsichordists were used in this test. Twenty musicians and twenty non-musicians, with ten men and ten women in each group, participated in the experiment. Most of the participants performed significantly better than chance, demonstrating that there was sufficient information in the excerpts to recognize the performance characteristics of any given performer. The grouping accuracy of musicians was significantly higher than that of non-musicians. Moreover, grouping accuracy was significantly different between both pieces, suggesting that their features differed in a way which rendered one of them more easily recognizable.

Keywords: musical performance; characteristics; recognition; categorization; musical expertise

Identity can be recognized in many aspects of human life. One of these aspects is facial recognition. People seem to be capable of perceiving the unique identity of a virtually unlimited number of faces (Haxby *et al.* 2000). They are also able to recognize themselves and others in a dynamic display of their movements (Johansson 1973, Loula *et al.* 2005). In the auditory domain, various studies have been conducted on clapping recognition. Repp (1987) found that people recognized clappers significantly better than chance and that they had an even better rate for self-recognition in clapping. Voice recognition studies showed that recognizing the voices of famous people is a relatively easy task and that even backward voice samples can be identified (Van Lancker *et al.* 1985). These studies provide good evidence of our ability to perceive identity cues across different perceptual modalities.

Musical performance can also convey cues about the performer's identity. Indeed, playing a well-known repertoire piece in a recognizably different way from another performance of the same piece can show a musician's unique personality and character (Lehmann *et al.* 2007). Although a handful of studies have investigated whether humans are able to process identity cues in music performance, none of them veritably focused on whether people can recognize a performer playing two different pieces. The present study aims to make this question its point of focus. Stamatatos and Widmer (2005) presented a computational approach to this issue and found that after having been trained on a set of Chopin pieces, learning ensembles were able to identify the same performers playing a different piece from Chopin. Furthermore, a previous study by Gingras *et al.* (2008) reported that most listeners were able to distinguish between unfamiliar performers playing excerpts from a single unfamiliar piece on the organ. The present study differs from the study by Gingras *et al.* mainly in its use of two different pieces instead of a single one.

METHOD

Participants

Forty participants completed the experiment. In order to investigate a potential relationship between the listeners' musical background and their performance in the task, 20 musicians (defined as people who have completed at least one year of musical training at university level), and 20 non-musicians (defined as people who have had less than two years of musical training of any kind) were selected to participate in the experiment. Both groups were equally balanced for gender, giving 10 males and 10 females in each group. Participants received a gift for their contribution and the chance to win one out of four prizes worth £20 GBP each.

Materials

Two musical pieces were used for the experiment: *Les Bergeries* (rondeau; from Pièces de clavecin, Book II, 6ème ordre) by Couperin (1583-1643), and *Partita No. 12 sopra l'aria di Ruggiero* (Variation III) by Frescobaldi (1668-1733). Both were performed by three prize-winning and three non-prize-winning harpsichordists on the same harpsichord which was equipped with a

MIDI console. The pieces were recorded (each of them at least twice) in Montreal, Canada, in 2008. For each piece, an excerpt of 10-14 s (depending on the performance) and corresponding to a syntactically coherent musical unit was chosen. Excerpts were edited to retain a sense of closure. Audacity was used for cutting out and editing the pieces.

Procedure

Before the actual task, the participants' hearing was tested in a soundproof booth, using a manually operated Amplivox 2160 pure tone diagnostic audiometer and following a standardized procedure for the measurement of hearing thresholds. Participants who passed the hearing test were allowed to continue the experiment. The main experiment was a computer-based task, carried out using a software interface within the Matlab environment. Before the actual experiment, participants had the opportunity to practice the task. In the main experiment, participants were presented with six colored boxes on the left side of the screen, each of them representing a performer. On the right side of the screen 24 icons represented the musical excerpts, each of them identified by random numbers. Participants were asked to group together the excerpts to which they believed to have been played by the same performer. They were able to listen to the excerpts by double-clicking on the icons. They had to listen to the excerpts at least once before being able to drag them into the boxes on the left side. At the end of the experiment they were required to listen to the content of each box before finishing the experiment. There was no time limit for the categorization but the time taken to arrange the selections was recorded. After finishing the computer-based main task, participants were asked to complete a questionnaire in order to ascertain information about their musical background, as well as the strategies they had used for completing the task.

RESULTS

The listeners' categorization was coded as a co-occurrence matrix. Their grouping accuracy was obtained by comparing their actual grouping to the correct grouping of the excerpts (when all the ones that are played by the same performer are grouped together). This number was evaluated by computing adjusted Rand index values which is a widely used statistical tool to measure the similarity between two data clusterings. The number obtained this way is the score. The overall (grand) mean score for all the participants was $M=0.17$ (see Table 1).

Table 1. Participants' mean scores and standard deviations.

	Musicians	*Non-musicians*
Men	0.24 (SD=0.14)	0.11 (SD=0.07)
Women	0.23 (SD=0.12)	0.10 (SD=0.09)

Of 40 participants, 39 managed to perform better than chance (had a score better than 0). Overall, 26 participants (65%) performed significantly better on the task than chance level ($p<0.05$). There was no significant difference in scores between men and women ($t_{38}=0.28$, $p>0.05$), but musicians (M=0.23, SE=0.03) performed significantly better on the task than did non-musicians (M=0.10, SE=0.02). The results also showed no significant difference between the numbers of correctly grouped pairs in the case of prize-winner and non-prize-winner performers ($F_{1,36}=0.88$, $p>0.05$), indicating that there was no effect of the performers' expertise on the grouping accuracy.

To examine whether there was a difference in participants' grouping accuracy between the two pieces, we looked at the number of the pairs of excerpts which they matched correctly. The repeated-measures analysis of variance (ANOVA) showed a significant difference between the two pieces ($F_{1,36}=23.82$, $p<0.01$). Participants showed better accuracy for grouping the excerpts of the Couperin than for the Frescobaldi. In order to explain this difference in accuracy, we looked at the tempo and found that there were significantly greater tempo differences between the two recordings of the Couperin ($r=0.46$, $p>0.05$) than in the case of the Frescobaldi ($r=-0.38$, $p>0.05$), negating the possibility that smaller tempo differences were responsible for the greater accuracy in the Couperin piece.

Finally, we also compared the grouping accuracy for pairs of excerpts from the same piece versus pairs containing one excerpt from each piece. A significant difference was found ($p<0.05$) between the grouping accuracy for pairs comprising two excerpts from the Couperin (M=53.33, SE=3.07) and pairs comprising one excerpt from each piece (M=20.42, SE=3.91), although no significant difference was found for the Frescobaldi. There was also a significant difference between musicians' and non-musicians' correct grouping of the excerpts from the same piece and the excerpts from different pieces. In the case of musicians there was also a significant difference ($p<0.05$) between the grouping accuracy for pairs with both excerpts from the Couperin (M=65.83, SE=2.39) and pairs with one excerpt from each piece (M=22.29, SE=5.34). This difference was not significant for non-musicians.

DISCUSSION

There have been very few studies which have investigated the ability of humans to process identity cues in music performance. To our knowledge this is the first study that examines whether people are able to recognize the same performer playing two different pieces. Although most people reported the task as being very difficult, everyone managed to complete the task at a level better than chance with the exception of one participant. In both this study and in Gingras *et al.* (2008), musicians performed better than non-musicians on the given task, but in the present case the difference between the two groups was significant, suggesting that musical training has an important role in recognizing personal characteristics in a short musical excerpt.

Gingras *et al.* (2008) found a significant effect of performers' expertise on the grouping accuracy, something which we also expected to find. However, our results did not show any significant effect of performers' expertise. Since participants' performance was significantly better for one piece over the other, it would appear that the musical features of a piece are important in picking up on its characteristics and thus in recognizing the identity of the performer. These results let us suggest that the performer's expertise is not as relevant in grouping the excerpts as are the characteristics of the pieces.

To investigate why the Couperin piece was sorted more accurately, we ran several analyses on the MIDI data. As one possibility we examined tempo differences within the same piece (between the two recordings) and between the different pieces and found that the tempo differences in the Couperin were significantly greater than in the Frescobaldi. Although this should make recognizing the matching pairs more difficult in the Couperin piece, that is not what we observed. Another explanation for the better grouping accuracy for the Couperin may be related to the duration of the excerpts, which were on average a few seconds longer than those for the Frescobaldi.

We were also interested in examining whether listeners fared better in matching excerpts from the same piece (either the Couperin or the Frescobaldi piece) or excerpts from different pieces but played by the same performer. A significant difference was found between grouping excerpts from the Couperin piece and grouping excerpts from different pieces by the same performer. Listeners showed notably better grouping accuracy in the first case. This result indicates that participants were not as successful in matching the excerpts from the different pieces played by the same performer, although they still performed better than chance.

In conclusion, this experiment yielded intriguing results in a domain of identity perception which has yet to be fully understood. Gingras *et al.* (2008)

provided a useful reference point as both studies share some common features. Although some findings differed between the two studies, such as the lack of effect of performer's expertise in the present study, they show globally similar results. Both of them showed that people are able to recognize a performer's individual characteristics in musical excerpts and that musically trained listeners generally showed a better grouping accuracy.

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Thematic session:
Perspectives on performance

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The problem with performing

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It is acknowledged that words have effects and affects as well as meanings, and that things happen when certain words and rhetorical structures are chosen and others are rejected. How scholars theorize performing is a matter as much of the words employed to phrase ideas as of the ideas "themselves." One such configuration is the rhetoric of "performing as problem solving." This article analyses a key performance studies text with regard to the way in which the theory of performing exhibited in it invokes and involves the rhetoric as a means of articulating the relationship between practicing and performing.

Keywords: rhetoric; metaphors; models; practicing; performing

The rhetoric of performing as problem solving has long influenced performance studies. Half a century ago, Thurston Dart's *The Interpretation of Music* set out its stall with an opening chapter on "The problem" (Dart 1984, pp. 11-17). Today the UK Quality Assurance Agency's Benchmark Statement on music contains ideas about the music graduate having, *inter alia*, the ability to identify problems and present solutions. The rhetoric influences performance studies from the aesthetic ideology of "analysis and performance" to the methodology of "perception and cognition". It is variously an explanatory tool, metaphor, method, and model; often it is a determined synecdoche for performing *per se*. There are strong and weak arguments concerning the value of problem solving. The strong argument is that it is essential to performing, and without it the event would be substandard or simply not performing. According to this argument, problem solving is the truth of performing. The weak argument is that problem solving contributes to performing alongside other tools and should be deployed appropriately. According to this argument, problem solving is a useful rhetoric. The strong case tends to define itself as all-or-nothing, using imperatives to emphasize its own importance, whereas the weak case happily acknowledges a continuum between problem solving and other tools. The strong argument for problem solving is largely discredited (recall critiques of Eugene Narmour and Wallace Berry), although traces remain in current theories of performing, as this article shows.

My case study here, the edited volume *Musical Performance* (Rink 2002), is an important textbook survey of the discipline of performance studies and of the academic study of Western classical performance. With a high degree of editorial conformity across its 236 pages, even in prose style and turns of phrase, there is a single theory of performing exhibited, and I shall treat it as such.

MAIN CONTRIBUTION

According to *Musical Performance*, performing can be "self-effacing" and allow the music to "come across" of its own accord (Rink 2002, pp. xi, 190). Alternatively, performing can "distort" the music, "something else [...can get] in the way," and it can become a vehicle for the performer (pp. 17-18). Somewhere between these two extremes, performing is "realisation," "reading," "translation," and "transformation." These are a matter of "[illuminating] its character or [making] palpable its emotional content," and "bringing out [its] meaning" (pp. xii, 15, 17, 32, 48, 60, 83-84, 102, 231-232). In general, "the outstanding performance of a fine musical work is, I suggest, an invitation to transcendental listening, in that, paradigmatically, it avoids drawing attention to itself *as* a performance (whether for positive or negative reasons)" (p. 190). The performance, that is, should present only a finished product to the listener, without revealing the manner of its emergence.

All of these configurations of performing are based on a standard point of departure, namely that "each work...makes its own interpretative demands" (p. 197). The rhetoric of problem solving is involved here: the grammar of the work's "demands" raises the stakes, tasking practicing with discovering ways of fulfilling these "demands." Unpacking the "demands" of the work is thus the task of articulating a problem(s) in response to which a particular way of proceeding is preferred.

According to this configuration of performing, the skills developed by the performer—reading skills, aural skills, technical motor skills, expressive skills, and presentation skills (pp. 18, 60, 98-99, 149)—are assimilated to the rhetoric of problem solving. Problem solving is also proposed as a treatment for performance anxiety (p. 174). More specifically, the three stages of skill acquisition (cognitive, associative, autonomous), the cognitive in particular (p. 105), are articulated in terms of methods of problem solving, with the consequence that problem solving itself becomes reduced to the gaining and interpreting of "facts," based on the assumption that "the musician has clear, achievable goals and has decided on the means of realising them" (p. 110).

When *Musical Performance* considers the activities involved in passing over the threshold between practicing and performing, ideas proliferate. One proposal involves analysis: "Some performers analyze in order to gain a detailed knowledge and understanding of the work which will then inform their interpretative decision-making, while others use analysis as a means of solving specific interpretative problems" (p. 108). Another invokes "intuition," although this is inflected with the adjective "informed" (pp. 36, 41, 67, 109) and displaced by a general rationalization and an enforced separation between those performers "more inclined to the intuitive approach, and those who feel that some kind of thorough cognitive underpinning yields better results" (p. 226). A third proposal involving "taste" fails to provide a rigorous basis for reliable and repeatable judgments, and it is displaced by the assertion that "knowledge can also usefully complement a performer's own taste" (assuming that knowledge and taste are separable) (p. 14). Another proposal explores "mental" activities during the early stages of practicing:

> the main aim of mental study is to liberate our musicality, to make sure that musical goals—not technical constraints—come first. The ideal is that music should be driven not by what we can (or cannot) do, but by what we want and need to do (p. 143).

A further proposal involves separating interpretative "decisions" (falsely elided with "choice" in one place, p. 36) from the process of making them (p. 35), the idea being that a solution to the problem of "what not to incorporate from the historical record in safeguarding the aesthetic presence of the music we perform is the beginning of musical judgment" (pp. 32, 76, 77, 82, 84).

Musical Performance acknowledges the basic principle that passing over the threshold between practicing and performing takes time. However, it provides few suggestions as to *how* this might actually happen, other than comments about letting "the pieces of the jigsaw slip into place" (p. 137), use of conditional tenses (could, would, should, might, ought, if-then), a note that problem solving improves with experience (pp. 39, 105, 110), and the acknowledgment that "conscious planning can usefully assist coordination, but it does not account for the moment-to-moment hunting and cooperation that necessarily go on throughout performance" (p. 155). Although "a performer may have more than one understanding of an event or passage in a piece, but in any given performance is obliged to settle for one interpretation" (p. 64), determining *how* and *when* the performer "settles" on her interpretation is undecided. *Musical Performance* relies upon knowledge production, as if simply finding it provides a means to perform: "the first job is to begin by developing our own view of the work: ...we have to be clear, in outline at least, about what we are trying to do before looking for the means to achieve it" (p. 133).

Why is this so? Why is there an impasse in *Musical Performance* just where the performer expects a pragmatics to guide her passing over the threshold between practicing and performing? Why does the volume stop short of actually opening the door between green room and stage? Recall the rhetoric of performing as problem solving: the musical work is configured as a problem to be solved; practicing is the search for the best solution; and performing is the repeatable means of embodying the solution. Why this rhetoric is attractive and why it is confined to the green room become clear when placed into context, and this context clarifies that the impasse is not a contingent failure of this particular text but a structural matter concerning the nature of problem solving *per se*.

Problem solving originates in the public domain. In this domain performativity is the driver of discourse, development, and debate, its terms of engagement are efficacy, efficiency, effectiveness, and its *telos* is productivity (McKenzie 2001). A common *cliché* is that "You're either part of the problem or part of the solution." This reflects broader developments in which everything at the intersection of self and other comes to be a problem requiring a solution: "We are led to believe that the activity of thinking...begins only with the search for solutions" (Deleuze 1994, p. 158). Some emblematic examples: the manufacturer Honda advertised their cars with the catchy alliterative slogan, "Isn't every problem a playground?" Music therapy treats "performing" and "music" as ciphers within a programme of clinical interventions and medical solutions. Dustbin men, as the magazine *Private Eye* satirizes, should be called "refuse solution providers." Problematic gestures like the *Tristan* and "Augurs of Spring" chords are tackled by every generation of music analysts in search of better solutions. Problem solving props up science, defining much of the data as quantifiable, measurable, and time-limited, and speeding up solutions to problems like urban regeneration, the modeling of viral epidemics, and the prediction of supermarket monopolies: such research proceeds according to the logic that experimental design is a solution to a self-imposed problem (which may have originally been an intuition). The infiltration of problem solving into these and other diverse domains is understandable, and vital for maintaining the onward march of human development.

Talking of "solution providers" is a way of managing the increasing complexity of human impacts on the planet. Similarly, theorizing performing in terms of the rhetoric of problem solving articulates it as a matter of technique: how the performer should solve the problem. This talk of *techne* and the capitalization of labor elides problem solving with cognition *simpliciter* and assumes that problem solving is the essence of rationality (Bruns 1999, p. 87). To invoke management acronyms, it is to configure performing as SMART and TRUE: Specific, Measurable, Achievable, Realistic, Timely; Timely, Relevant, Understandable, Effective.

Underlying the social context of the rhetoric of performing as problem solving is the ideology: performativity or "communicative action." Recall the rhetoric again: the musical text or script is configured as a problem to be solved; practicing is the search for the best solution; and performing is the repeatable means of embodying the solution. This can now be revised. The musical text is configured not merely as a problem to be solved, but as an object to be comprehensively endowed with value, significance, and meaning. Practicing is not merely the search for the best solution, but the un-distracted search for an un-mediated mode of communicating with the listener that unfolds a shared understanding of the music. And performing is not merely the repeatable means of embodying the solution, but a serious vessel through which musical communication takes place: while such things as taste, pleasure, and intuition may feed into cultural communication, they cannot support performing proper, which is publically and professionally accountable, and framed in terms of claims that are articulated clearly, empirically verifiable, and hermeneutically plausible. As such, performing can always get better.

IMPLICATIONS

In this article, I have tried to avoid value judgments about the rhetoric of performing as problem solving. My aim has been simply to offer a diagnosis of the *status quo*, as manifest in a key text, unpacking its conceptual ideology and apparatus and its rhetorical assumptions and maneuvers. My view of the rhetoric can be guessed from the fact that I called my description a "diagnosis": *is* does not imply *ought*. That judgment, however, along with the pragmatics of passing over the threshold from practicing to performing, is for a future paper.

What are the implications of the argument in this paper? First, performance studies texts need to be careful about choosing words and rhetorical strategies, for these influence the way in which they are understood to be conceptualizing its object and thus what kinds of significance performing is said to have. Secondly, performers should simply bear in mind that how they think about performing influences how they perform.

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The British clarinet school: Legacy and legend

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At the beginning of the twenty-first century, music surrounds us on a daily basis. Instant access to recordings and immediate comparisons of performances worldwide have become an integral part of our lives. Yet arguably there has been a heavy price to pay. In Mozart's day, major European cities such as Vienna and Prague boasted distinctive musical personalities; nowadays, even such a hitherto distinctive ensemble as the Czech Philharmonic Orchestra has assumed an international aura, with a less identifiable corporate sound. Opportunities provided by air travel have further encouraged such a process. Early recordings provide valuable evidence of what has been lost in terms of individuality and national styles, and these have increasingly been the subject of detailed research. A useful case study is provided by the British Clarinet School. "The Clarinet has long been considered by the whole Musical Profession as the most beautiful of wind instruments," remarked the great English clarinetist Thomas Willman in 1826 (p. 1). "That king of the reed instruments, the clarinet…," wrote his successor Henry Lazarus in 1881 (preface, p. 1). Since 1900 or so there has been aural evidence for these assertions. As one of Mozart's contemporaries put it, some musical subtleties cannot really be described—they must be heard.

Keywords: clarinet; Lazarus; national styles; recordings; Willman

As recording has developed over the past century, so the clarinet itself has become more and more popular. The celebrated soloist Jack Brymer (1976), principal clarinet in the London Symphony Orchestra (LSO), remarked in the 1950s and again in the 1970s that everybody one met seemed either to play the clarinet, to want to play it, or to have once played it at school and given up. A decade ago, 46,000 children in the British state-school system were taking clarinet lessons of some sort, fewer than the violin, guitar, or the flute, but a great deal more than the mere 3000 tenacious enough to grapple with the oboe.

Does the British Clarinet School have any meaningful identity? Some prominent musical figures have certainly thought so. In the early 1890s, George Bernard Shaw (1931) reckoned that with notable exceptions the German woodwind player was content with a cheaper tone than the English one. German clarinet reeds, he remarked, produced a strident and powerful tone that gave a passion and urgency that seemed ideal for Weber's *Freischütz*. But when it comes to the *Parsifal* Prelude or the second movement of Beethoven's Fourth Symphony, he wrote, "one misses the fine tone and dignified continence of the English fashion" (vol. I, p. 91). By the 1950s, Brymer (1979) was paying tribute to the work of three or four past generations of British clarinetists who were not content merely to sit in orchestras but were also students of human psychology and philosophy, and so were inspirational teachers. One of Brymer's celebrated predecessors in the LSO and professor at the Royal College of Music, Sidney Fell (1957), declared unequivocally in the 1950s that the British School was "still the leading one among musicians the world over" (p. 42). The great British clarinetist, Reginald Kell (1957, pp. 60-62), went rather further than that; he had lived in America for almost a decade and bemoaned the lack of imagination and inspiration among the wind players there. For him the absence of real individuality meant that all American orchestras sounded the same. In contrast, the exceptional imaginative and individual qualities of the finest British wind players made for an unrivalled level of achievement.

MAIN CONTRIBUTION

Individual distinctive musicality allied to mellowness of sound is arguably a hallmark of the British Clarinet School. The second half of the nineteenth century was dominated by Henry Lazarus, whose career lasted for almost 60 years up to his death in 1895. Shaw (1889) noted that "a phrase played by Mr. Lazarus always came, even from the unnoticed ranks of the woodwind at the opera, with a distinction and fine artistic feeling that aroused a longing for an orchestra of such players". The usual clarinet player, Shaw said, was stolid, mechanical, undistinguished, correct at best, vulgar at worst. Significantly, the great Bach scholar Philipp Spitta (1889) wrote: "Wind instruments are now out of fashion for concert playing, and one seldom hears anything on such occasions but the piano and violin, instead of the pleasing variety which used to prevail with so much advantage to art" (p. 426). At the dawn of recorded clarinet history appears the highly influential Spaniard Manuel

Gomez, who studied in Paris, arrived in London in 1888, and then became the LSO's first principal clarinet in 1904. Typically, he recorded short, light virtuoso pieces, often with operatic connections.

How each of us responds to Gomez may well depend on age and individual musical experience. But there is at least one other equally important factor. As inhabitants of the digital age, are we in fact over-concerned with surface detail as opposed to overall characterization of the music? In 1904, there was no editing of any kind to feed our obsession with technical accuracy. Overall, Gomez emerges with credit from his recorded legacy, his firm tone allied to secure technique and no more than a hint of the sharpness that has been the bugbear of many a clarinet performance throughout history.

The great English virtuoso Charles Draper, born in 1869, made early records of similar material, including variations on "Home sweet home" on a wax cylinder from ca. 1901-03. In the early years of the century Draper was Elgar's favorite clarinetist, and he inscribed Draper's name in his scores whenever important clarinet passages appeared. The Brahms Clarinet Quintet was often played in Britain by its dedicatee Richard Mühlfeld in the years before his untimely death in 1907. When he heard Draper play the piece in London he was generous enough to observe that Draper's interpretation had revealed subtleties within the work that he himself had not previously observed. In these circumstances Draper's 1917 recording of abridged versions of the first two movements carries an unusual authority. His playing is epic and dramatic, providing a valuable link back to the nineteenth century.

It now seems extraordinary that Mozart's Clarinet Concerto did not feature at all in London's Philharmonic Society concerts between 1838 and 1916. Indeed, in the latter year the amateur clarinetist Oscar Street (1916) claimed only to have heard one complete performance, by Charles Draper in the early days of the Beecham Orchestra. It fell to Draper's pupil and nephew Haydn Draper in 1929 to make the first recording of the Mozart Concerto.

Haydn Draper's fellow pupil Frederick Thurston was himself a great teacher, and in his own case, the relationship between legacy and legend is especially complex. Thurston was someone for whom each performance was a fresh event, and he hated the sterile procedure of recording. He once wrote:

> ...I should be on somewhat dangerous ground if I ventured to say that perhaps a higher degree of musicianship is required from players of woodwind instruments than from those who play, for instance, the violin. However, it may be mentioned that at all parts of the register, absolute control of intonation depends on the subtle muscles of the lips and the breathing tract; changes in temperature, and the like, affect the instru-

> ment in a manner that the string player is spared, and therefore woodwind instrumentalists must be alert to the finest shades of intonation all the time they are playing (Thurston, 1948, p. 38).

Notwithstanding his dislike of recording, Thurston inspired a huge number of composers to write for the clarinet, including Malcolm Arnold, Bax, Bliss, Howells, Ireland, Lutyens, Maconchy, and Rawsthorne. In the light of Thurston's influence, it is salutary to reflect that in the early part of the twentieth century the clarinet was widely regarded as an unsatisfactory instrument for sonatas, owing to its comparative inflexibility and somewhat monotonous tone-color. One critic asserted that "even Brahms could do nothing with it" (Street, 1916, p. 113). A 1938 *Radio Times* article began: "Apart from the foxy-looking little men who patiently play the instrument at street corners and apart from the inimitable Mr. Benny Goodman…one seldom gets the chance of hearing the clarinet as a solo instrument" (Bradbury and King, 2001, p. 5). Thurston changed all that, as can be heard (for example) in the live BBC broadcast of Ireland's *Fantasy-Sonata* with the composer, dating from 1948.

The broadcast shows Ireland's piano playing to be eloquent in both left and right hands, while Thurston projects the work with strength and vitality. Clearly, the surface of the clarinet line does not have the polish we have come to expect nowadays, but neither does the effect of the microphone balance. The whole piece, like others associated with Thurston, was a huge technical challenge at the time. Its quality was immediately recognized, however. The *News Chronicle* reviewer stated that he had never imagined that clarinet and piano could be combined so satisfactorily; nor that (by a mixture of tact and daring) they could form such an exciting ensemble (cited in Bradbury and King, 2001, p. 7).

Another clarinetist who won praise for his tuning was the legendary Reginald Kell. He was especially proud of a *New York Times* review that described him as "one of the greatest Mozart interpreters of our time, on any instrument" (Kell, 1957, p. 57). All of his Mozart recordings benefit from his detailed small-scale phrasing, although his rubato certainly owes a great deal to the Drapers, while being intensified in a very personal way. Kell's discography was wide-ranging (extending into the LP era), but generally not matching Thurston's contemporary interests. It was his prominent vibrato, inspired by Léon Goossens's rich oboe sound, that proved especially controversial. Kell felt ostracized by colleagues at Covent Garden in the 1930s, when Wilhelm Furtwängler told him during a rehearsal of *Tristan* that he was the first clarinetist he had ever heard who played from the heart. Kell had once been a violinist himself; when he heard Kreisler, Casals, or the vibrancy of a singer like Flagstad, he simply could not imagine persevering with a naïve clarinet sound as pure as a lily. But on moving to the USA in the late 1940s, he met with a mixed reception. The American clarinetist Robert Willaman (1954) gives some idea why; he described vibrato as originating on the saxophone in dance bands around 1920, as a palliative for crude tone production. "It may be that vibrato is a real improvement. Some people put sugar on ice cream. A great many do not and never will" (p. 246).

Other players drew upon both Kell and Thurston to produce an instantly recognizable and individual presence. In this respect, few could rival the fluency of Gervase de Peyer. "His style is suave and confident" wrote *The New Grove* (Weston, 1980, p. 379) and not many would argue with that on hearing his concerto and recital discs of the early 1960s. A typical example is de Peyer in the elevated company of Rostropovich and Britten at the 1964 Aldeburgh Festival, his vocalized vibrato matching the singing cello to perfection. De Peyer was a much recorded clarinetist, especially with the Melos Ensemble. At the end of the 1960s, he gave some stunning performances of the radical and innovative Clarinet Concerto by Thea Musgrave, before taking Kell's route and settling in the USA—a move that inevitably diminished his influence in Britain.

IMPLICATIONS

New generations of British clarinetists continue to emerge in succession to the figures considered in this article. French clarinets now dominate the British market. And in our digital age within a global village, solo and orchestral sound-worlds are surely becoming increasingly international and less identifiable? It seems inevitable that the distinctiveness of national schools of performance will suffer a continued decline; in these circumstances, early recordings provide an especially valuable source of evidence for a more colorful past.

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Breaking traditions: Art song theatre cognitive shifts through staged modalities

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Art Song is an intricate fusion of poetry and music, a text/tone symbiosis capable of activating synaesthetic cognition and powerful states of emotional, visceral, and ideational perception. The coalescence offers fascinating cross-modal insights into the dialectical codes of composers, suggesting a philosophical journal and a personal lexicon of auditory gestures. In theory, its exceptional specificities make Art Song a uniquely approachable genre within the abstract realm of Western classical music. So, why aren't audiences packing concert halls? Paradoxically, surveys indicate that a majority of audiences report experiences of disengaged alienation. The burgeoning popularity of contemporary opera, using comparable vocal techniques within dramatic environments of converging multimedia stimuli, presents a daunting challenge to the recital's minimalist stagecraft. If creative innovation would ameliorate Art Song's reception, its common practice enjoins proscribed expressive parameters that are intractable to alteration despite a proliferation of evidence that its domain as performance art is at risk. Addressing the sources of disconnection, this project explores experimental and controversial theatre practices in pedagogical and production environments. A cohort of adjunct empirical research measures multi-modal shifts in performative outcomes. Breathing, vocal production, speech flow, physical expressivity, and phrasing are all demonstrably impacted, with immediate concomitant perceptual shifts of comprehension for audiences.

Keywords: gesture; contextualization; speech-flow; authenticity; multi-modality

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Thematic session:
Evaluating performance

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Investigating critical practice

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This article offers a preliminary overview of a large-scale study of 845 reviews of commercial recordings of Beethoven's 32 piano sonatas published in *The Gramophone* between 1923 and 2010. Data regarding publication date, repertoire reviewed, pianist(s) reviewed, music critic, label, release status, and length of the text were extracted and analysed. The results highlight that, despite the high number of critics (n=59), labels (n=136), and pianists (n=216) involved, a large proportion of reviews were written by relatively few critics (n=7) of recordings released by few labels (n=8) and of performances given by few pianists (n=17). The analyses showed that labels and pianists who produced more recordings received longer reviews. Two of the seven most prolific critics seem to have been given more freedom to write idiosyncratically, with particularly long and short reviews. In a second phase, a pilot text content analysis was carried out on a subset of 63 reviews. Results reflect an increasing focus on interpretative issues over the course of the century, with later reviews providing more text on interpretation. This is in line with the growing quantity of reviews of reissues (from the 1950s) and releases of old recordings (from the 1980s) found in the full dataset.

Keywords: criticism; recording; record industry; Beethoven; piano sonatas

Music criticism is a common practice in which the description and evaluation of a composition and/or performance play constitutive parts (Carroll 2009). Yet, this practice has been neglected in performance evaluation research, such that there is currently no structured enquiry on offer of the phenomena or outcomes involved. A systematic investigation into music criticism can offer new perspectives on this well-established tradition, providing insight into the phenomenological and psychological processes that underpin it and the role that expertise plays therein. As a first step to this investigation, this article offers a preliminary overview of a large sample of music reviews regarding Beethoven's piano sonatas published between 1923 and 2010.

METHOD

Materials

The online archive of *The Gramophone* (www.gramophone.net) was chosen as the reference source. From this archive, all reviews were extracted that concerned commercial recordings of one or more of Ludwig van Beethoven's 32 piano sonatas.

Procedure

Reviews were collected in two successive phases, first using the *search* tool of the Gramophone website and successively browsing every issue page-by-page as they appear in the scanned online version. That was essential in order to assure as complete a collection of material as possible. The reviews were ordered chronologically and divided per decade. For each review, a database was compiled of the following data: issue (date, page); sonata(s) reviewed; pianist(s) reviewed; label; critic; release status (i.e. new release, re-issue, and first publication of an old recording); repertoire reviewed (i.e. only Beethoven sonata(s) or Beethoven sonata(s) plus other works); length of the review text (in words).

Table 1. The 17 most often reviewed pianists. Names in italics are among the performers most often used for comparisons.

Name	*Frequency*	*Name*	*Frequency*
Arrau, Claudio	53	*Barenboim, Daniel*	18
Brendel, Alfred	52	*Gieseking, Walter*	18
Kempff, Wilhelm	49	*Gulda, Friedrich*	16
Backhaus, Wilhelm	38	Lill, John	16
Ashkenazy, Vladimir	27	Michelangeli, Arturo Benedetti	14
Richter, Sviatoslav	26	*Kovacevich, Stephen*	14
Schnabel, Artur	26	*Pollini, Maurizio*	13
Solomon, Cutner	25	Serkin, Rudolf	13
Gilels, Emil	20		

Descriptive and exploratory data analyses were carried out on the whole dataset. Subsequently, a subset of 63 of the total 845 reviews was chosen for a pilot quantitative text analysis. This included seven reviews per decade randomly chosen among reviews that (1) concerned solely Beethoven piano sonata(s) and (2) had a text length of between 130 and 800 words, to assure having enough text with which to work and to exclude long, article-like reviews that offered a different journalistic product. Reviews were analysed by the first author, and different content sections were marked in the text according to the following three categories: *interpretation/performance*, *composition*, and *recording*. This process was repeated independently by the second and third authors (all three had professional training in piano performance), and results were compared and agreed upon.

RESULTS

The collected material summed up to 845 reviews (ca. 400,000 words) published between April 1923 and September 2010. The publication rate for the first three decades (until 1950) was 2.6 reviews per year. After 1950 and until 2010, the rate increased to 12.9 reviews per year. First releases of new recordings accounted for 67.3% of reviews, and re-issues and first releases of old recordings covered 29.5%, with "old" understood as recordings produced more than 15 years prior to the publication date of the review. A residual 2.7% of reviews concerned recordings of groups of sonatas, some of which had been previously reviewed. Re-issues started to appear in the 1950s and increased toward the 1980s, when the ratio between new recordings and reissues reaches almost 1:1. After 1990, this tendency recedes but was compensated by the new phenomenon of old, unpublished recordings made suddenly commercially available. In the collected corpus of critical texts, 216 different pianists were reviewed, but 50% of reviews concerned only 17 pianists, with 117 performers reviewed only once. Comparisons between pianists by reviewers were common, found in 41.2% of all reviews and 53.1% of the reviews of only Beethoven sonatas. Beginning in October 1953, comparisons were also stated officially in the titles of the reviews. Out of the 216 pianists, 81 were used throughout the century for comparisons. Of the 16 performers most often used for comparison, 14 correspond with those included among the 17 most reviewed pianists (see Table 1).

There were 136 labels that produced recordings reviewed in *The Gramophone*. Out of the 136 labels, eight (i.e. Philips, DGG, HMV, Decca, Columbia, RCA, EMI, CBS) cover 61.51% of the total. Starting in the 1950s, the predominance of those labels constantly decreases. The percentage of produced re-

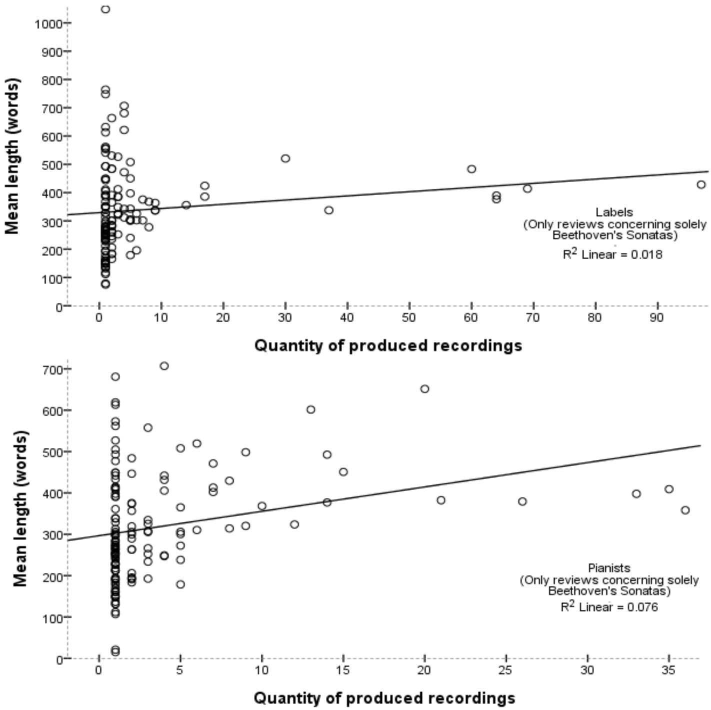

Figure 1. Distribution of mean length of reviews against quantity of produced recordings reviewed for labels (top panel) and pianists (bottom panel).

cordings was 84.2% in the 1950s; 20.9% in 2000s. This tendency is strongly accentuated in the last two decades.

The length of review was extremely varied, ranging from 10 to 2426 words (mean=409.86, SD=277.70); however, the distribution presents a strong positive kurtosis (kurtosis=11.89, SE=0.17) and a comparatively small interquartile range (IQR=251). For reviews concerning solely Beethoven's sonatas, relationships were explored between length and decade, critic, label, and pianist, respectively. Kendall's Tau (two-tailed) revealed a moderate positive correlation between quantity of produced recordings and length of reviews for labels ($\tau=0.234$, $p<0.001$) and pianists ($\tau=0.277$, $p<0.001$).

Among the 845 reviews, it was possible to identify 59 different critics (8.88% of reviews were unsigned). Out of the 59 critics, seven cover 51.95% of the reviews written, their average period of activity is 27.14 years. Between these seven critics, mean values of length of produced reviews were compared through a Kruskall-Wallis test that showed significant differences (H_6=23.33, $p<0.005$). However, it was thought that those differences could be influenced by historical tendencies; therefore, the mean lengths for each of those seven critics were compared with those of their colleagues, for the period of time in which each critic was active. Two critics scored reviews significantly longer (R.O.) and shorter (M.M.) than their contemporaries according to Mann-Whitney tests (U_1=17,689.50, Z=2.78, $p<0.05$ and U_1=3,999.50, Z=704.12, $p<0.001$). From the text analysis run on the subset of 63 reviews, the categories *interpretation/performance*, *composition*, and *recording* accounted for 76.34% of all text, on average. They were distributed as follow: 54.74% interpretation/performance, 11.60% recording, and 10% composition. The residual text contained diverse information regarding, for instance, the categories labelled *shopping tips* (e.g. "Buy X and you will have all important sonatas in just 3 discs") and *recording policy* (e.g. "One more Moonlight? When will we have an Op. 79?"). This internal distribution of categories varies along the century. The distribution of the three categories within the reviews text among decades is shown in Figure 2.

The amount of text given to the category *interpretation/performance* increased over time. In particular, a strong growth is seen at the beginning of

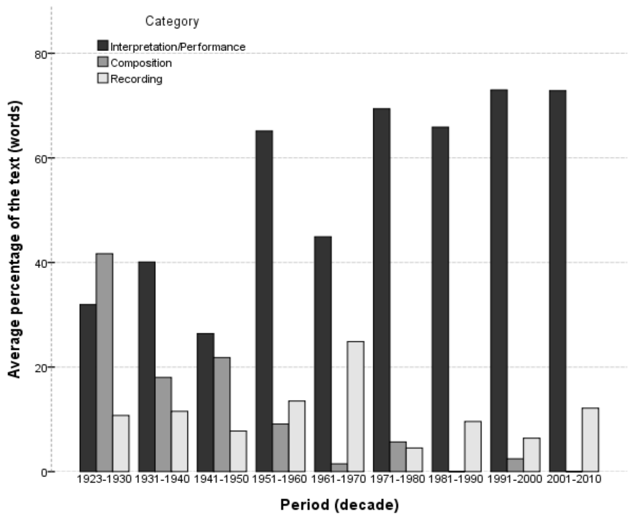

Figure 2. Distribution of text according to the three content categories across decades.

the 1950s. After this date, the increase is marginal. The years 1961-70 do not belong to this picture, showing a low percentage of *interpretation* text. The category *composition* plays a major role at the beginning of the century and decreases toward 1960. After this date, almost no text at all is devoted to it. The *recording* category scores a peak in 1961-70.

DISCUSSION

This study serves as the first step for a larger investigation of the practice of music criticism. The first picture emerging from the data is extremely varied with a high number of critics, pianists, and labels involved. However, the distribution of reviews is polarized around small subgroups of them, and those subgroups also receive longer reviews on average. That suggests a focus on high profile performers and labels, which could make an in depth investigation of a reduced number of authors, players, and producers fruitful. First, however, more contextual information is needed in order to interpret the emerging patterns properly. For labels, it will be important to reframe the analysis taking into account the different merging and splitting movements between record producers and trademarks (see Patmore 2009). Editorial issues and standard procedures behind the selection of recordings to be reviewed should be clarified with regard to the relationships between quantity of produced recordings (by pianist and label) and length of reviews. Differences in the average text length among critics, in particular for R.O. and M.M., should be investigated through a text content analysis aimed at enlightening divergences in linguistic style and use of expressions.

Acknowledgments

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Piano performance assessment: Video feedback and the Quality Assessment in Music Performance Inventory (QAMPI)

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This study assesses the validity of a new self-report measure of piano performance quality, the *Quality Assessment in Music Performance Inventory* (QAMPI), and the adaptability of sport video analysis methods to piano performance evaluation. Piano students from Brandon University's School of Music (n=21) volunteered to have real rehearsal and concert performances video recorded. Students employed QAMPI before and while watching the video recording to assess the perceived quality of their concert performance compared with their individual performance potential established in the rehearsal. An expert also employed QAMPI to evaluate each student's concert piano performance quality after reviewing the rehearsal and concert video recordings. Initial results indicate that piano students' assessment of their performance quality measured by QAMPI before and while watching the video recording differ substantially and that the students' self-evaluation while watching the performance video recording is closer to that of expert assessment. Cronbach's alpha demonstrated good internal consistency. These initial results indicate that QAMPI provides a consistent measure of music performance elements using video feedback and insight into pianists' self-perception of performance quality.

Keywords: music performance assessment; QAMPI; video feedback; performance perception; music performance anxiety

Sport studies have established the efficacy of video feedback for training, performance analysis, and understanding (Wang and Parameswaran 2004, Cassidy *et. al.* 2006, O'Donoghue 2006) and practical aspects for systematic video recording for seated athletes (Frossard *et. al.* 2006). Video recordings of music performances are also increasingly common means of assessment for acceptance to training institutions, competitions, and music performance research. However, research has shown that music performance quality assessment methods are problematic, often with unreliable measuring schemes (Thompson and Williamon 2003). Researchers of music performance evaluation regard rating scales to improve the reliability of judgment (Okay 2010). Little information is available in the literature about the practical aspects of systematic video recording of pianists' performance. Considering the significant similarities that exist between sports and music performance, this initial study has two aims: (1) to determine the adaptability of sports performance video recording setup and assessment methods to pianist performance in real practice and concert settings and (2) to assess the feasibility of a new self-report *Quality Assessment in Music Performance Inventory* (QAMPI) to measure elements of piano performance quality and to identify possible differences in pianists' self-perception of performance quality without and with video feedback.

METHOD

Participants

Twenty one Brandon University undergraduate and graduate piano students (11 female, 10 male; mean age=21.0 years, SD=2.32) volunteered to participated in the study. A professional pianist with extensive experience evaluating at the university level was the expert assessor and a research assistant with professional recording experience positioned and operated the audio and video recording equipment.

Materials

Rehearsal and concert performances were video recorded with two compact Sony DCR-SR82 video camcorders on tripods and audio recorded using two B&K cardioid condenser microphones in an X-Y stereo arrangement suspended above the stage, recording to a Roland CD-2 CF/CD. A new self-report measure survey *Quality Assessment in Music Performance Inventory* (QAMPI) was developed so that eight different items of performance quality in concert could be compared with rehearsal performance quality. Each of the eight performance categories was scored using a 7-point Likert-type scale ranging from -3 (much worse) to 3 (much better) (see Table 1).

Table 1. QAMPI form. Directions: Compare your concert performance with your rehearsal performance by completing two QAMPI forms. One after your concert performance *before* watching your video and the second *while* watching your concert performance video. Circle the appropriate number to the right of each category.

	Much worse	*Worse*	*A bit worse*	*Same as in practice*	*A bit better*	*Better*	*Much better*
Memory control	-3	-2	-1	0	1	2	3
Note accuracy	-3	-2	-1	0	1	2	3
Control of tempo	-3	-2	-1	0	1	2	3
Rhythmic accuracy	-3	-2	-1	0	1	2	3
Articulation accuracy	-3	-2	-1	0	1	2	3
Dynamic accuracy	-3	-2	-1	0	1	2	3
Tone quality	-3	-2	-1	0	1	2	3
Expressiveness	-3	-2	-1	0	1	2	3

Procedure

Based on models of procedure and bi-planar video-camera setup adapted from sports research on seated athletes (Frossard *et al.* 2006), various camera positions were tested for optimal capture without intrusion on the pianist. The two cameras were set at the back of the hall approximately 2 m left and right of the meridian, 12 m from and 3 m higher than the keyboard to capture full-body lateral and frontal views of the students, piano keyboard, and pedals. These positions also allowed camera placement where jurors would normally be seated in recital and competition settings. One rehearsal session and one concert performance for each student was video and audio recorded for sound quality control. As these were real concert performances of university piano students in different years, the duration of the recordings between participants varied from 10 minutes to 50 minutes. Each participant completed the QAMPI form immediately after their concert performances before watching and then again while reviewing the video recordings. The expert completed the QAMPI after watching the practice and while reviewing the performance video of each participant.

RESULTS

As the eight items included in QAMPI measure separate aspects of the same underlying construct of performance quality, Cronbach's alpha was calculated

Table 1. Correlation coefficients (Spearman's rho).

	QAMPI self without video	*QAMPI self with video*	*QAMPI expert with video*
QAMPI self without video	1.00	0.87*	0.79*
QAMPI self with video	-	1.00	0.94*
QAMPI expert with video	-	-	1.00

Note. * $p<0.01$.

as an estimate of QAMPI's internal consistency. The computation was completed for the eight items once without use of video analysis and once while using video analysis. Cronbach's alpha for performers' self assessment without video (n=21) was α=0.96, while α=0.95 for the self assessment with video (n=21).

For each of the 21 concert performances, QAMPI was applied three times: self assessment without video, self assessment with video, and expert assessment with video. For each of these applications the respective sum score was calculated by adding up the eight item scores ranging from -3 to +3. Table 2 shows the correlation coefficients for these QAMPI sum scores.

This demonstrates a particularly high correlation (0.94) between the performer's self assessment with video and the expert's assessment with video. The graphical representation of this is shown in Figure 1 (left panel).

The lowest correlation (0.79) was found between the performer's self assessment without video and the expert's assessment with video, which is shown in Figure 1 (right panel). The correlation between the performer's self assessment without and with video (0.87) is shown in Figure 2.

DISCUSSION

The preliminary data shows evidence of good internal consistency of the QAMPI scale. The high correlation between self assessment during video feedback and expert assessment are an indication of the validity of QAMPI. Further validation of these data should be explored with an expanded sample of students and experts and by a comparison of QAMPI results with an external measure of performance quality such as their recital grade.

The positioning of cameras for the video recording of pianists adapted from studies of seated athletes in competition proved useful in capturing analyzable bi-planar visual and sound representations of their performances. Examining the interface between software, technology, and computational analysis of sport performance for adaptation to assess and understand piano

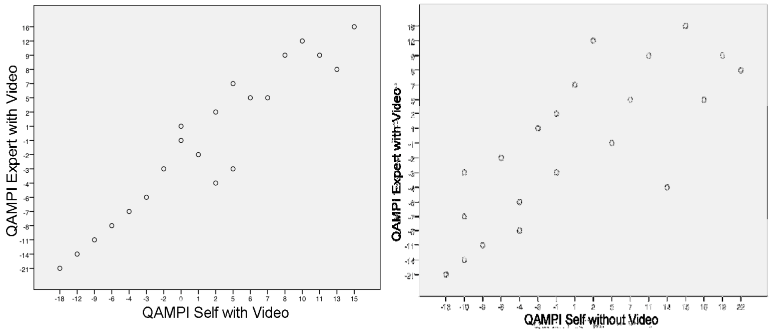

Figure 1. Scatter plots showing self assessment with and expert assessment with video analysis (left panel) and self assessment without and expert assessment with video analysis (right panel).

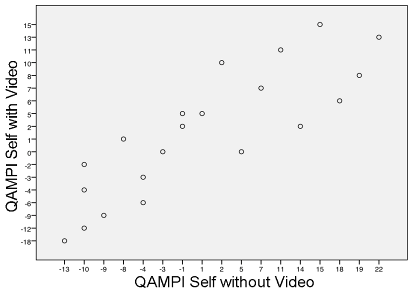

Figure 2. Scatter plot showing self assessment without and with video analysis.

performance quality could also be beneficial for training and performance enhancement.

QAMPI is a tool that allows pianists to rate their concert performance against their previous rehearsal performance. The main distinction between both concert and rehearsal conditions are different levels of performance anxiety. Further QAMPI studies with an increased sample of pianists might show how different aspects of performance are influenced by performance anxiety. As the use of video analysis together with QAMPI substantially increases the correlation with expert assessment, it enables the performer to judge the performance quality more objectively. Whether differences between pianists' self-perceived performance quality measured by QAMPI without and with video feedback can predict performance success, manage performance anxiety, or ultimately enhance effectiveness of training to achieve desired performance outcome warrants further exploration.

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An evaluation of parameters in performance: The effects of aural and visual stimuli

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The performance of the Brazilian composer C. Guarnieri's *Ponteio 22*, interpreted and evaluated by undergraduate and graduate piano students (n=15), was monitored over 16 weeks. Each participant evaluated audio-only and audio-visual modalities for nine musical parameters: articulation, tempo, timing, dynamics, texture, phrase contour, accuracy, character, and global coherence. A strong correlation was found between the pre-arranged parameters of phrase contour and global coherence in the audio mode, while in the audio-visual case, the strongest correlation occurred between the parameters of timing and global coherence. Data were analyzed by statistical multidimensional scaling. Data have shown that the nature of the stimuli affects the relationships among dynamics, accuracy, articulation, and tempo. The synchrony between audio and video seems to interfere with perception and evaluation by students in this sample.

Keywords: musical performance; musical perception; audio stimulus; audio-visual stimulus; evaluation

Most human performances involve the perception of multisensory information in a particular environment. Music making, a highly demanding type of human performance, requires accurate timing, motor control, and coordination in the planning and execution of intentional movements. Musical performance is also subject to evaluation. Appraisals require the processing, in both space and time, of information in different sensory modalities. The effect of visual and aural stimuli has been investigated in the literature from various perspectives (Thompson *et al.* 2005, Repp and Knoblich 2009, Hadjidimitriou *et al.* 2010, Smith *et al.* 2010, Petrini *et al.* 2010). In a previous study (Gerling *et al.* 2009), we observed that evaluators reached a consensus in the appraisal of an excerpt of one of Bach's preludes when the prelude was experienced in an audio-visual modality, but a consensus was absent when evaluators experienced the piece in a video modality only.

Extending our previous study, we investigated the effect of the nature of stimuli (audio or audio-visual) on the evaluation of a performance of Brazilian composer Camargo Guarnieri's *Ponteio 22*. This evaluation encompassed a series of musical parameters: articulation, timing, dynamics, texture, contour, accuracy, character, and global coherence.

METHOD

Participants

This study involved 15 undergraduate and graduate piano students at the Federal University of Rio Grande do Sul (UFRGS).

Materials

Guarnieri's *Ponteio 22* was prepared by the students without guidance from their teachers. The preparation was monitored over a period of 16 weeks through recorded performances and interviews.

Procedure

The best recorded performance, according to each student's choice, was evaluated under conditions of audio-visual and audio-only stimuli. Students were individually asked to evaluate audio-visual recordings and to assign grades according to a Likert-type scale (1=weak to 5=very good) for nine musical parameters: articulation, tempo, timing, dynamics, texture, phrase contour, accuracy, character, and global coherence. The students had been previously introduced to these parameters. Subsequently, they were asked to evaluate the audio results in random order. This second evaluation was self-administered through the web. The data were analyzed by the use of multidimensional scaling (MDS).

RESULTS

The scores assigned by the students to the audio-visual and audio-only recordings for Guarnieri's *Ponteio 22* are presented in Table 1. For a given parameter, the mean rating was consistently higher for the audio modality than for the audio-visual modality. The lower SD observed in the case of the audio stimulus suggests a higher degree of consistency.

Table 1. Mean (and standard deviation) for the scores assigned by the students for *Ponteio 22* when presented in audio and audio-visual modalities (n=15).

Parameter	*Audio*	*Audio-visual*
Articulation	4.21 (0.79)	3.46 (1.03)
Tempo	4.08 (0.87)	3.47 (1.06)
Timing	3.77 (0.88)	3.60 (0.94)
Dynamics	3.77 (0.92)	3.46 (1.08)
Texture	4.05 (0.82)	3.16 (1.13)
Phrase contour	4.04 (0.84)	3.36 (1.12)
Accuracy	4.15 (0.84)	3.25 (1.25)
Character	3.51 (1.14)	3.38 (0.97)
Global coherence	3.98 (0.81)	3.38 (0.99)

The analysis of the data (Figure 1) confirms an asymmetrical distribution for the audio-visual stimuli (see median), which may suggest that in this modality, the visual and aural channels compete in a way that interferes with evaluation. Moreover, one cannot disregard the possible interference of the visual recognition with the audio evaluation. This set of data was analyzed according to Pearson correlations. For the audio stimulus, the correlation between texture and global coherence ($r>0.7$) and between shape (contour) and global coherence ($r=0.76$) was strong. These results confirm previous findings (Gerling *et al.* 2009) and thus show a pattern of correlation. Interpreters' levels of comprehension seem to approximate audiences' levels of perception, thus suggesting that global coherence may be affected by phrase contour.

One cannot neglect the fact that, throughout this short polyphonic piece, the association between global coherence and texture also presented a strong correlation. In other words, participants seemed to be aware of the work's texture, an overall response irrespective of their level of expertise. The audio-visual stimuli did not produce a similar association between global coherence and texture.

In the audio-visual modality, several correlations were observed between some parameters: timing and global coherence ($r=0.72$), tempo and phrase contour ($r=0.72$), tempo and timing ($r=0.72$), as well tempo and character ($r=0.74$), dynamics and texture ($r=0.71$), dynamics and accuracy ($r=0.72$), accuracy and contour ($r=0.74$), and texture and contour ($r=0.75$). These results show strong correlations between so many parameters, which appear to be a

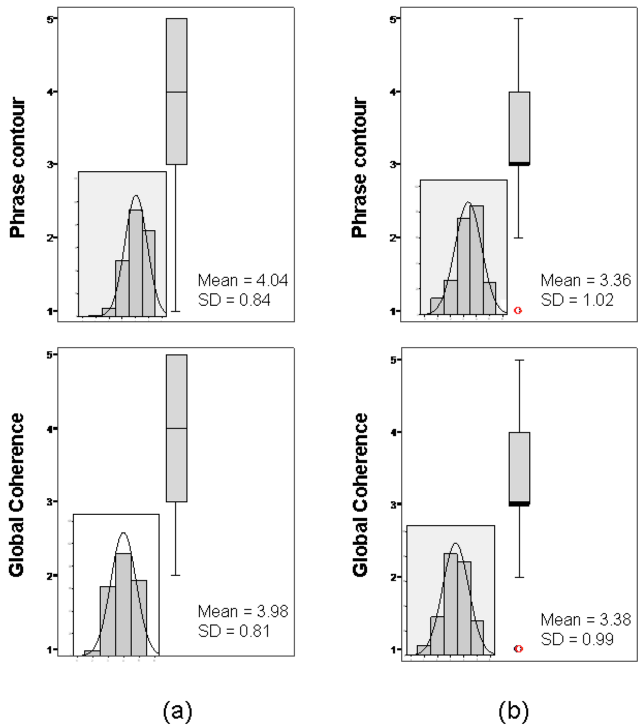

Figure 1. Examples of boxplots for phrase contour and global coherence: (a) audio stimulus and (b) audio-visual stimulus.

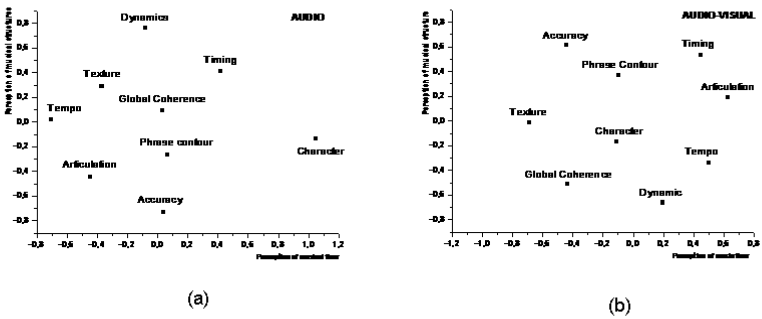

Figure 2. Perceptual map of the distribution of musical parameters obtained from the students' evaluations (n=15): (a) audio stimulus and (b) audio-visual stimuli.

little misleading. One possible hypothesis for such results could be assigned to the fact that the students might have scored the performances influenced by the reputation of his/her colleagues. Another hypothesis is that some scores were paired, taking into account that there were several correlations among three parameters: accuracy, tempo, and texture. The results were further analyzed using multidimensional scaling (MDS), which is a set of related statistical techniques often used in information visualization to explore similarities or dissimilarities in data. These data are then transformed into distances that allow for the construction of the perceptual map (Hair *et al.* 2006), as shown in Figure 2. In the perceptual map, we interpreted the abscissa as perception of musical flow and the ordinate as perception of musical structure.

DISCUSSION

The perception and evaluation of performances according to a series of prearranged parameters seem not to have been an easy task for the participants. Considering that each participant attributed 225 grades, it is understandable that they felt fatigued. From the statistical point of view, the perceptual map demonstrated that the impressions of musical parameters tend to be dispersed in spite of correlations extracted in each modality. An alternative mode of evaluation would have been the application of an open-ended questionnaire. The literature, has consistently demonstrated that perception and evaluation of musical parameters tend to shift the focus more to global issues than to the actuality of the heard product (Madsen *et al.* 2007).

Researchers have observed high degrees of dispersion from listeners. At any rate, the standard deviations found in this investigation are relatively high. On the other hand, studies have shown that listeners are directed to specific aspects of performance (Madsen *et al.* 2007) as isolated modalities (audio, for instance) and in combination (audio and video), as has been the case with this study.

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Thematic session: Solo and ensemble expertise

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A self-study of practice: Words versus action in music problem solving

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This study explores the strategies, thoughts, and artistic behaviors involved in learning a new piece for memorized performance. It discusses how an experienced cellist (the first author) prepared the *Prelude* from Bach's Suite No. 6 for cello solo, BWV 1012, for performance. The paper describes her experience and insights as a musician studying her own practice in collaboration with psychologists. This longitudinal case study took place over a period of 3.5 years during which the entire process of learning, memorizing, and giving ten public performances of the Prelude was recorded and analyzed. The results highlight the contrasts between thoughts (articulated in words) and actions (demonstrated through playing). Although a large number of comments were on technique, practice was shaped by general musical understanding, from very early stages of learning. Expert music learning can, therefore, be compared to theories of expert problem solving: identifying underlying principles, developing a deeper understanding of the issues before proceeding, taking steps toward solving the problem guided by a big picture. This is in line with Neuhaus' suggestion that a musician's first goal in approaching a new piece should be to develop an "artistic image" of its musical shape.

Keywords: learning; performing; memorizing; practice; self-study

The pianist and pedagogue Heinrich Neuhaus (1973) suggests that when a great musician first approaches a new piece, "an instantaneous and subconscious process of 'work at the artistic image' takes place" (p. 17). This points to an important characteristic of expert problem-solving: experts start with the big picture while novices plunge into the details without developing a clear idea of the big picture. As a result, their understanding of problems is more superficial and their efforts in problem-solving less effective (Glaser and

Chi 1988). But how do expert musicians form "artistic images" of new pieces? Can this function as a "mental model" which guides practice and learning? Musicians and scientists have long been interested in practice and performance, and research has demonstrated that a minimum of 10,000 hours of deliberate practice are required to achieve expert-levels (Ericsson 1997). Given the number of hours involved in preparing for performance, even small differences in the effectiveness of practice may be important. To detect such differences, this study extends previous methodological approaches by enlisting the cooperation of the artist (i.e. the musician) as a full member of the research team. This study focuses on the comparison of thoughts (articulated in words) and actions (demonstrated through playing) during practice.

METHOD

Participant

Tânia Lisboa was trained in classical cello and piano in Brazil, England, and France and currently lives in London performing as a cello soloist. Due to her initial training as a pianist, she has always chosen to perform from memory.

Materials

The *Prelude* from Bach's Suite No. 6, BWV 1012, was chosen as it explores both the mellow quality and virtuoso aspects of the instrument. Written for a five-string instrument, it presents modern cellists with substantial technical challenges when performed on a modern four-string instrument. Musically, however, the *Prelude* is of comparable richness to the other five Bach Cello Suites. Notated in 104 bars in $^{12}/_{8}$ time, the piece takes about five minutes to perform.

Procedure

The entire practice of the *Prelude* was video-recorded (75 sessions, 38 hours), including practice sessions (n=21) and public performances (n=10) over a period of 3.5 years. Reports of musical features thought about during practice were provided in copies of the score. These included: bowing, fingering, technical difficulties, dynamics, intonation, and phrasing, along with performance cues for each (see Chaffin *et al.* 2010). During learning, the cellist also talked about musical intentions, goals, focus of attention, and much else to the camera. These spontaneous comments were transcribed and classified by topic. Practice was transcribed by recording the location of starts and stops during practice. Half bars were numbered consecutively from the beginning of the

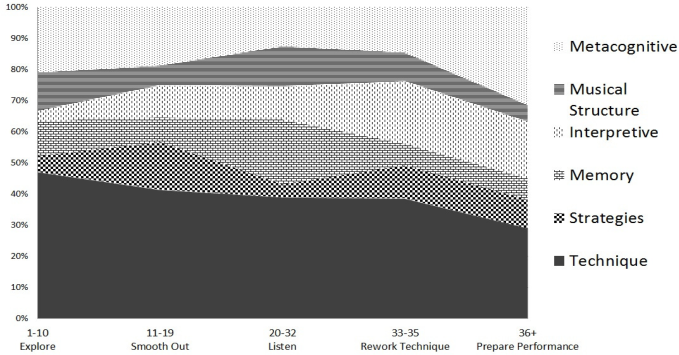

Figure 1. Proportion of categories of comments in each of five stages of learning.

piece. Statistical analyses allowed for comparison between reports and practice, providing an overview of how practice was shaped.

RESULTS

The results highlight a dramatic contrast between words and actions: two different windows into a musician's mind. Generally, words referred to preoccupations (e.g. with technique), while practice reflected less explicit musical aspects (e.g. intuitions that shaped music-making). Figure 1 shows the proportion of comments (by category) for each of the 5 stages of the learning process: *exploring* (sessions 1-10), *smoothing out* (sessions 11-19), *listening* (sessions 20-32), *reworking technique* (sessions 33-35), and *preparing for performance* (sessions 36-75)—similar to stages identified in previous research (Wicinski 1950, cited in Miklaszewski 1989).

Figure 1 shows that in the initial stages, she made more comments about technique and fewer about interpretation. Across the five stages, the proportion of comments on technique decreased steadily, and the proportion on interpretation increased. The pattern makes sense: first technique, then interpretation. However, this is the opposite of the pattern for practice identified in Figure 2. In the early sessions, comments were mostly about technique because she needed to make decisions about basic fingering and bowing. However, she left the extended work needed to secure technique until much later sessions. Meanwhile, playing was shaped by musical intuitions. She did not talk about these because they were less problematic and also because they were harder to articulate. Later, when working more on projecting musical

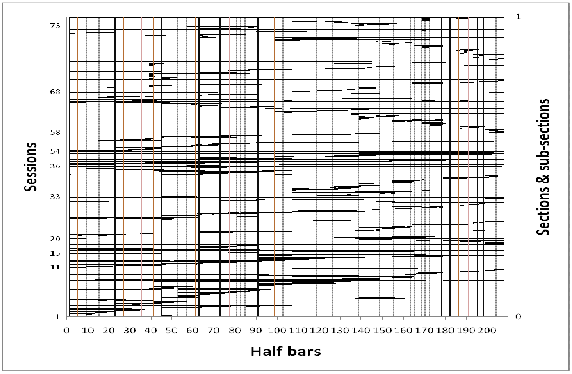

Figure 2. Practice graph of sessions 1-75 with vertical lines marking the locations of sections (dark lines) and sub-sections (paler lines).

ideas, she made more comments about interpretation. Reports of musical features were also related to practice. The main question when analyzing each report was: were starts, stops, or repeats more frequent at places where she reported that kind of feature? If so, it was assumed that she was responding to that aspect of the music. Graphs such as Figure 2 were used (but for each session separately) to highlight when each of these different aspects of the music related to the way in which the piece was practiced. Figure 2 shows the entire record of practice for sessions 1-75.

The graph reads from bottom to top with horizontal lines representing practice *segments*: uninterrupted playing. The horizontal axis represents the music, in half bars. The vertical axis represents successive practice segments. The numbering identifies the first practice segment in selected practice sessions. Inspection shows that she alternated between *section-by-section* and *integrative* practice (Chaffin *et al.* 2010)—a characteristic of expert music practice (Miklasewski 1989). Student musicians, in contrast to experts, are more likely to simply play through the piece (Lisboa 2008). Second, the vertical lines in Figure 2 represent reports of the beginnings of main (harmonic) sections and sub-sections. Inspection shows that she often started and stopped at these locations. The intersections of horizontal lines, representing practice, and vertical lines, representing the reports, show that the formal structure of the music provided a framework for practice. This is another characteristic of expert practice (Chaffin *et al.* 2002). We used multiple regression to simultaneously relate each of the 15 different types of report to the number of starts, stops, and repeats. Table 1 summarizes the results. The top

Table 1. Summary of effects ($p<0.01$) on practice at each stage of learning. Effects on starts (B), stops (E), and repetitions (R) are shown separately for different types of performance cues and for each type of decision about interpretation and basic technique. Intensive practice (simultaneous effects on starts, stops, and repetitions) is shown in *italics (*condensed from Chaffin *et al.* 2010).

Stage	*Explore*	*Smooth*	*Listen*	*Re-work*	*Prepare performance*
Sessions	1-10	11-19	20-32	33-35	36-75
Structural cues					
Expressive/Sections	B	BE	BE	B	B
Subsections	BE	BE	B		BE
Switches	E		E		
Performance cues					
Interpretive				*BER*	*BER*
Intonation				ER	ER
Basic: left hand		ER	ER	E	*BER*
Basic: right hand			*BER*		-E
Interpretation					
Dynamics	*BER*				-R
Sound quality	R	R		R	*BER*
Intonation	R	-E	ER		*BER*
Phrasing		BR			B
Basic technique					
Hand position	R	R	R		R
Fingering					
Bowing/change string		E	ER		E
Technical difficulties			ER		*BER*

two rows of data in Table 1 show that the beginnings of sections and subsections were used as starting and stopping places throughout most of the learning process. Thus, the analyses confirm the conclusion already reached from visual inspection of Figure 2: the musical structure was used as a framework for practice.

DISCUSSION

Decisions about technical and musical issues were interwoven throughout the learning of the *Prelude*. The cellist seemed to have followed Neuhaus's advice and that her "artistic image" for this piece was developed with the cello and bow in hand. From the outset, practice was organized around the musical structure. In other words, she was thinking about the general musical shape of the piece. Also, priority was given to developing the artistic image over solving technical difficulties. She did not invest in intensive practice of the technical difficulties until she was sure that her musical ideas were going to work. The nature of this project imposed certain strains as for example, inevitable tensions between the first author's roles as artist and research participant, which needed constant management. Deep reflection upon the artistic processes can disrupt the flow of artistic work, a risk of reflection-in-action. She found that providing reports of musical decisions was extremely difficult as she had to exteriorize feelings and intuitions about the music that would normally remain tacit. However, systematic self-study is a good route to improving the effectiveness of one's practice. Self-reflection deepened the cellist's understanding of her musical goals for the *Prelude* and subsequently practice has become more efficient.

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Ensemble performance: The sum of performers?

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This paper presents measurements of timing and dynamic variation and deviation in musical passages, and similarities/differences among repeated musical parts.

Keywords: performance; ensemble performance; performance analyses; music analyses; audio recordings

How do we perform as an ensemble? How do I behave playing my part in the symphony orchestra? How am I affected by my superb drummer to the left and the solo pianist to the right in a jazz concert?

Concerning solo performances there are several models like rule-based systems, statistical distribution systems, or algorithmic systems that describe behavior. So far ensemble behavior is neither sufficiently understood nor described. Most of the performed music includes ensembles (i.e. two or more musicians playing together) communicating. Comprehensive knowledge about how they do it is lacking. Interdisciplinary studies of musicians' and audiences' sound experience in relation to a limited number of parameters of ensemble performances has been presented (a.o. by the author), analyzed, and published. This paper is a follow-up on quantitative analyses.

It is important to gain knowledge about music creation beyond solo performances as the basis for modeling ensemble performances. The aim of the present paper is to obtain fundamental knowledge about musicians' behavior "talking together" as they play in small and large groups.

In acoustical measurements, we often need more musicians (small and large ensembles) as a live and acoustically correct sound source. Repeatability is then a rising problem. One possible approach is the construction of a rich sounding choir based on one singer, or an acceptable sounding violin section made from the acoustical recording of one violin using statistical signal proc-

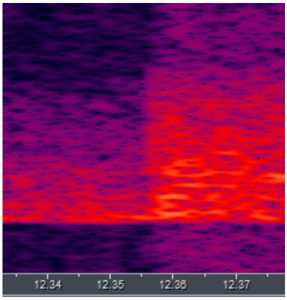

Figure 1. Spectrogram of cymbal strike. Horizontal time-axis (s). (See full color version at www.performancescience.org.)

essing methods (Ursin 2007). Details of ensemble-performed variation and deviation and similarities and differences among repeated musical parts are important basic knowledge for modeling ensemble-created sound fields.

METHOD

Materials

The combination of being both a composer and performer makes it possible to include experience from composing activities, planning musical expressiveness, instructing musicians, conducting the orchestra, playing together on the recording set, and analyzing what eventually happened. Data have been obtained from the music score and by audio analyses of excerpts from some of my own compositions (mixed church choir and jazz big band).

Procedure

In order to produce statistical data both the score and the audio recordings have been analyzed and compared. The audio analyses have been done by "matlab" and "Cool Edit" processing including adaptive digital filtering and spectrogram analyses. Figure 1 shows the precision of the timing analyses down to a few ms.

RESULTS

Data are mainly based on analyses of timing, sound level, and dynamic contours. Tempo stability differs significantly between church choir (conducted)

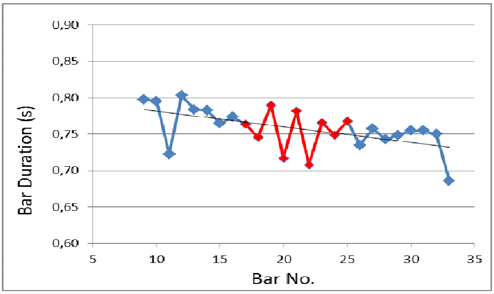

Figure 2. Timing variation (see explanation in text). (See full color version at www.performancescience.org.)

and jazz group (un-conducted). There are significant sound level differences during a performance.

Figure 2 shows the timing variation measured by the drummer's cymbal strikes through several bars. The score indicates a tempo of 300 bpm in this up-tempo jazz composition which equals 0.8 s per the 4-beat bar. During a few bars of the performance the tempo increases and stabilizes at 320 bpm (0.75 s per bar). The most unstable part is indicated with red color. Several possible explanations for this tempo change will be discussed. Bar onsets numbers 12 and 34 have been syncopated and make the previous bars shorter.

Further results and sound examples will be presented at the conference.

DISCUSSION

Statistical analyses of ensemble performances have been carried out. The interdisciplinarity of doing research on one's own composed, performed, and recorded music has a huge advantage when it comes to detailed discussions on interpretation, intonation, phrasing, acoustical feedback, and cooperating as ensemble musicians.

Quantitative analyses have been performed. The changing jazz tune tempo may be explained as "Participatory Discrepancies" (Keil 1994).

Among questions raised and discussed, all significant for establishing ensemble models, are:

- Is choir ensemble talking pitch influenced by sound level?
- What is the deviation among repeated vocal verses?

- Increased tempo in jazz performances may be accepted. Why and how does it happen?
- Who is taking the "lead" in ensembles without a conductor?
- How do tempo and dynamics differ from part to part?

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Workshops

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Understanding vocal performance: Excavating and exhibiting life's voice

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Recognized as one of the first and final signs of life and identification, the human voice mirrors age, health, gender, wellbeing, emotions, culture, and art. For those educators and performers devoted to musical expression through singing, our teaching tasks are multi-layered, sequential, and highly interpersonal. Discovering the vocal personality of each singer and the inherent texture of the vocal instrument begins the process. Coordinating the mind and body organizes and frames the instrument, while provoking the singer's musical and dramatic imagination frees it for public display. From childhood throughout old age, the voice speaks for our minds and sings for our hearts. This workshop provides tools of excavation for singing at a variety of stages and ages through demonstration, discussion, and performance. Voice sampling of childhood, adolescence, young adult, professional, and late adult singing is included, and attendee participation is encouraged.

Keywords: voice; performance; pedagogy; health; culture

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Dynamic artistry: Unlocking sound potential

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We have the great fortune to work with sound in all of its many shades and colors. Yet, it is only when the core of the tone emanates from a dynamic body in balance that the sound begins to resonate in our ears and bodies. Playing the piano is a physical endeavor that requires total mind/body/ear coordination for optimal performance. Much like athletes, pianists undergo hours of training to improve efficiency, speed, and agility, all to serve an artistic goal. Drawing from our experience as performers, teachers, and researchers—as well as the latest scientific research in biomechanics and arts medicine—this workshop explores how optimal body alignment and an increased awareness of cycles of activity and rest while playing may reduce the risk of playing-related pain and musculoskeletal disorders in pianists and, most importantly, lead to heightened musical freedom and expressivity. Using aural, kinesthetic, and visual cues through the use of biofeedback from the ProForma Vision sEMG system and the Nintendo Wii Balance Board, we demonstrate how the art of dynamic balancing can help us unlock our core sound and artistic potential in a healthful, vital way.

Keywords: piano; pedagogy; body; alignment; biomechanics

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Saturday
27 August 2011

Symposium:
Multimodal models of music performance

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When vocal training masks structure: Individual differences in visual aspects of sung interval size

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Vocal training typically emphasizes aspects of production that are important to pitch and voice quality such as vocal control and breathing. By contrast, visually available aspects of production tend to receive far less attention. Nonetheless, recent research suggests that visual aspects of performance are relevant to audience experience, influencing perception of emotion and structure. With regard to the latter, a linear relation has been demonstrated between the size of sung melodic intervals and the extent of head movement, eyebrow lifting, and mouth opening. Observers track these visually available aspects of song production, and they influence judgments of interval size in a manner that is pre-attentive and automatic. We wondered whether the emphasis on vocal control in classical training might somehow interfere with visual aspects of performance. We asked classically trained and competent amateur vocalists to produce ascending melodic intervals ranging in size from unison to octave. Participants were asked to make estimates of interval size based on observation of visual-only recordings. Accuracy of estimates was higher for intervals that were produced by the untrained group. This provocative finding may have implications for vocal pedagogy.

Keywords: singing; visual influences; motion tracking; audience experience; training

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Poor-pitch singing as an inverse model deficit: Imitation and estimation

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Research on the phenomenon of poor-pitch singing is puzzling in that most of the evidence to date has ruled out rather than supported possible sources of the deficit, including pitch perception ability, motor control, and memory capacity. I propose a new way to conceptualize deficits of singing rooted in motor control research. That is, poor-pitch singing may reflect a vocal-specific deficit of inverse modeling, the ability to plan motor gestures based on an intended output.

Keywords: singing; motor control; internal models; auditory feedback; tone deafness

Singing is a non-trivial motor task in which the performer has to imitate gestures that are usually unobservable. Although the majority of the population can imitate musical pitch when singing within a semitone, a small but important portion of the population (approximately 15%) consistently sings sharp or flat by more than a semitone (see Berkowska and Dalla Bella 2009 for a review). This deficit, which we term poor-pitch singing, is accompanied by a tendency to compress the size of pitch intervals in production (Pfordresher and Brown 2007) and a general lack of consistency (imprecision) in singing (Pfordresher *et al.* 2010).

Pfordresher and Brown (2007) tested three canonical models of poor-pitch singing, each based on a particular source for the deficit. None of these models appeared to account for the deficit. One prediction, that poor-pitch singing may reflect an underlying pitch perception deficit (literal "tone deafness"), was tested by comparing singing performance with performance on a pitch discrimination task. In general, poor-pitch singers did not differ from normal singers with respect to pitch discrimination ability, a finding that has been replicated elsewhere (Dalla Bella *et al.* 2007, Pfordresher and Brown 2009). A second canonical model was based on the assumption that poor-pitch singers are limited with respect to the range and precision with which they can vary the fundamental frequency of their voice, a motor deficit hypothesis. However, poor-pitch singers do not differ from normal singers with respect to spontaneous vocal range (Pfordresher and Brown 2007) or with respect to their ability to sustain a consistent pitch (Pfordresher and Mantell 2009), although their deficit does seem to be limited to vocal imitation of pitch (as opposed to reproducing pitch using a slider; Hutchins and Peretz in press). Finally, the notion that poor-pitch singing may reflect an underlying memory deficit was disconfirmed in that poor-pitch singers were in fact more accurate when singing melodies with a greater diversity of pitch information as opposed to monotone (single pitch) sequences.

As such three canonical models of poor-pitch singing—the perceptual deficit model, the motor deficit model, and the memory deficit model—do not account for individual differences in singing ability. As such my collaborators and I have turned to a new way of conceptualizing pitch imitation deficits in singing.

MAIN CONTRIBUTION

Based in part on the failures of the three canonical models described above, Pfordresher and Brown (2007) suggested that the source of singing deficits may lie in the conversion between perception and action that is necessary for vocal imitation of pitch. That is, poor-pitch singers may in general have no difficulty in perceiving and conceptualizing pitch information and may have no difficulty in controlling phonation as long as phonation is not intended to match a specific referent. However, when phonation has to match some predefined target (i.e. the participant is imitating), an additional step that involves translation from perception to action must occur, which is deficient in poor-pitch singers.

Internal models in motor control: Theoretical underpinnings

Recent research on motor control has adopted the notion from control theory that performers use *internal models* to control movements (see Kawato 1999 for a complete description). Internal models are based on anticipated input-output relationships within a system. Two basic sub-classes of internal models are *forward* and *inverse* models. Forward models are used to anticipate the perceptual outcome of an action. In so doing, the perceptual system compares the actual with anticipated outcome of an action to regulate the use of sensory feedback. Though forward models certainly play an important role in singing, it is unlikely that such feed-forward relationships between action and perception account for poor-pitch singing. A more likely source of the deficit is in the second class of internal models, the inverse model.

Inverse models are used to plan motor gestures based on the anticipated outcome of an action. With respect to singing, an inverse model would allow the singer to adjust the tension of his or her vocal folds in anticipation of the pitch that would result from these muscular settings. Importantly, this process can only work if the singer has fine-grained associations between motor gestures and outputs that can work in both feed-forward and inverse directions. We suggest that poor-pitch singers may lack such associations.

Application to poor-pitch singing

We suggest that a poor-pitch singer is unable to control the fundamental frequency of their voice in the service of matching a specific output, though they may be able to control their voice in other circumstances and may even be able to appropriately gauge whether their own produced pitch appropriately matches what they hear (e.g. if auditory feedback is altered).

In one sense, this account is associationist, in that a deficient internal model might result from poorly formed associations between perception and action. However, an important constraint is that the deficit is unidirectional, with singers being unable to plan actions based on anticipated outputs while being able to predict outputs based on their produced actions. Moreover, it is not a foregone conclusion that such a deficit, should it exist, is rooted in learned associations as opposed to one's genotype, given evidence that music-specific deficits can be highly heritable (Peretz *et al.* 2007).

The hypothesis that poor-pitch singing is an inverse model deficit leads to three critical predictions. First, and most obvious, it predicts that singing deficits should appear only during imitative tasks and may not appear during non-imitative perceptual, motor, or even sensorimotor tasks. Second, the imitative deficit of poor-pitch singing need not be music-specific, though it may be a vocal-specific deficit. Third, singing-related deficits may be enhanced in situations where perception/action associations are less well formed but may be reduced when perception/action associations are better formed.

Relationship to Pfordresher and Brown (2007)

An earlier version of this hypothesis was introduced by Pfordresher and Brown (2007), referred to there as the "mis-translation" deficit. That is, perceptual pitch events are associated with inappropriate motor events. This model, though related to the one proposed here, is different in that it suggests a more constrained deficit. Specifically, the notion of "translation" suggests that pitch event *X* will be mapped onto motor gesture *X′* under all circumstances. This prediction is parsimonious and it accounts for the fact that singers are often consistently sharp or flat across repeated productions (Pfordresher and Brown 2007). However, this account has difficulty with other results, even those found in the paper in which the hypothesis was proposed. Specifically, it is difficult to reconcile the mis-translation hypothesis with compression of pitch intervals (Dalla Bella *et al.* 2009, Pfordresher and Brown 2007), with the fact that singing out of tune often is accompanied by imprecision (Pfordresher *et al.* 2010) and with the fact that patterns of sharp versus flat singing are mediated by the relationship between the imitated pitch and the pitch an individual finds most comfortable to sing (Pfordresher and Brown 2007).

In light of these weaknesses, the current hypothesis offers a prediction that is more flexible with respect to the specific outcomes of the system, yet still constrained with respect to the conditions under which deficient singing should be found. I now consider what existing empirical support there is for the current hypothesis and consider avenues for future research.

Empirical support

Recent research has offered support for the three critical predictions listed above. Prediction one is based on negative evidence, absence of deficits in non-imitative tasks. Evidence that poor-pitch singers are not deficit in non-imitative motor tasks was described earlier. More recently, my lab has investigated the effect of alterations to auditory feedback during singing, in samples that include both normal and poor-pitch singers. We found that the relationship between mistuning in singing and the disruptive effect of alterations to feedback pitch was negligible ($r^2=0.01$).

The second two participants are more amenable to empirical testing in that they are based on positive effects. With respect to the prediction that poor-pitch singers have a deficit of vocal imitation that is not necessarily music specific, we have found that poor-pitch singers show strikingly similar deficits when imitating intonational pitch in speech (Pfordresher and Mantell 2009).

In order to address to the third prediction (reduced deficit when associations are better formed), my lab has recently run a series of studies examining vocal imitation of one's own performances versus those of others. The inverse model deficit hypothesis suggests that poor-pitch singers may be better able to imitate their own performances than those of others, based on having greater familiarity with their own vocalizations. Preliminary results verify this prediction. Interestingly the advantage to imitating one's own performances persists even when recordings are transformed to be a complex tone lacking vocal timbre. Thus, the benefit of self-imitation is not entirely due to timbre matching or to voice-specific recognition cues.

IMPLICATIONS

The study of poor-pitch singing from a cognitive perspective is very recent (the tradition in music education dates back much further, cf. Welch 1979) and holds great promise. In keeping with this perspective, I argue that one's singing ability is not simply a manifestation of music-specific talents, practice, or aesthetic sensibility, though unquestionably singing is influenced by all these things. My point is that singing, as a complex motor task, to a large degree reflects the demands of motor control, memory, perception, and sensorimotor integration that are common to a wide range of abilities. Thus a starting point to understanding poor pitch singing involves addressing whether the deficit lies in any of these basic, domain-general functions.

As stated before, the inverse model deficit hypothesis in its current form makes predictions about the conditions in which poor-pitch singing will be observed but does not commit to specific patterns of behavior. Future research will be aimed at this latter goal. Specifically, we suspect that manifested behaviors reflect attempts to *estimate* the outcome of one's motor gestures, based on an unreliable internal model, a prediction that is consistent with results suggesting that poor-pitch singers are imprecise in their production (Pfordresher *et al.* 2010).

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Facial expressions in vocal performance: Visual communication of emotion

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This study investigated observers' emotional responses to facial expressions during song and speech. Silent presentations of facial expressions from neutral, happy, and sad song and speech productions were divided into three regions: prior to vocal onset, during vocal production, and following vocal offset. Observers were highly accurate and confident at identifying emotion during and following vocal production, but were less accurate for the region prior to vocal onset. Emotionally neutral presentations were identified less accurately and confidently than happy and sad presentations in all regions. Producers are known to exhibit decreased facial movement prior to vocal onset and for emotionally neutral utterances. These findings indicate that facial expressions may be important for the perception of emotion during vocal communication.

Keywords: facial expressions; emotion; perception; singing; speech

Facial expressions are integral components of non-verbal emotional communication and have been widely studied in a static posed context (Russell *et al.* 2003). However, normal conversation contains a variety of expressions that are rarely, if ever, static. Recent work (Livingstone *et al.* 2009) found that singers encode emotion using distinct facial movements that changed over the time-course of vocal production. Facial movements during vocalization differed from those prior to and following vocal production. It is unknown if these dynamic facial movements facilitate observers' perception of emotion.

We investigated observers' emotional responses to silent video recordings of facial expressions accompanying song and speech. Recordings were divided into three regions: prior to vocal onset (pre-production), during vocalization (production), and following vocal offset (post-production). Two measures of response were analyzed: chosen emotion and response confidence. It was hypothesized that pre-production would be identified less accurately and less confidently, as this region typically contained significantly smaller facial movements (Livingstone *et al.* 2009). It was also hypothesized that production and post-production regions would be identified with similar accuracy and confidence, as both regions typically contained significant facial movements (Livingstone *et al.* 2009).

METHOD

Participants

Sixteen native English speaking adults (12 female), ranging in age from 18 to 37 years (mean=22.40, SD=4.47), were recruited from the Montreal area. Participants had received varied amounts of private music instruction (mean=4.81 years, range=0-12) and singing experience (mean=1.75 years, range=0-14). Two highly-trained female singers (model targets), with at least 9 years of vocal experience (first=10 years; second=9), were recruited from McGill University.

Materials and design

Singers were recorded (JVC Everio GZ-HD6 camera, AKG C 414 B-XLS microphone) while speaking or singing three neutral statements with one of three emotional intentions: neutral, very happy, or very sad. Statements were sung to a 0.3 ms inter-onset-interval (IOI) isochronous melody (F4, F4, G4, G4, E4, E4, F4). Recordings were divided into three vocal regions: pre-production (1.90 s prior to vocal-onset), production (vocal-onset to vocal-offset, mean duration=2.05 s; speech mean=1.62 s, song mean=2.48 s), and post-production (1.90 s after vocal-offset). Vocal regions were marked using Praat (Boersma and Weenink 2009), and recordings were edited using Adobe Premiere Elements. Video-only presentations (no audio) were presented to participants using E-Prime software. The within-subjects design contained 108 trials (2 vocalists x 2 production (speech/song) x 3 statements x 3 emotions x 3 regions).

Procedure and analyses

Participants were asked to rate the emotion of the performer using a 5-point bipolar scale (1=very sad, 2=sad, 3=neutral, 4=happy, 5=very happy), and their confidence of that judgment (1=very unsure, 2=unsure, 3=neutral, 4=sure, 5=very sure). Trials were blocked and counterbalanced by production, vocalist, and region (production region first), and randomized across statement and emotion. Emotion ratings were recoded for proportion correct responses (Sad=1, 2; Neutral=3; Happy=4, 5). Analyses were combined across vocalist and statement.

RESULTS

Viewers' mean accuracy is shown in Figure 1. The overall mean proportion correct scores was 0.93, which was significantly greater than chance values of 0.4 for happy and sad and 0.2 for neutral [$F_{1,15}$=7522.09, $p<0.001$]. A three-way repeated measures analysis of variance (ANOVA) revealed a significant main effect of emotion ($F_{2,30}$=9.45, p=0.001). Post-hoc comparisons (Tukey's HSD=0.07, α=0.05) confirmed that participants were less accurate for neutral (mean=0.87) than for happy (mean=0.98) and sad (mean=0.95). There was also a significant interaction of production with emotion ($F_{2,30}$=5.34, p=0.01) and of Production x Emotion x Region ($F_{4,60}$=3.09, p=0.022). Accuracy for speech-sad-pre-production (see Figure 1) appeared to be lower than other sad regions, suggesting a role in the 3-way interaction. Post-hoc comparisons (Tukey's HSD=0.13, α=0.05) confirmed that speech-sad-pre-production was less accurate than song-sad-pre-production, speech/song-sad-productions and speech/song-sad-post-productions.

As ratings for the production region were not originally hypothesized to be significantly different from post-production, a similar three-way repeated measures ANOVA was conducted, combining production and post-production regions. A significant main effect of region was reported ($F_{1,15}$=5.55, p=0.033), in which pre-production (mean=0.90) was significantly less accurate than prod-post-production (mean=0.94). There was also a main effect of emotion ($F_{2,30}$=6.93, p=0.003). A significant interaction of production with emotion was reported ($F_{2,30}$=7.52, p=0.002) as was emotion x region ($F_{2,30}$=4.28, p=0.023).

To confirm that ratings for production did not differ from post-production, a similar three-way repeated measures ANOVA was conducted, comparing only production with post-production (pre-production removed). No effect of region was reported. These results confirm that production and post-production regions had similar accuracies and were more accurate than pre-production.

Mean confidence ratings are shown in Figure 2. The overall mean confidence across conditions was 4.10/5 (82%). A three-way ANOVA revealed a significant main effect of emotion ($F_{2,30}$=14.05, $p<0.001$). Post-hoc compare-

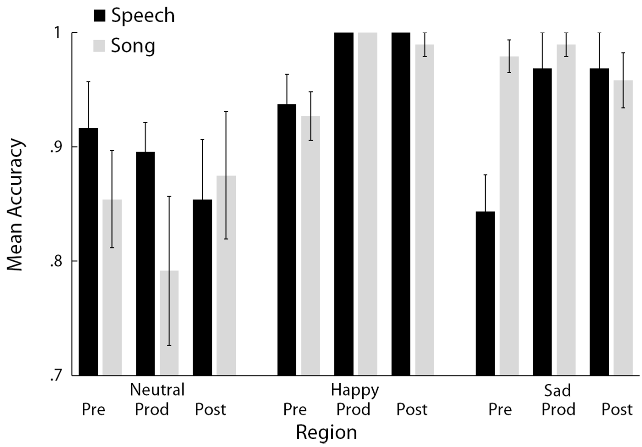

Figure 1. Mean proportion correct scores. Error bars denote the standard error of the means.

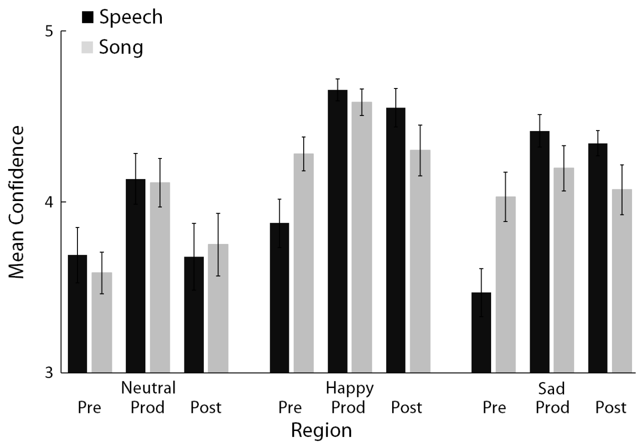

Figure 2. Mean confidence scores. Error bars denote the standard error of the means.

sons on emotion (Tukey's HSD=0.26, α=0.05) confirmed that participants were less confident for neutral (mean=3.83) than for sad (mean=4.09) and happy (mean=4.38), and less confident for sad than for happy. There was also a main effect of region ($F_{2,30}$=39.88, $p<0.001$); post-hoc comparisons on region (Tukey's HSD=0.18, α=0.05) confirmed that participants were less confident for pre-production (mean=3.82) than for post-production (mean=4.12) and production (mean=4.35), and less confident for post-production than for production. There was also a significant interaction of production with region ($F_{2,30}$=14.00, p<0.001) and production x emotion x region ($F_{4,60}$=5.31, p=0.001).

Confidence for speech-sad-pre-production (see Figure 2) appeared to be lower than other sad regions, suggesting a role in the 3-way interaction. Post-hoc comparisons (Tukey's HSD=0.46, α=0.05) confirmed that speech-sad-pre-production was less confident than song-sad-pre-production, speech/song-sad-productions, and speech/song-sad-post-productions. Confidence for speech-happy-pre-production also appeared to be lower than other happy regions. Post-hoc comparisons confirmed that speech-happy-pre-production was less confident than speech/song-happy-productions and speech-happy-post-production. Similarly, song-neutral-pre-production was less confident than speech/song-neutral-productions. These results suggest that participants were consistently less confident in their evaluation of pre-production than production and post-production regions.

Participants' accuracy and confidence results suggested a relationship between the measures. A Spearman's rank correlation between mean accuracy and confidence responses was significant (r=0.80, p<0.01), indicating that when participants were more accurate they were also more confident.

DISCUSSION

Observers' emotional responses to facial expressions during speech and song were highly accurate. These results were achieved in the absence of auditory information, suggesting that facial expressions may play an important role in the perception of emotion before, during, and after vocal communication.

Observers were also accurate and confident at identifying emotions from facial expressions that occurred after the offset of vocal production. This suggests that speakers and singers continue to sustain facial expressions long after vocal production has ended and that this behavior accurately conveys emotional information (Livingstone *et al.* 2009). Observers were significantly less accurate and less confident at identifying emotions prior to the onset of vocal production, supporting the initial hypothesis. This hypothesis stemmed from previous work which reported that pre-production exhibited significantly smaller facial movements than production and post-production (Livingstone *et al.* 2009). Emotionally neutral presentations were identified less accurately and less confidently than either happy or sad recordings. It is thought that the decreased facial movements exhibited by neutral vocal productions (Livingstone *et al.* 2009) elicited these results. One potential weakness of the study was that accuracy ratings were all close to ceiling for the facial expressions used in the study. Future work will address this concern.

This research demonstrates that facial expressions that accompany speech and song may facilitate the perception of emotion and, in the absence of sound, are sufficient for robust emotional communication.

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Sensorimotor integration in solo and duet performance

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Performing ensemble musicians must isolate and integrate the auditory consequences of their actions with those of others. We compare solo and duet piano performance in terms of the influences of structural relationships between musical parts and individual differences between ensemble performers. The same pianists performed novel two-part musical compositions that varied in the structural complexity of the rhythmic and harmonic relationships between the parts, in both solo and duet performance conditions. The structure of the left-hand part was designed to be "simple" or "complex" in its melodic contour and in the required hand and finger movements, while the right-hand melody remained the same. Tempo and synchronization measures between parts indicated that duet performance reflected adjustments by both performers while retaining some influence of their individual tempo preferences. The difficulty of the structurally complex part resulted in a slower performance tempo, in both duet performance and in solo performance. The timing of each part showed adaptation by each performer to tempo changes in the other performer's part. These findings suggest a closed-loop model of successful ensemble performance in which motor actions result from a combination of planning for anticipated outcomes, combined with fast adaptation to sensory events produced by others.

Keywords: ensemble performance; sensory feedback; sensorimotor integration; synchronization; duet performance

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Visual and auditory cues in jazz musicians' ensemble performance

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When musicians perform together live in the same physical space, they rely on a range of auditory and visual cues in order to coordinate as an ensemble. The available cues vary depending on the instruments and musical genre (and thus the motoric and auditory information each performer displays) and the physical arrangement of the performers. For example, different sightlines of the other performers affect the extent to which those performers' bodily and gaze signals—as well as movements that provide useful information even if they are not intended communicatively—are available to aid coordination. Despite musicians' lore, little work has empirically investigated the extensive multimodal integration required to coordinate in an ensemble. The aim of this paper is to lay out a basis for empirically studying ensemble coordination, by outlining the known and proposed visual, auditory, and motoric cues that performers display (as intentional signals or not) and that can be used by ensemble partners for coordinating. Along the way, illustrative results of analyses of our corpus of performances of the same piece by 30 pairs of jazz pianists and saxophonists in three modes (face to face, via remote video, and via remote audio) are used to demonstrate the utility of this scheme. The paper's main contribution is to demonstrate that musicians' use of coordination cues is more complex and multifaceted than one might at first think. Musicians in ensembles are faced with multiple competing cognitive demands for planning and executing their own performances while monitoring their partners; our evidence suggests that different cues are useful at different moments during a musical piece. So, for example, visual information from one's partner does not appear to be particularly useful during an ongoing rhythm, and can even be distracting and harmful for a saxophonist during an improvised solo, but it is enormously useful for successfully producing a simultaneous attack that is not during an ongoing rhythm. Different musicians also appear to vary substantially in their reported and demonstrable need for visual cues and physical co-presence, suggesting that more complex models that include individual variability in cue use are likely to be needed. A more solid empirical basis for understanding how musicians of different performance skills and proclivities, in different genres and ensemble sizes and physical arrangements, will allow a fuller science of musical coordination, as well as a deeper understanding of how musicians integrate multimodal information—their own and their ensemble partners'—in performance. Understanding which cues are useful for which kinds of coordination can potentially inform pedagogy for musical collaboration.

Keywords: ensemble; coordination; visual cues; auditory cues; multimodal integration

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Two comparative case studies of facial gesture and bodily expression in contemporary interpretations of *Liebestraum* by Franz Liszt

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This paper investigates how facial expressions/gestures map against structural features and/or narrative and non-narrative meaning in music being performed and how these relate to overall bodily movements. Recordings of live performances of Liszt's piano *Nocturne No. 3 in A-flat Major* by Lang Lang and Evgeny Kissin provide the data for analysis. Comparative analyses reveal: (1) a high degree of congruence in the overall style and content of overall expressive body movements (e.g. body sway) and facial expressions (e.g. smiling with eyes closed and eyebrows raised); (2) very different bodily and facial expressions employed by each performer; (3) specifically identifiable gestures manifest and intensified at moments of musical structural significance (e.g. climatic cadence points) and high consistency in the locations of gestures between performers; (4) facial gestures that can be mapped against existing classifications (e.g. Ekman). In Kissin's case, many of the gestures employed simultaneously generate/reflect physical tensions (e.g. held breath). For Lang Lang, explicit erotic imagery is contained in facial and physical expressions (e.g. open mouth, head thrown back, surging swaying movement). The expressions generated have a communicative association with the title's "Dream of love," the gestures communicating explicit images of passion and eroticism in an individualized manner.

Keywords: facial gesture; body movement; expression; performance; emotion

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Thematic session:
The science of piano playing

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Protecting the pianist's hand: The *carrezando* touch and more

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There is a high incidence of non-structural musculoskeletal problems and pain among pianists. This is not surprising, since pianists in general focus on developing their finger strength and independence, one from another, by adopting high, moderate, or small tapping movements of the fingers to depress the note to the key bed. The fingers are subjected to an enormous number of repetitions in this way throughout the lifetime of the pianist, who often fails to give due consideration to the function of the hand. There is an alternative approach to the development of the hand which may be traced back to J. S. Bach and includes advocates such as Deppe and Chopin, but since then has been largely forgotten. It is called the *carrezando,* or caressing, touch. This is the natural prehensile function of the hand and maybe performed by individual or groups of fingers and the opposable thumb, as in scales or chord playing. In this article, I discuss the efficacy of developing such an approach over the more traditional finger training.

Keywords: piano performance; carrezando touch; prehension; friction; transverse arch

I will begin by briefly summarizing how the *carrezando*, or prehensile function of the hand is perceived by a few practitioners in historical accounts from 1650-1930, before looking at a study by Ghez *et al.* (1996) into the kinematics factors in prehension movements in felines. Their research is invaluable, but it accounts only for part of the prehensile movement in piano performance, which must consist of "friction" and "release" to complete the cycle. Thus, I will look at research into the function of friction (Salisbury and Craig 1982), while the "touch-down" and "lift-off" (Raibert 1988) of the foot in running may provide further insights into this complex issue.

MAIN CONTRIBUTION

Historical background: The carrezando touch

The aim of the *carrezando,* or caressing, touch is to produce a singing quality of sound or *bel canto,* a technique which was extolled by the Italian vocal school in the 1830s. This caressing or "grasping" movement of the hand is in direct contrast to the percussive sound produced by striking the keys with a perpendicular movement of the fingers in the traditional way. Forkel (1749-1818) gives what may be the first account of the *carrezando* or grasping movement. He writes that Bach (1685-1750) bent his five fingers "so that their points come in a straight line [and the finger is] not raised perpendicularly from the key [in the traditional way], but that it glides off the forepart of the key, by gradually drawing back the tip of the finger towards the palm of the hand" (David and Mendel 1966, pp.307-308). This was the beginning of a mode of practice which did not emerge again until the nineteenth century in the teaching of a few such as Kontski, Marx, Deppe, and Chopin.

Kontski advises that to caress the keys the performer should hold the wrist in a low position while the pad of the finger slides from the middle of the key to its edge "in a delicate manner" (1851, pp. 15-17). Czartoryska, a student of Chopin, describes his hands as "often seeming to caress the keys" (Eigeldinger 1986, p. 30). Others, like Adolph Marx (1795-1866) writes that: "the key must be felt, not pushed or struck, it must be seized with feeling as one presses a friend's hand only with sympathy" (Kullak 1893, p. 85). Ludwig Deppe (1828-1890), a pupil of Marx, advises that playing a scale, should be like "gathering the hand into a nut shell" (Fay 1979, p. 300), while the American pianist William Mason (1897) says that the cushion of the finger may make a clinging contact with the key so that "players will have the sensation that they are pulling the key toward them" (p. 9). Thomas Fielden (1927) and Maria Levinskaya (1930) go further and attempt to describe the anatomical structure and muscles of the forearm/hand which are engaged in the caressing movement. Since then, the efforts of these pioneers has been largely forgotten and the traditional approach to finger training still persists.

As we have seen in these brief historical accounts, the focus is largely on the caressing action of the hand. It was not understood that caressing or grasping with the hand, as I have pointed out, is only part of the movement cycle. To gain a broader view I shall draw upon research in other fields such as kinematics, neurophysiology, and robotics, which has established some important factors engaged in the organization of prehension movements.

Kinematics in the coordination of prehension movements

In 1996, Ghez *et al.* (1996) undertook a study which examined the organization of prehension in the feline, "an animal with natural speed and great skill in catching its prey with its paws" (p. 189). The aim was to establish, among other issues, a kinematic analysis of a feline "reach to grasp" movement. Since their experiment is a complex one, I will simplify those findings which bear directly on prehension in piano performance.

The feline was trained to retrieve a small piece of meat by extending its paw into a narrow food well which was positioned in front of it. The head and body of the feline was restrained in a hammock to avoid the need to evaluate any other movements of its body except the shoulder complex, the forearm, and paw. Retroreflective markers were attached to the glenohumeral (shoulder) joint, the metacarpophalangeal joint (the knuckle), the wrist, and skin paw tip. From the kinematic quantitative analysis they were able to compute the feline's movements during prehension. This enabled them to identify the "elementary components", which they say are similar to primate prehension. For example, the scapula of the feline first retracted, or extended to "linearize" the paw path during the lift, and then protracted, or flexed the scapula to increase the elbow extension during the thrust (p. 193). Where the feline failed to retract the shoulder during the initial lift there were marked "systematic end point errors" (p. 193), a point to which I shall return. They observed also that the wrist speed of the feline has the bell-shaped tangential velocity profile typical of humans performing similar movements of the shoulder complex and the forearm/hand. Furthermore, the feline adapted the "angulation of distal joints to the changes in orientation of the target" (p. 190), a response which they say is similar to hand pre-shaping in humans. They infer too, that the overall tempo of the movement components of the feline are determined by the nervous system "quite early as it establishes the movement plan" (p. 203).

Their research reveals several useful parallels with piano performance. First, as the feline lifts its upper limb, the shoulder blade retracts to stabilize the movement. Stabilizing the shoulder blade of the performer during the lifting of the humerus is prerequisite to grasping the keys with accuracy. Second, the prehension movement of the feline is fluid—i.e. there is no hesitation before the grasp takes place which would impact unfavorably on the control of the joint dynamics; this would equally be the case in piano performance. Third, it took the feline several days to learn to adapt their wrist angle to the inclination of the food well. In piano performance determining the "target distance" to the keyboard and the "location" of the notes is critical in the planning of the kinematic reach. Without this, "profound trajectory disturbances and errors in aimed hand movements" (p. 188) which they noted in the feline, may result. In piano performance this requires, like the feline, time, planning, concentration, and repetitive practice.

Friction

However, the approach by Ghez *et al.* (1996) forms only part of the movement cycle in prehension. Indeed, Salisbury and Craig (1982) say research such as this is the "classic kinematic approach" (p. 408)—i.e. it considers contact without friction. In reality they say that frictional forces must be present in common prehension movements and that "without friction, most manipulator end effectors would be unable to grasp a common object." They describe this as a "closed-loop kinematic chain" (p. 407).

In piano performance there is no precedent for what happens as the grasping action of the hand makes contact with the key bed. However, inference may be drawn from research into balance and symmetry in running by Raibert (1988). He concurs with Salisbury and Craig's view that friction is an integral part of the process of prehension, which in the case of running prevents the foot from sliding. Furthermore, he says that friction provides a point of support in the foot which he describes as the "touch down" (p. 490). The parallel in piano performance is that during touch down the friction of the finger pads impact against the key bed causing the control architecture—i.e. the intrinsic muscles of the hand (the palmer and dorsal interosseous and the lumbrical muscles) to brace and support the transverse arch at the metacarpal (knuckle) head.

The release

In piano performance, the movement cycle is not completed until the bracing of the transverse arch of the hand is released by the dorsal muscles in the back of the hand. A description of the release or "lift off" (Raibert 1988) of the supporting leg is as follows:

> During support the foot remains stationary and the leg exerts a combination of vertical and horizontal forces on the body. Because the legs are springy, the body's vertical motion is an elastic rebound that returns the system to the flight phase after each collision with the ground (p. 490).

In piano performance we may draw a parallel with the release or "lift off" of the arm with that of the release of the supporting leg. Like the leg, the braced hand remains stationary, and like the leg, the arm is “springy” also, and with the release of the agonist muscles which support the hand in the brace position, the next movement cycle maybe initiated once again.

Conclusion

Like felines, human limbs are comprised of relatively straight segments, and during the transport of the upper arm, the performer is able to pre-shape the hand to the contours of the music before reaching the keyboard. While this may provide a welcome reduction in trajectory disturbances and errors in hand-aimed movements in piano performance, it is only part of the movement cycle. To complete the movement cycle I suggest, on the evidence provided by Raibert (1988) that the performer may develop the feeling of friction with the pads of individual fingers or groups of fingers and the thumb as in chords, as the hand impacts against the key bed and allows the transverse arch to brace until a release is required for the next prehension movement.

IMPLICATIONS

Future research may consider ways of developing strategies which will help the pianist to optimise the use of all the muscles groups engaged in piano performance so that eventually with the correct muscular use they will be able to produce the correct force, direction, and timing.

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Exploring real-time sonic adjustments in the performance of notated music: Morton Feldman, space acoustics, and the variable timbres of piano sound

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In an essay titled "Coping with pianos," Alfred Brendel assures us that "anyone who has ever travelled with a piano knows that the same [instrument] not only sounds different in different halls, it even seems to feel different in its mechanism…" (p. 336) Even more strikingly, this difference in the feel of the instrument manifests itself in the same space and on the same day between the afternoon rehearsal and the evening performance. On Brendel's account, the acoustic difference the presence of an audience makes figures into the performance experience of the pianist in significant ways, impacting even the experience of an intimately familiar instrument. The present research focuses on the role of listening in acts of performance, aiming to open to investigation the ways that pianists may adjust their actions in performance in order to obtain a desired sort of sound under particular acoustic circumstances. It further aims to complicate the idea of timbre in piano performance, seeking to move away from a conception of timbre as an aspect of sound given solely by the instrument and move towards a conception of timbre as a given range of possibilities available to the pianist.

Keywords: piano performance; timbre; spectral analysis; acoustic conditions; Morton Feldman

Performers are continually faced with different performing situations. Typically variable factors of performing situations include space acoustics, the presence and size of an audience, as well as the particularities of different instruments, when these are provided by the performance space. On an artistic level of performance, these variable conditions have to be taken into account by the performer(s), as they significantly impact the overall sound of the performance. Taking such variability into account may well mean incorporating minute but important real-time adjustments into the execution of a performance, even when the performance is of a fully notated score, as is the case with the overwhelming majority of music of the classical repertoire. Although the performance of classical music is not typically associated with acts of improvisation, achieving a desired sort of sound in the conditions of a particular performance situation may well require actions that could not have been fully worked out in rehearsal. When focusing on this dimension of a performance act, a certain degree of improvisatory adjustability may be a routinely present characteristic of a classical music performance.

The present research is part of a larger program which focuses on timbral (coloristic) aspects of classical music piano performance. Timbral (coloristic) aspects of piano performance are considered in line with Augoyard and Torgue's (2006) definition of "sonic effects" (see pp. 3-18) as phenomena which incorporate both "physical and human dimensions of sound" (p. 11). The long-term aims of the research are (1) to describe and document ranges of variability in the timbral profiles of comparable points in the performance of notated piano works and (2) to solicit and analyze introspective accounts by performers focusing specifically on experiences of sound during performance. The coupled approach of this research program aims to contribute to understanding the ways in which physical and human dimensions of sound interact in experiences of artistic music performance.

MAIN CONTRIBUTION

Experimental design

The current study is being conducted at the Computer Music Center at Columbia University. The studio used for the study is equipped with an eight speaker surround sound system. Using a Max/MSP patch and Matrix reverb software, the sound generated by an acoustic Yamaha grand piano is being subtly enhanced and played back into the room in real-time. The amount and type of reverb is controlled through the patch. The effect is a slightly altered overall sound, which the pianist hears as s/he performs in the studio.

Particularly important for the purposes of this study is that any enhancement to the sound in the studio be kept to a barely perceptible level. The type of reverb and the volume of the output sent through the speakers are kept so that the overall change in the sound of the room remains subtle throughout.

Pianists are asked to prepare for performance part of Morton Feldman's *Last Pieces*. They are asked to perform the same excerpt three times in the studio, taking as much or as little time as they wish between the three performances. The amount and type of reverb varies subtly between performances but is consistent throughout each performance. After the recording session, pianists are asked several open-ended questions about their experience in the studio.

For the purposes of this study, it is important that the sounds being analyzed be part of musical performances. It is the musical context of these sounds that allows for the criteria of musical appropriateness of a particular sound to be considered. A performer's sense of what sound is suitable ("works") for the performance of a given piece of music is a focal point for this study. As a performer's sense of how well a given sound works musically is tied to the performer's relationship with the piece of music s/he is performing, the choice of repertoire for this study is important. The considerations which led to the choice of Feldman's *Last Pieces* were technical feasibility and likelihood that performers have explicit observations about listening in performance.

Preliminary data

At this stage, two pilot studies have been completed. One focuses on timbral variability by comparing timbral profiles of the first chord of *Last Pieces* played under identical studio conditions. The other focuses on the interview responses of one participating performer, New York City-based pianist Amir Khosrowpour.

Comparing timbral profiles

Comparison of the trimbral profiles of corresponding points in several recordings of *Last Pieces* recorded under identical conditions suggests that sonorities of identical timbral characteristics are extremely unlikely to occur in piano performance. Although the pitch content is identical across all recorded performances and dynamics levels are very similar for the excerpts selected for comparison, the presence, strength, and mix of partials varies for corresponding sonorities in each recording. On careful listening, the variations in spectral characteristics can be appreciated as variations in the sound heard.

Handling the instrument

In talking about performing the Feldman pieces, pianist Amir Khosrowpour continually referred to how well a particular sound "worked." During the in-

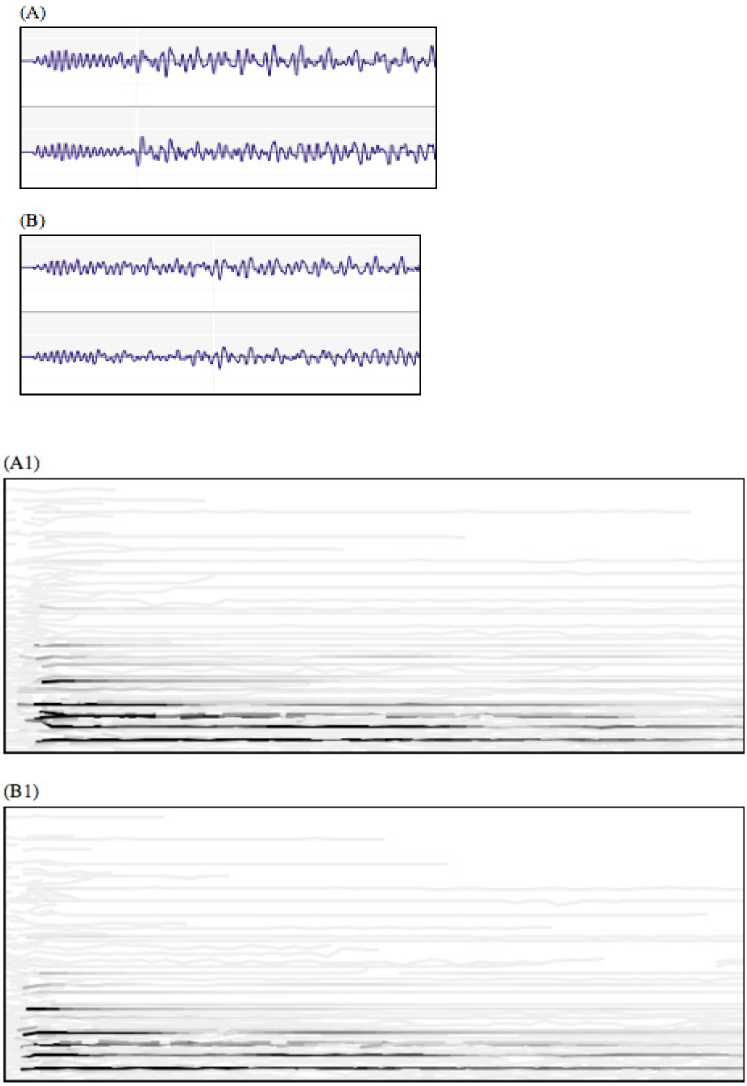

Figure 1. Graphic images comparing the sound of the first chord in two performances of Morton Feldman's *Last Pieces*. Even for chords chosen for maximal similarity in voicing (relative dynamic level between the notes comprising the chord) and overall dynamic level, both the sine wave representation (A and B) and the spectral profile representation (A1 and B1) show detectable differences.

terview after the studio session, Khosrowpour recalled several instances of being more or less happy with points in each of the three performances we recorded. He particularly recalled that during one of the three performances, things kept going wrong in a particular way: "…I kept playing louder than I wanted to"; "the outer [pitches of a chord] was always a little startling, it didn't work"; "the attacks were stronger…than I expected." During this particular performance, the enhanced sound played back through the speakers, although kept to a very low volume level, was simulating the acoustics of a large, reverberant space. Although nothing about the instrument had changed, obtaining a sound that "worked" (in this case a sound that was softer and not startling) became more difficult in comparison to the other performances.

Khosrowpour talked of the sounds that "didn't work" in terms of his own actions at the instrument. From his practical perspective, the change in room acoustics was experienced in terms of these actions. As the performer, he did not control the acoustic conditions of the performing situation, but he did expect himself to be able to handle the instrument in such a way as to obtain sounds that "work." Implied in his remarks is the observation that with the change in acoustic conditions, the actions which would obtain a sound that works would have to change as well.

IMPLICATIONS

At this stage, it is premature to generalize on the implications of this project. It was designed, however, with two broader aims in mind. First, a considerable body of research exploring sound quality in piano performance exists in physics and related fields. Often with a focus on instrument design, such research offers a wealth of information on piano sound in terms of the dynamics between the action mechanism, string vibrations, and soundboard behavior (Vyasarayani *et al.* 2009, Guillaume 2006). Sound quality in music performance, however, is a phenomenon with subjective perceptual dimensions as well as physical ones. The current study aims to explore interactions between these different dimensions. Second, another relevant and exciting body of research exists focusing on experience-dependent, enhanced linkages between auditory and sensorimotor function for skilled musicians (Lenay *et al.* 2003, Zatorre *et al.* 2007). A preliminary hypothesis behind the current study is that skilled pianists come to "feel" the sound through the keyboard and pedals. Obtaining a desired sound in different performance conditions likely entails adjustments in the keystroke and use of the pedals which are affected *as* a sound is being made. Such adjustments suppose an acquired, instrument-specific ability which relies concurrently on auditory and haptic cues.

Acknowledgments

Heartfelt gratitude to Brad Garton, Director of the Computer Music Center at Columbia University, whose support was instrumental in the development of this project. Thanks also to Sampo Haapamaki for musical insight and technical know-how, to Bryan Jacobs for valuable technical assistance in the studio, and to Amir Khosrowpour for thoughtful and enthusiastic participation.

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Thematic session: Performance anxiety

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Electrophysiological markers and pianists' anxiety: A preliminary study

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Subjective measures of music performance anxiety have been commonly applied to assess the impact of relaxation techniques and cognitive behavioural therapy as coping strategies. This pilot study attempts to assess the impact of a stress-management programme (SMP) in the management of performance anxiety levels of piano students playing at public concerts. A descriptive longitudinal controlled study was carried out comparing two groups of music students: pianists who undertook 10 sessions of SMP (the experimental group); music students who did not undergo these sessions (the control group, with 1 guitarist and 1 singer). For both groups, subjective and objective measures of assessment were carried out. A self-report questionnaire and measures of brain activity and physiological arousal—electroencephalogram (EEG) and electrodermal activity (EDA), respectively—were undertaken 30 minutes before public performance. This was done twice for both groups: before the SMP (baseline) and 12 weeks after. Results suggest mild effects of SMP on objective measures. Inconclusive results regarding subjective measures suggest the necessity for developing future protocols applying both subjective and objective measures of music performance anxiety on larger-sized sample groups.

Keywords: cognitive behavioural training; EEG; performance anxiety; coping strategies; performance optimization strategies

Maladaptive music performance anxiety (M-MPA)—i.e. elevated stage-related arousal that impairs music performance (Lehmann *et al.* 2007)—has been reported as one of the most debilitating problems for musicians. Previous studies suggest that half of all instrumentalists may be negatively affected to some extent (Lehmann *et al.* 2007). Several coping strategies have been advised to musicians: (1) behavioral therapy, (2) hypnotherapy, (3) Alexander technique, (4) behavioral strategies, and (5) cognitive behavioral therapy. Biofeedback using self-regulation of brain activity through electroencephalogram (EEG), also called neurofeedback, has been found to be another efficient strategy. Decreased anxiety levels were observed for anxiety-prone students using alpha neurofeedback training (Hardt and Kamiya 1978) and significant enhancement of performance skills were found associated with alpha/theta neurofeedback (Egner and Gruzelier 2004). However, the precise nature of the alpha/theta neurofeedback has not been completely understood, and effects have not yet been related to relaxation techniques nor to monitoring of pre-performance anxiety (Gruzelier and Egner 2004). This pilot study attempts to assess the impact of a stress-management program (SMP) on piano students, combining both subjective and objective measures of M-MPA.

METHOD

Participants

Portuguese university students were involved in this longitudinal descriptive study: second year piano students that undertook 10 consecutive sessions of SMP (the experimental group, n=4), and a matched group of students who did not participate in SMP (the control group, n=2 pianists: 1 guitarist and 1 singer). All were healthy volunteers, with age ranges between 18 and 26 years. A consent form was previously signed after participants have been informed about the experimental procedures.

Materials

Portuguese validated version of the Spielberger State-Trait Anxiety Inventory (Silva and Campos 1999) was applied to assess both state (STAI Y1) and trait (STAI Y2) anxiety. Both scales include 20 items, each using a 4-point Likert-type scale, running from 20 (low anxiety) to 80 points (high anxiety).

EEG and tonic electrodermal activity (EDA) were selected as psychophysiological measures. Anxiety levels and music performance quality have been successfully monitored through brain activity (Egner and Gruzelier 2004), and individual arousal levels through EDA (Dawson *et al.* 2000). Both EEG and tonic EDA were acquired through a computerized data-acquisition system (MP100, Biopac Systems Inc.) connected to a laptop computer. All recorded data were shown online on the monitor and simultaneously stored in the hard disk using the software AcqKnowledge 3.9 (Biopac Systems).

Procedure

STAI Y1 and Y2 were filled in by each participant prior to psychophysiological data collection. EEG was recorded from 4 electrodes positioned according to the 10-20 international system and sampled at 250 Hz. The tip of the nose was used as reference. EEG signals were digitally filtered with FIR Blackman-61-dB bandpass filters for the following frequency bands: 4-7 Hz (Theta), 8-12 Hz (Alpha), and 13-30 Hz (Beta). As previous studies suggested that "optimal arousal" (moderate levels) may facilitate performance quality (Lehmann *et al.* 2007), brain activity was expressed in terms of beta-theta ratio. Increased amplitude of beta waves has been related to enhanced attention (Egner and Gruzelier 2001) and semantic working memory (Vernon *et al.* 2003), important features for optimal performance. It seems reasonable to assess beta/theta ratio while imagining the performance scenario to understand whether adaptive anxiety was promoted with the SMP. EDA was recorded from the middle and ring fingers of the non-dominant hand with a TSD203 skin resistance transducer (Biopac Systems). Mean amplitudes were calculated for periods of 60 s in each of the three instructions conditions for both EDA and the various EEG band signals. EEG and EDA signals were amplified with EEG100C and GSR100C amplifiers, respectively (Biopac Systems). Participants were seated in a comfortable chair while EEG and EDA recordings were performed simultaneously under three different states: relaxed with the eyes closed, with the eyes open, and imagining a performance-related scenario (i.e. imagining stage performing). Each state lasted approximately 90 s.

All data collection lasted around 25 minutes so that participants could be on stage around 30 minutes after. This choice of situation and timing was based on results of previous research on anxiety levels across musical genres and under different situations (Welch *et al.* 2008). Subjective and objective datasets were collected twice for each participant: the first assessment constituted the baseline measurement; the second assessment was carried out 12 weeks later after 10 sessions (once a week) of SMP, carried out with the experimental group only. During the SMP, participants met weekly for 2 to 2.5 hour sessions to receive instructions and practicing skills which included discussion of stress, coping, and relaxation techniques. Homework was also assigned at the end of the sessions, to promote consolidation of learned practices. At the end, the SMP was assessed by a self-report questionnaire.

RESULTS

Two of the participants included in the control group failed to complete the whole study and did not participate in the second assessment. Thus, the re-

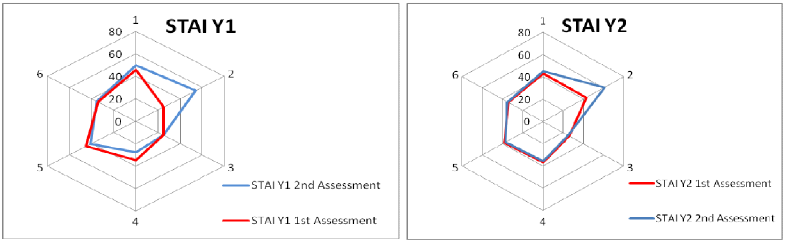

Figure 1. Scores for STAI Y1 (left panel) and STAI Y2 (right panel) for each participant for first (red) and second assessments (blue). Participants 1 to 4 belong to the experimental group, whereas participants 5 and 6 constitute the controls. (See full color version at www.performancescience.org.)

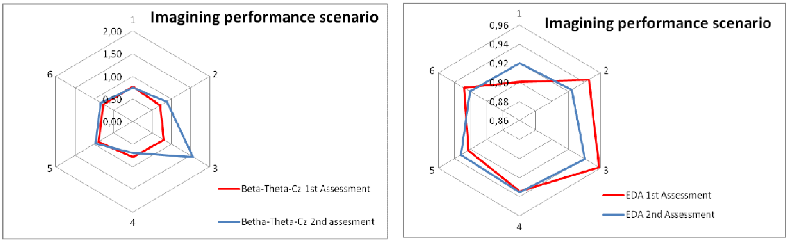

Figure 2. Scores for Beta-Theta ratio (left panel) and EDA (right panel) for each participant for first (red) and second assessments (blue). Participants 1 to 4 belong to the experimental group, whereas participants 5 and 6 constitute the controls. (See full color version at www.performancescience.org.)

sults here presented concern only 4 pianists in the experimental group and 2 controls (rather than the initial 4), allowing for descriptive analysis only.

Figure 1 shows state and trait anxiety levels (STAI Y1 and STAI Y2, respectively) for all participants. For the baseline measurement (i.e. first assessment), participants 1 and 5 present the highest anxiety levels, followed by participants 4, 6, and 2. The lowest values were presented by participant 3. As expected, STAI Y2 scores did not differ between the first and second assessments; however, this was not verified for participant 2. Also, STAI Y1 results were rather unexpected: although state anxiety seemed to decrease after the SMP for participant 4, participants 1 and 2 seemed to be more anxious before the performance after the SMP intervention. Controls 5 and 6 showed mild differences between baseline and after SMP assessments.

Figure 2 shows the variation of beta-theta ratio and EDA for both baseline and after the SMP. For the second assessment, participants 2 and 3 present an increase in beta-theta ratio, whereas EDA decreased. Participant 1 almost does not show changes between first and second assessments for beta-theta ratio; however, EDA are higher for the second assessment as compared with the first. The same can be observed for participant 5 (control). Participant 4 almost does not show changes in EDA and only small differences between beta-ratio, showing higher values for the first than the second assessments. Participant 6 shows an opposite behavior compared with participant 5 as regard to EDA, which was higher for the first assessment. Participants 2 and 3 show increased beta-theta ratio and decrease EDA after the SMP.

DISCUSSION

The results, although of an exploratory nature, may provide interesting insights for future assessments of SMP impact on M-MPA. For example, differences between baseline and after-SMP conditions for STAI Y2 for participant 2 highlight the importance of combining subjective and objective measures. It is possible that perceived levels of M-MPA might not correspond to the underlying psychophysiological processes related to the performance itself. Thus, both measures should complement each other to allow more robust results. The increased beta-theta ratio and decreased EDA observed for participants 2 and 3 after SMP suggest that this type of program may assist students to enhance adaptive performance anxiety, thus being beneficial for the improvement of overall performance quality. This was further supported by the participants' comments on overall quality and efficacy of the SMP. Research to date has been mainly focused on how maladaptive anxiety affects performance quality and how it can be reduced. Thus, it would be interesting to promote strategies of increasing adaptive anxiety, expressed as means of moderate arousal, controlled sympathetic autonomic activation and working memory activation. It would be interesting to assess the effects of beta-theta training and its relation to perceived peak experiences and enhanced performance quality, as a complement to the demonstrated positive effect of alpha-theta training through neurofeedback. The higher values of EDA for participants 1 for the second assessment may indicate the necessity of including personality tests, as personality may influence anxiety levels, and affect the moderated levels needed for an optimal performance.

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An investigation into the acute effect of exercise on physiological and psychological responses to musical performance

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Musicians experience anxiety and stress as an occupational hazard. Various approaches are available to the individual that may mitigate perceptions of excessive anxiety. Acute exercise (EX) has been shown to reduce the level of psychological and physiological response to laboratory stressors, although its impact on music performance anxiety (MPA) is less clear. Twelve classically trained musicians completed a baseline familiarization session, with 20 minutes of EX and quiet rest (NEX) in a counterbalanced order prior to a performance, videoed as part of a performance competition. Cardiovascular measures (heart rate [HR], heart rate variability [HRV], and blood pressure) were collected at baseline, pre-, during, and post-performance. Anxiety and self-reflective performance ratings were collected pre- and post-performance. EX reduced HR reactivity significantly during and post-performance, but not prior to performance. HRV showed signs of vagus withdrawal during and post-performance in EX. Blood pressure changes and anxiety were not significantly different between conditions, nor were reflective appraisals with the exception of "importance of winning the competition," which was lower in EX. Acute exercise appears to alter cardiovascular responses to a musical performance, although not how individuals perceive anxiety.

Keywords: musical performance; exercise; anxiety; cardiovascular

Musical performance has long been associated with elevated levels of anxiety and stress (Fishbein *et al.* 1988), and studies have identified various elevated physiological responses to these events (Abel and Larkin 1991, Valentine *et al.* 1995). While some of these responses may be adaptive, extreme levels may impact the performance experience for the musician and the listener. Acute exercise has been shown to impact physiological and psychological responses to laboratory stressors (Probst *et al.* 1997, Steptoe *et al.* 1993), but there is limited evidence using a psychosocial real-world stressor such as musical performance. Four studies have utilized speech preparation/performance as a parallel to a real-life stressor (Bartholomew 2000, Ebbesen *et al.* 1992, Rejeski *et al.* 1992, Steptoe *et al.* 1993), with some evidence that acute exercise alters individuals' responses to the stressor. This study evaluated the effect of 20 minutes of acute exercise on the psychological and physiological responses of classical musicians to an assessed performance.

METHOD

Participants

Twelve classically trained musicians (2 men with mean age=22 ± 1 years, 10 women with mean age=23 ± 2 years) with an average 17 years of musical experience took part in the study. The participants were either violinists (n=3) or pianists (n=9). All provided consent to take part, and there were no drop-outs.

Materials

State anxiety was assessed using the short, 10-item version of the original 20-item State Anxiety Inventory (SAI, Spielberger *et al.* 1983) due to its suitability for repeat-measures as required in this protocol.

Self-reflective ratings of the importance of the performance situation and confidence were obtained prior to the performance using six questions, each with a visual analogue scale. The questions assessed the importance that the musicians placed on playing in general and on the forthcoming performance, as well as the importance they attached to winning the competition in which they were about to take part. Their perceived self confidence in their general musical ability and in their ability to win the competition was also rated, as was their satisfaction with their pre-performance preparation.

Procedure

Participants completed four sessions: (1) a baseline fitness and laboratory stressor assessment, (2) a protocol familiarization session, (3) 20 minutes of exercise at 70% HR_{max} pre-performance (EX condition), and (4) 20 minutes of quiet rest control pre-performance (NEX condition). Exposure to the EX and NEX conditions was counterbalanced across individuals. Heart rate (HR), heart rate variability (HRV), and blood pressure were measured pre-, during, and post-performance, while state anxiety was measured pre- and post-performance. The reflective ratings were obtained pre- performance. After the second performance, they selected the recording that they preferred (EX or NEX) to be entered into a competition where performance quality was to be evaluated. Seven participants chose their NEX performance, while five their EX performance.

RESULTS

HR reactivity to the musical performance was significantly lower in EX than in NEX ($F_{2,22}=21.12$, $p<0.001$). Post-hoc analyses (with Bonferroni correction) revealed that there was significantly higher reactivity in the NEX condition during musical performance ($p<0.05$) and post-performance ($p<0.05$) but not pre-performance (see Figure 1). High frequency HRV was significantly lower in the EX condition in pre- versus during performance ($Z=2.67$, $p<0.01$) and pre- versus post-performance ($Z=3.06$, $p<0.01$). However, no differences in blood pressure response between EX and NEX conditions were observed.

Anxiety, as assessed through the SAI, was lower pre- and post-performance in the EX condition, although not significantly so from the NEX condition. Reflective ratings were lower in EX, with the "importance of winning the competition" reaching significance ($t_{11}=2.63$, $p<0.05$).

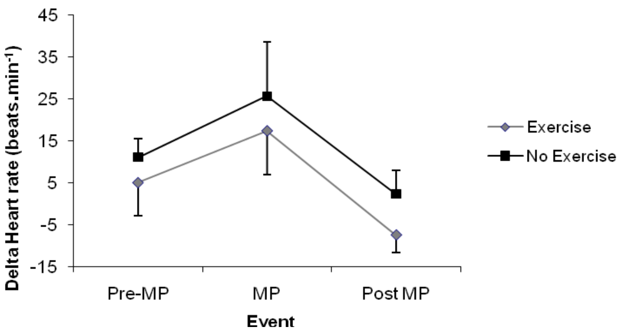

Figure 1. Mean and standard deviation of heart rate reactivity during experimental events by condition.

DISCUSSION

A 20-minute bout of exercise alters the HR during and after but not prior to a musical performance, demonstrating some agreement with other psychosocial stressors (Bartholomew 2000, Ebbesen *et al.* 1992, Rejeski *et al.* 1992, Steptoe *et al.* 1993). However, blood pressure alterations were not observed in tandem with these changes, suggesting that vascular adjustments are distinct to stressor types as reported by, among others, Bongard *et al.* (1997), Prkachin *et al.* (2001), and Suarez *et al.* (1993). A reduction in reactivity is generally seen as desirable, but in combination with the reduced HRV, the effect appears to be caused by vagus withdrawal which is not considered an indication of relaxation (Long and Verrier 1976, Tsuji *et al.* 1996). The trend for lower state anxiety in the EX condition may be welcome, but the concomitant reduction in importance attached to winning the competition may suggest that exercise interfered with musicians' normal behavior; however, after reviewing their performance recordings, five of the participants chose the EX performance, which suggests an alternative view to this. Overall, there appears to be support for further investigation of the effects of acute exercise on the physiological and psychological responses of musicians to performance.

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The effect of virtual training on music performance anxiety

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This study investigated the effects of virtual reality training on music performance anxiety. Seventeen music students were randomly assigned to a control group (n=8) or a virtual training group (n=9). Participants were asked to play a musical piece by memory in two recitals at three weeks interval. The anxiety was then measured with the Personal Report of Confidence as a Performer (PRCP), the S-anxiety scale of the State-Trait Anxiety Inventory (STAI-Y), the Subjective Units of Distress scale (SUDS), and by pulse rate. The virtual training consisted of six one-hour long sessions of virtual exposure. Results indicate a significant decrease in performance anxiety (PRCP) for women in the treatment group and a significant decrease of State Anxiety (S-anxiety scale) for musicians with high levels of trait anxiety (T-anxiety scale) in the treatment group.

Keywords: performance anxiety; music; training; virtual reality; exposure

Forty percent of musicians are affected by music performance anxiety (MPA; Fishbein *et al.* 1988). In fact, MPA is recognized to be a significant problem among orchestra musicians, opera chorus artists, music students, and faculty members (Kenny *et al.* 2004, van Kemenade *et al.* 1995, Wesner *et al.* 1990). Fortunately, exposure turns out to be an effective intervention for the treatment of anxiety disorders (Olatunji *et al.* 2010). For the last 15 years, virtual reality has increased as a mode of delivery of exposure treatment and studies have consistently shown a large mean effect size for virtual reality exposure compared with control conditions (Powers and Emmelkamp 2008). The purpose of this study was to examine the effect of virtual training on music performance anxiety in piano and guitar music students. The hypothesis was that the group who received virtual training would show greater reduction of music performance anxiety compared with the control group not receiving the intervention in a pre-test/post-test design.

METHOD

Participants

Seventeen guitarists and pianists participated in the study, but one pianist dropped-out after the pre-test assessment. Participants were pursuing their music studies either at a college, a conservatory, or a university in Quebec City, Canada. To be included in the study, participants who were taking anxiolytic medication had to be on a stable dose for at least three months prior to the beginning of the study and agree not to modify their medication or dose for the duration of the study. The sample consisted of 10 women and 7 men with a mean age of 21.8 years (SD=5.2).

Materials

The State-Trait Anxiety Inventory Form Y (STAI; Spielberger 1988), which is comprised of two separate scales , the S-anxiety and the T-anxiety scales, was used to evaluate state and trait anxiety of participants. The Personal Anxiety Inventory (PAI; Nagel *et al.* 1981), the Personal Report of Confidence as a Performance scale (PRCP; Appel 1974), the Subjective Units of Distress scale (SUDS; Wolpe 1990) and the Pulse Rate (PR) collected with pulse oximeter were used to assess anxiety during initial interview and/or during pre- and post-test evaluation.

Procedure

Initial interview

During the initial interview, participants completed a consent form. They then filled out a personal and musical history questionnaire, the Personal Anxiety Inventory (PAI; Nagel *et al.* 1981) form and the State Trait Anxiety Inventory Form Y (STAI; Spielberger 1988). In order to achieve equivalence between groups, participants were paired according to their instrument (piano or guitar) and their PAI results. They were then randomly assigned to the virtual training group (n=9) or to the control group not receiving the intervention (n=8).

Pre-test/post-test

To evaluate music performance anxiety, a public recital was scheduled for all participants before and after the virtual training. Subjects were asked to play a short musical piece in front of an audience comprised of parents, friends, teachers, and other guests. The specific time of the scheduled performance and the playing order were the same for pre-test and post-test assessments. Each participant's pulse rate (PR) was monitored before and after their performance. Participants completed the S-anxiety scale and the Subjective Unit of Discomfort Scale (SUDS) before their performances and the Personal Report of Confidence as a Performer scale (PRCP) after their performances.

Training sessions

Between pre-test and post-test, the experimental group completed a total of six weekly 60-minutes virtual training sessions. In the first session, psychoeducation was given on anxiety and exposure. Then, participants took part in virtual exposure sessions in which they played a musical piece. Each exposure situation represented a typical classical music audience that musicians are usually exposed to during their study and later on in their career. Virtual training sessions took place in the Laboratory of Museology and Engineering of Culture (LAMIC) at Laval University. The virtual stage was composed of four 10 x 10 feet screens on which virtual environments were projected, four speakers, and a stage spotlight that lit the musician while s/he was playing.

RESULTS

Repeated measures analyses of variance using SPSS mixed model procedure were conducted to compare changes in anxiety scores between pre- and post-test and between both groups. Homogeneity of variance between the groups was verified before conducting the analyses. Mean scores and standard deviations at pre-and post-test assessments (PRCP, S-anxiety, SUDS, PR) for the experimental group and the control group are shown in Table 1.

For both groups and all measures, lower means at post-test compared with pre-test were observed. No significant interactions were observed between Time and Group for each of these variables.

Sex and PRCP

Differences between genders in training efficacy were assessed using interaction analyses. Results indicate a significant interaction effect between Time, Group, and Sex for the PRCP: $F_{1,13}=5.10$, $p=0.043$. Post hoc analyses show a

Table 1. Adjusted pre- and post-test means (and standard errors) for PRCP, S-anxiety, SUDS, and PR by group.

	Control group		*Experimental group*	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
PRCP	13.13 (2.08)	8.80 (2.19)	17.33 (1.96)*	12.11 (1.96)*
S-anxiety	43.00 (4.77)	37.59 (3.24)	50.56 (4.49)	43.33 (2.90)
SUDS	5.75 (0.70)	4.46 (0.73)	6.00 (0.66)	5.28 (0.66)
PR	104.9 (5.96)	99.96 (6.12)	89.61 (5.61)	85.27 (5.61)

Note. * Mean difference is significant at $p<0.05$.

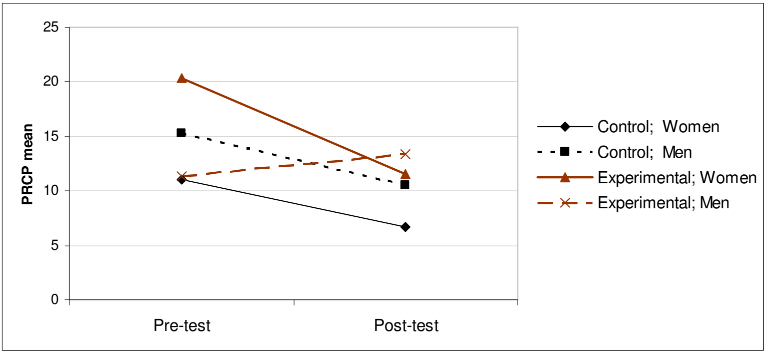

Figure 1. PRCP evolution according to sex.

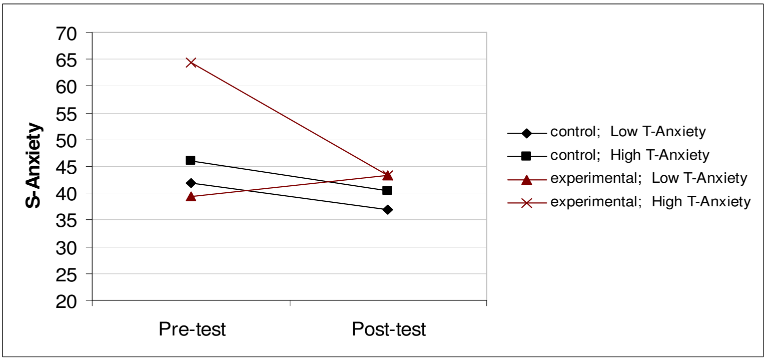

Figure 2. S-anxiety evolution according to the level of T-anxiety at initial interview. (See full color version at www.performancescience.org.)

significant decrease of PRCP score between pre-test and post-test for women in the experimental group, $F_{1,12}$=19.21, p=0.001, and no significant difference for the three other groups.

T-anxiety and S-anxiety

Differences between high (range=45-59) and low levels (range=29-44) of T-anxiety in training efficacy were verified using interaction analyses. Results indicate a significant interaction effect between Time, Group, and T-anxiety for the S-anxiety variable: $F_{1,12}$=9.29, p=0.01. Post hoc analyses show a significant decrease of S-anxiety between pre-test and post-test for participants in the experimental group with high levels of T-anxiety, $F_{1,13}$=13.98, p=0.002, and no significant differences for the three other groups.

DISCUSSION

The hypothesis of this study was that virtual training would decrease anxiety for the experimental group receiving virtual training compared with the control group. This hypothesis was partially confirmed. We found a significant decrease in anxiety for two subgroups of participants in the virtual training condition: (1) women and (2) high trait anxiety participants. The efficacy of virtual training for the high trait anxiety group and not for the low trait anxiety group could be explained by a floor effect. Indeed, we observed that those who had a low score for trait anxiety had a low level of state anxiety at pre-test (r=0.547, p=0.02). It is therefore difficult to decrease their anxiety level as it is already low, although we should be careful in interpreting this result given the small sample size of the study.

Considering that the results of this pilot study indicate an improvement in anxiety levels in specific groups (i.e. women, high trait-anxiety), research on virtual reality should be pursued in larger randomized controlled trials. Virtual exposure seems to be a promising way to help musicians who suffer from music performance anxiety.

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Thematic session:
The science of drumming

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"Play in time, but don't play time": Analyzing timing profiles in drum performances

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This paper investigates how professional drummers intentionally vary the micro-timing of their playing. Performances of two drummers, playing a simple rhythmic pattern in different "feels" (phrasing styles), were recorded. The onset times of all rhythmic events were measured with computer-aided methods, and the timing data were analyzed. Each "feel" shows particular timing patterns. In addition, the micro-rhythmic fingerprints of the two drummers are identifiable.

Keywords: micro-timing; groove; jazz; rock; drum performance

Micro-rhythmic features are said to be an important factor in the creation and reception of emotional qualities ("feels") in beat-oriented musics like jazz or rock. The ability of a drummer to play rhythmic events with flexible timing while keeping the tempo constant is widely accepted as a sign of competence and professionalism. "Playing ahead" or "playing laid back" are the most common feels in the musicians' parlance. In the first, note onsets are expected to be earlier than the beat; in the latter, note onsets are said to be later than the beat. While these concepts are common in musicians' conceptions of their music, the connection between the "feels" and the physical timing features of a performance has not yet been studied.

Ethnomusicologist Charles Keil was the first to offer a procedural perspective on micro-rhythmic phenomena. According to Keil, musicians performing in an ensemble permanently synchronize their mutual timing and adapt their intonation, dynamics, and timbre to each other. During these negotiation processes there arise, in each analytical category, minute differences (participative discrepancies or PDs), which Keil (1966, 1987, 1995) considered to be crucial for the expressivity and emotional impact of a performance. Keil assumed that the quality of an ensemble's playing depended on how the conceptions of the musicians interact—particularly the conceptions of rhythm. In an early article (1966), Keil already observed that "on top" playing drummers in jazz rhythm sections fit well with "chunky" bassists (those who play with a heavy, percussive sound), whereas "laid back" drummers are best complemented by "stringy" bassists (those who play with a light, sustained tone). Every combination within this typology results in a particular kind of ensemble groove. When Keil initially formulated his thoughts, he had no access to objective timing measurement data. From the mid-1980s on, scholars started to study temporal features of recorded performances with empirical methods (for an overview, see Pfleiderer 2006 and Doffmann 2008) and showed that performances were patterned on a micro-temporal level. Temporal PDs usually lie in a range between 10-40 ms (Rose 1989, Butterfield 2010) but can also amount to 80-90 ms in particular situations (Prögler 1995, Doffmann 2008). It remains an open question, however, how these patterns relate to performance styles, specific performance situations, or the acquired playing habits of performers.

This study, conducted in a laboratory setting, tested how the assignment of playing a rhythmic pattern with different feels affects the timing of two drummers' playing. It was hypothesized that (1) in the "ahead" feel the strokes would generally be placed earlier than the beat, whereas in the "laid back" feel, the strokes would be placed after the beat. It was also assumed (2) that the timing relations between the individual instruments of the drum kit would not change from one feel to the other because they were expected to be based on the drummers' acquired body motion patterns.

METHOD

Participants

For the present study, performances of two professional drummers were recorded. Drummer 1 is 42 years old and has played the drums for 32 years. Drummer 2 is 41 and has 28 years of experience on the drums.

Procedure

The recordings took place in the participants' private rehearsal rooms. Each instrument of the drum kit—ride cymbal, hi-hat cymbals, snare drum, and bass drum—was close-miked with a separate microphone. The players wore a headset, providing a metronome click and a monitor mix of the recording. Both musicians preferred to have the microphone signals mixed in on a very low level in relation to the metronome click. The four microphone signals were recorded alongside the metronome click on five separate tracks of a

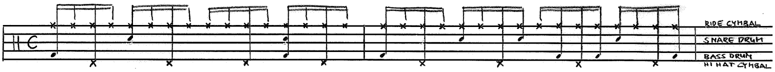

Figure 1. Rhythmic pattern used in the recordings.

digital audio workstation. The drummers played a simple 2-bar rhythm pattern (see Figure 1) for approximately three minutes in each "feel." They had time to memorize and practice the pattern for ten minutes prior to the recordings. The pattern in 4/4 meter featured periodical events on ride and hi-hat cymbals. Snare and bass drum played a mixture of metrically regular and syncopated rhythmic elements.

The three "feels" or phrasing styles were: "ahead," "on top," and "laid back." The first is supposed to have a driving quality, the second is said to appear on the beat, whereas the latter is expected to sound relaxed. In a fourth recording, the drummers played the ride and hi-hat cymbal tracks alone and tried to synchronize them as precisely as possible to the metronome.

All physical note onsets of the approximately 17,000 rhythmic events were detected using the software LARA (www.hslu.ch/lara). For the metronome click track a threshold level of -60 dBFS was defined, and the first sample exceeding the threshold was considered as the onset of each metronome sound. For the instrumental sounds, a two level approach was used. In a first step, onset times were detected with an automated process. In a second step, the resulting data was manually reviewed and compared to the waveform plots of the recordings. Due to the close-miking, characteristic features of the transients were clearly visible in the waveforms and served as visual cues for the manual adjustment of the onsets. A second application of the procedure to a subset of around 1,000 events yielded an average error of 0.1 ms for the snare, bass drum, and hi-hat and 1 ms for the ride.

A rigid sixteenth-note reference timing grid was computed from the measured metronome beats. For each instrumental onset time, the difference to the corresponding time of the grid was calculated (deltaGrid). These values represent the displacements to the external metrical reference. In addition, the differences between hi-hat cymbals, snare, and bass drum onsets to the ride sixteenth onsets was also computed (deltaRide). These values represent the relative displacements from the internal metrical reference.

RESULTS

For the descriptive analysis, the deltaGrid values were used. An overview of the results for performers 1 and 2 is given in Tables 1 and 2, respectively. The

Table 1. Timing profile of player 1.

	Ride	*Hi-hat*	*Snare drum*	*Bass drum*
Ahead	-22 (23)	-35 (22)	-24 (18)	-34 (19)
On top	-10 (18)	-19 (19)	-12 (17)	-20 (20)
Laid back	14 (17)	3 (21)	17 (16)	5 (21)
As precise as possible	-9 (16)	-20 (15)		

Table 2. Timing profile of player 2.

	Ride	*Hi-hat*	*Snare drum*	*Bass drum*
Ahead	-17 (13)	-22 (13)	-13 (11)	-18 (15)
On top	-19 (10)	-25 (10)	-11 (8)	-12 (11)
Laid back	-3 (11)	-13 (13)	5 (10)	-3 (14)
As precise as possible	-26 (9)	-27 (10)		

Note. Mean deltaGrid values are shown, with SD in parentheses.

tables show the mean values and standard deviations of the measured deltaGrid for each instrument played in each feel. All values are shown in milliseconds, rounded to 1 ms for clarity. Positive values denote that the instrument lagged behind the metronome in the average; negative values denote that the strokes anticipated the metronome.

The timing profile of player 1 (Table 1) confirms the basic assumption (hypothesis 1) very clearly. The playing instructions "ahead"/"on top"/"laid back" appear consistently in all instruments: in the "ahead" feel, the strokes are placed between 22 ms (ride) and 35 ms (hi-hat) earlier than the metronome clicks. Conversely, the strokes in the "laid back" feel are played between 3 ms (hi-hat) and 17 ms (snare drum) behind the metronome. The playing instruction "on top" resulted in a rhythmic placement right between "ahead" and "laid back," with an anticipation between 10 ms (ride) to 20 ms (bass drum), relative to the reference timing grid. The playing instruction "as metronomically precise as possible" resulted in mean displacements similar to the "on top" feel. The standard deviation is slightly smaller than in the other playing instructions. For player 1, to perfectly synchronize with the metronome means to actually play the strokes 10 ms (ride) and 20 ms (hi-hat) earlier than the perceived metronome clicks.

In player 2's data, "ahead" and "laid back" feels are clearly differentiated. On average, "ahead" strokes are between 9 ms (hi-hat) and 18 ms (snare drum) earlier than "laid back" strokes. The "on top" timing is basically identical to "ahead" timing. It is worth mentioning that drummer 2 distinguishes the "ahead" feel from the "on top" feel essentially with dynamic means: strokes in the "ahead" feel are generally more aggressive on the ride cymbal, and the difference of stressed and non-stressed metrical positions is emphasized. Surprisingly, the playing instruction "as precise as possible" led to an even stronger anticipation (26 ms) than the "ahead" feel in drummer 2. He showed comparable standard deviations for all feel variations, but his standard deviation values are considerably lower than the values of player 1.

The examination of the differences between the individual instruments shows characteristic patterns for both drummers, which pervade all renderings of the different feels. Drummer 1 played the foot-operated instruments (hi-hat and bass drum) consistently 10 ms earlier than the hand-operated instruments (ride and snare drum). Drummer 2 on the other hand led with the hi-hat, followed by ride and bass drum; the snare drum sounded last. The independence of these relative timing patterns from the different feels is supported by regression analyses. The variable, which encodes the "feels" is the most important predictor variable for the deltaGrid values (β=-0.48, t_4= -49.78, p<0.01). But it shows no influence on the deltaRide values: the feels do not seem to influence the relative succession and timing of the strokes in the four instruments.

DISCUSSION

The last observation supports the assumption that the relative timing between the instruments' onsets seems to be a stable part of the drummers' acquired motor behavior (hypothesis 2). The analysis of the data further shows that both drummers implement the different feels in their micro-timing (thus supporting hypothesis 1), but in significantly different ways. The players' timing data showed diverse personal characteristics: drummer 2 had a tendency to play ahead of the beat, regardless of the expressed feel. Based on this characterization drummer 2 may be generally addressed as an "ahead" drummer. For drummer 1, this label does not seem to apply: he plays the "on top" and "ahead" feels before but the "laid back" feel after the beat. A further predicate of jazz/rock parlance might be applicable to the two players: the data of drummer 1 show considerable standard deviations; he seems to be a rather "loose" drummer, who varies the placement of his strokes freely around the metric positions. The data of drummer 2 showed noticeable smaller standard deviations; he could be addressed as a "tighter" drummer than his colleague, setting his strokes closer to the metric positions defined by the metronome.

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Estimating musical score of drum performance based on the Bayesian method

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We designed a system that estimates the musical score of a player's performance based on the MAP estimation. The proposed method matches the inputted performance to a drum pattern in the database of 12,395 patterns. After matching, onset deviation from drum patterns in the database is calculated as the adaptation probability of the inputted performance. A posterior probability of each pattern in the database is then calculated by multiplying the adaptation probability by a prior probability, where the database is used to obtain the prior probability from the occurrence frequency of each pattern. The pattern with the highest prior probability is used as the estimated musical score. Experimental results showed that an averaged F-measure of 0.88 was obtained, indicating that the proposed method is an effective means of estimating musical scores.

Keywords: drums; MIDI; musical score; Bayesian method; F-measure

Musicians face many challenges when practicing through self-learning, one of which is that they cannot obtain objective evaluations of their performances. Several researchers have previously reported support systems for practicing of musical instruments (Schoonderwaldt *et al.* 2004, Iwami and Miura 2007, Morita *et al.* 2009). In particular, a support system to automatically evaluate the proficiency of drum performances was developed (Iwami and Miura 2007). However, this system requires users to input musical scores, which is often difficult for beginners. Therefore, we have developed a system that can evaluate proficiency of drum performance without inputting a musical score.

To evaluate the proficiency of users' arbitrary performances, we need to estimate the musical score of the performance with a previous method for evaluating the proficiency of playing particular musical scores [2]. Our method is based on the maximum a posteriori (MAP) estimation.

MAIN CONTRIBUTION

The MAP estimation is used as the score estimation method. This estimation considers a parameter θ *for* maximizing a probability distribution $P(\theta|X)$ of observed signal X as estimated value $\hat{\theta}$, which is calculated as:

$$\hat{\theta} = \arg\max_{\theta} P(\theta \mid X)\,. \qquad (1)$$

We refer to an assuming score as an “intended score.” On the other hand, an observed performance is called a “recorded performance,” each note of which is called a “performed note.” The estimated score obtained by the proposed method is called an “estimated score.” The rhythm patterns of drums in the database are called “drum patterns.”

Target style of practice

We used a style of performance called “drum-loop performance” (DLP) (Iwami and Miura 2007). It consists of one measure under a given tempo. The DLP musical score is primarily denoted by only a bass drum, snare drum, and closed hi-hat cymbal.

Database for estimating musical score

The score estimation method uses a database constructed in a previous study (Murakami and Miura 2009). It stores timing and occurrence frequencies in the MIDI data. Also, it consists only of a 4/4 meter within a bar. The frequencies are derived from the MIDI data. The drum patterns are quantized under the accuracy of a thirty-second note (8 divisions per beat). We redefine the database of 12,395 patterns, which is constructed using only a bass drum, snare drum, and closed hi-hat cymbal.

Detail of musical score estimation

Calculating a normal distribution

A normal distribution $T_n(t)$ with parameters μ_n and σ is calculated as:

$$T_n(t) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(t-\mu_n)^2}{2\sigma^2} \right), \qquad (2)$$

where t is a time, μ_n is onset time of a n^{th} performed note and σ is a standard deviation. The standard deviation σ is substituted with 15 ms because we consider the inevitable deviation of the MIDI system.

Algorithm for matching performance and drum pattern

In our method, which uses only onset time and intensity information, the matching process is done with each percussion instrument. The first performed note on the first measure to the first note for a drum pattern to be referred allows us to obtain the onset time. A performed note is then matched with a score note that has a relatively small onset deviation from the performed note, where the maximum deviation is set to 45 ms, or 3σ.

Calculating posterior probability for recorded performance

After matching, a cumulative probability p_n for the n^{th} performed note is calculated from the nth onset time μ_n of the performed note and the m^{th} onset time R_m^k of the k^{th} drum pattern's note, shown as:

$$p_n = \begin{cases} \int_{R_m^k}^{\infty} T_n(t)dt & (R_m^k > \mu_n) \\ \int_{-\infty}^{R_m^k} T_n(t)dt & (R_m^k \le \mu_n) \end{cases} . \tag{3}$$

An adaptation probability $P(X|A_k)$ is then calculated by subtracting coefficient from multiplying all cumulative probabilities p_n, shown as:

$$\log P(X \mid A_k) = \sum_n \log p_n - (wI + vM) , \tag{4}$$

where X is a recorded performance actually observed, A_k is k^{th} drum pattern, I and M are the number of inserted or missing notes respectively, and w and v are a weighted coefficient for inserted or missing notes.

A posterior probability $P(A_k|X)$ of each pattern is then calculated by multiplying the adaptation probability $P(X|A_k)$ by a prior probability $P(A_k)$, shown as:

$$P(A_k \mid X) = P(A_k)P(X \mid A_k) . \tag{5}$$

Estimating a musical score

After all the steps, the drum pattern with the highest posterior probability $P(A_k|X)$ is introduced as the estimated score.

Calculating a prior probability

A way to calculate the prior probability of A_k to estimate a musical score is by using the occurrence frequencies in the database, but this is not appropriate because the similarity among patterns is not considered when obtaining the occurrence frequency. This is generally called a "zero frequency problem."

To prevent such problem, we use another method that smoothes its occurrence frequency, so as to calculate the prior probability. This method we used is based on the concept of the Parzen window (Duda *et al.* 2001).

PCA of onset times in database

We calculate a score of similarity based on the eigenphrase of drums (Abe *et al.* 2010), which is obtained by using the principal component analysis (PCA) on the database. The size of the matrix for performing PCA is 12,395 (patterns) x 96 (bits), representing whether or not each of three instruments (bass drum, snare drum, or closed hi-hat cymbal) is played (1 or 0) at 32 onsets (4 beats x 8 divisions). After obtaining the eigenphrase of drums by using the PCA on the database, the 96-dimensional eigenscore of each drum pattern is calculated from multiplying the eigenphrase of drums by the onset of the drum pattern in the database. The score of similarity $d_{k,j}$ is then calculated from the eigenscore of drum patterns between A_k and A_j, shown as:

$$d_{k,j} = \sum_{i=1}^{96} (e_{ki} - e_{ji})^2 , \qquad (6)$$

where e_{ki} and e_{ji} correspond to the ith eigenscore for A_k and A_j, respectively.

Smoothing an occurrence frequency and calculating a prior probability

A probability representing the degree of similarity between A_k and A_j is obtained by converting the score of similarity between them. To obtain smoothed occurrence frequencies, we propose to add a summation of f_j multiplied by the probability defined by the score of similarity shown as:

$$F_k = f_k + \sum_j \left[f_j \times \exp\left(-\frac{\left\| d_{k,j} \right\|^2}{2} \right) \right] \quad (j \le 500), \qquad (7)$$

where f_k and f_j are the occurrence frequencies of A_k and A_j, respectively. Drum patterns are sorted and relabelled by j in the order of nearest from A_k, so the nearest 500 patterns are considered.

After obtaining F_k for all drum patterns, we obtain prior probability $P(A_k)$ by dividing F_k by the total of smoothed occurrence frequencies for all drum patterns in the database, calculated as:

$$P(A_k) = \frac{F_k}{\sum_l F_l} . \tag{8}$$

IMPLICATIONS

Experiment method

Recorded performances used in the experiment was 10 (players) x 24 (patterns) x 2 (tempi) x 2 (trials) = 960 patterns. We estimated a musical score under three different conditions: condition Q which is the conventional quantization method under demisemiquaver, condition NP which does not use prior probability, and condition PP which is the proposed method.

Results and discussion

The F-measure is calculated from the relationship between the estimated score and the intended score to determine the proposed method's accuracy. The F-measure is defined as:

$$\text{F - measure} = \frac{2 P_{recision} R_{ecall}}{P_{recision} + R_{ecall}} . \tag{9}$$

The precision is defined as:

$$P_{recision} = \frac{H}{S} , \tag{10}$$

where H is the number of corresponding notes of the intended score to notes of the estimated score and S is the number of notes of the estimated score. The recall is shown as:

$$R_{ecall} = \frac{H}{T} , \tag{11}$$

where T is the number of notes of the intended score.

The F-measure is calculated from each player's performance. F-measure averages are shown in Table 1 and Table 2, where P1 to P5 are professional players and A1 to A5 are amateur players. These averages were obtained from each condition. Obtained F-measures of professional players are 0.87 of condition Q, 0.91 of condition NP, and 0.92 of condition PP. Those of amateur players are 0.77 of condition Q, 0.83 of condition NP, and 0.85 of condition

Table 1. F-measure averages calculated from performances of professional and amateur players for conditions Q, NP, and PP.

Professionals	*Q*	*NP*	*PP*	*Amateurs*	*Q*	*NP*	*PP*
P1	0.89	0.93	0.95	A1	0.71	0.78	0.79
P2	0.92	0.97	0.97	A2	0.86	0.92	0.94
P3	0.92	0.96	0.97	A3	0.67	0.76	0.78
P4	0.75	0.78	0.80	A4	0.76	0.85	0.86
P5	0.90	0.92	0.93	A5	0.84	0.85	0.86
Average	0.87	0.91	0.92	Average	0.77	0.83	0.85

PP, indicating that condition PP is better than conditions Q or NP for estimating a musical score.

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Use of relationship between characteristics of rebound and surface EMG of arms to measure physiological load during drum performance

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We analyzed the motion of performance using an acoustic and three electronic snare drums, and investigated the relationship between characteristics of rebound and electromyograms (EMG) on drummers' arms. We used the coefficient of the rebound as the characteristic of rebound to obtain the difference in the drumhead for each snare drum. Ten drummers (five professional and five intermediate) were asked to play single-strokes. We recorded surface EMGs signals from their performance for the four different snare drums. We measured surface EMG signals of the flexor carpi ulnaris muscle and extensor carpi ulnaris muscle of both arms. EMG signals on playing electronic snare drums are compared with those on playing acoustic snare drum. We found that electric drums with the high-value rebound coefficient increase the physical load for intermediate drummers whereas they decrease it for professional drummers, implying that only the professional drummers can take advantage of the rebound feature for suppressing the physical load when drumming.

Keywords: electromyogram; drums; performance movement; characteristic of rebound; playing strength

Performances of several musical instruments have recently been investigated by using biological techniques (Fujisawa and Miura 2010, Montes *et al.* 1993, Ackermann *et al.* 2002). In an investigation into drumming (Fujisawa and Miura 2010), motions were observed for not only professional but also intermediate drummers, showing that only professional drummers suppress physical loads of arms when drumming. Moreover, to achieve such performances, they usually took the features of rebound and inertial of drumsticks into account. From the results we could see that the feature of rebound and drumstick may affect the drumming. This investigation compared several drumsticks but used only a specific snare drum, so the drumming when using various snare drums was not investigated. Moreover, the differences in the features of rebound have not yet been studied.

We investigated how the rebound feature affects the playability of drumming. The difference in the motion of sticks due to the difference in constitution or material is called "rebound feature" in this study. Several types of information can be used to analyze drumming, such as acoustic signal, motion capture data, and/or physiological data. The drumstick is controlled by the motion of arms, so by measuring the motion of arms we can analyze the details of the playing. Because the electromyogram (EMG) can obtain the amount of muscle activity for intended motion, the EMG is appropriate to use for analyzing the performance. EMG is proportional to the amount of muscle activity (Kizuka *et al.* 2009) and can be used to measure the amount of arm strain. In this study, we measured the EMG of drummers' arms when drumming as the index of physiological data as the physical loads. By measuring the EMG of several arm parts when drumming, we can clarify the physical loads when drumming.

MAIN CONTRIBUTION

The effect of the rebound feature on the motion of a drumstick may differ due to the inter-stroke-interval (ISI) and the intensity of the single stroke. Specifically, drummers need to suppress the rebounding drumstick when playing under a long ISI, whereas they need to do it less under a short ISI because to take advantages of it for the preparation motion for the next stroke. In other words, under a short ISI, drummers can control drumsticks by taking advantage of its rebound. The conceptual flow of the motion and force of a drumstick is shown in Figure 1.

Therefore, we examined types of the rebound features with various tempi and stroke intensities to measure the EMG of drummers' arms, so the relationship between the rebound feature and motion of drumming was investigated, clarifying how the rebound feature affects the motion of drumming.

Investigation of the rebound feature of snare drum

The physical index corresponding to the rebound feature is the rebounding coefficient. To measure the rebound feature, the rebound coefficient is introduced as the index of the rebound strength, so that the coefficient is expected to correlate with the physical load of drumming (Fujisawa and Miura 2010).

Figure 1. Motion of drumstick and force of drumstick for a single stroke.

The rebound coefficient was then introduced as the index of rebound feature.

In this investigation, we used an acoustic snare drum and three electric snare drums. The rebound coefficient for each snare drum was measured. The snare drums are listed in Table 1. An iron ball was magnetically controlled so that it fell down vertically onto the drumhead of each drum. The velocity of falling down and bouncing upward was measured by using a high-speed camera (2000 fps). Firstly, an iron ball 8 mm in diameter was set up to 30 mm above the drumhead and dropped onto the drumhead. The velocity for falling down and bouncing up was then measured. The required time the iron ball takes to fall 50 mm onto drumhead is called T_a, and the time that takes after hitting the drumhead to rise 50 mm is called T_b. From the pictures taken on the high-speed camera, the T_a and T_b were obtained. By obtaining T_a and T_b, the coefficient of rebound e was then obtained by the following equation:

$$e = \frac{T_a}{T_b}$$

For all snare drums, the iron ball was dropped onto the drumhead five times and the average of obtained e, called $\bar{e}$, was then used. Obtained results are shown in Figure 4, showing that each average rebound coefficient differs among snare drums. Moreover, the differences in the rebound coefficients between AD and ED1 or between ED2 and ED3 are relatively small compared with those between the differences in constitution (between film and pad). The order of the coefficient of rebound is: AD, ED1, ED2, and ED3.

IMPLICATIONS

Experiment method

Signals used were EMG, metronome, and the hitting signal of snare drum, where the metronome was used as the standard for playing and the hitting signal means the acoustic signal obtained through the microphone. The strain of the flexor carpi ulnaris, extensor carpi ulnaris, flexor carpi radialis, and extensor carpi radialis muscles on each arm were measured. Ten drummers (five professional and five intermediate) participated in this test.

Table 1. Snare drums used in this study.

Name		*Material of drum head*	*Shape of drum head*
Acoustic snare drum (AD)		Polyester film	Film
Electric snare drum 1 (ED1)		Mesh	Film
Electric snare drum 2 (ED2)		Rubber pad	Pad
Electric snare drum 3 (ED3)		Silicon pad	Pad

We used two conditions of EMG: 40% and 70%. For the condition of tempi, five conditions (30, 80, 130, 180, and 240 bpm) were used for a specified musical score comprised of eighth notes for $^4/_4$.

Flow of measurement

The flow of the measurement was as follows: (a) Each drummer was asked to do the volar flexion as strongly as possible, and the maximum strain on flexor carpi ulnaris and flexor carpi radials muscles were obtained as the standards for his/her measurement. (b) Obtained EMG signal was calculated and represented as the ratio compared with the maximum amount obtained in (a). It was displayed every 30 ms in real time. (c) Using the system, the drummer had been asked to practice to keep the specified amount of EMG without seeing the spontaneous EMG. (d) The drummer was asked to play a snare drum under a specified condition.

In this experiment, the steps of (a) were conducted only once, and the steps for (b) and (d) were conducted for each trial. Finally, the combinations of experimental conditions were 4 (the types of snare drum) x 5 (the types of tempo) x 2 (40% and 70% intensities) x 40 patterns in total.

Method of analysis

The four muscles were recorded to be analyzed. A 50 Hz low-cut filter and 500 Hz hi-cut filter were prepared. After this, a full-wave rectification was conducted. The region of stroking was obtained by using the metronome signal and hitting signal of the snare drum. The amount of EMG became greater before the 100 ms of the hitting time, so the region between 100 ms before the current stroking and that before the next is extracted. Figure 3 shows the extraction of each signal.

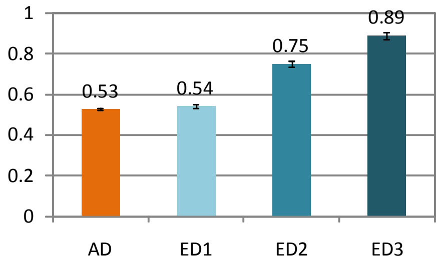


Figure 2. Average of the coefficient of rebound.

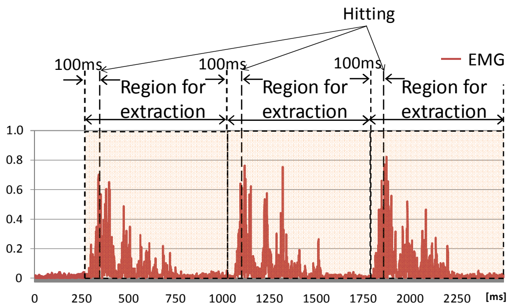
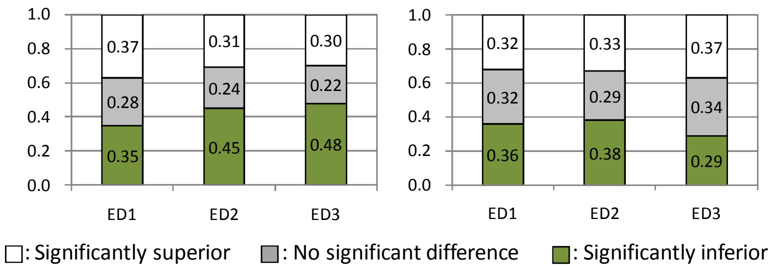


Figure 3. Extraction of EMG signal for extensor carpi ulnaris muscle of left arm.



(a) Professional drummers (b) Intermediate drummers

Figure 4. Ratio of the number of cases where EMG was much higher than AD. (See full color versions at www.performancescience.org.)

Results and discussion

The amount of EMG for each stroke for all performances was obtained. To investigate the relationship between the rebound feature and EMG, the t-test for significant difference was conducted for each electric drum. Then the number of significantly different cases was determined. Concretely, the average amounts of EMG between each electric snare drum and the acoustic snare drum, which had the lowest rebound coefficient, were compared by the t-test for significant difference. The test results determined the ratio of significantly different cases. The number of cases was 5 (drummers) x 5 (tempo conditions) x 4 (parts measured) x 2 (left and right hands) = 200 patterns. We then compared the number of significantly different cases among the patterns for each electric snare drum. Results for the professional drummers are shown in Figure 4a, and those for the intermediate drummers are shown in Figure 4b.

The results reveal that for professional drummers the electric snare drums with high-value rebound features suppress the physical load of drumming more than those with low-value rebound features. Thus, the electric snare drum with the high-value rebound coefficient is appropriate for professional drummers. On the other hand, for the intermediate drummers, snare drums with the high-value rebound coefficient give the physical load for drummers, implying that they cannot take the rebound of drumsticks into account even though the professionals can. Finally, we found that the electric snare drum with high rebound features is appropriate for the professional drummers whereas it is not for intermediate drummers.

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Thematic session:
Imagery and performance

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An fMRI study of expert musical imagery: To what extent do imagined and executed performance share the same neural substrate

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Mental rehearsal is advocated as an expert learning strategy. Our research explores the neural basis of the type of multi-modal musical imagery employed by expert pianists. We have developed functional neuroimaging paradigms to investigate musical imagery in more detail, in order to examine the reported benefits of mental rehearsal as an expert learning strategy. We report here on our preliminary findings.

Keywords: fMRI; music; imagery; Middle Frontal Gyrus; learning

Expert musicians use integrated auditory, motor, and visual imagery during learning and performance (Holmes 2005). Mental rehearsal of these images may to some extent replace or supplement physical training (Driskell *et al.* 1994) and has, therefore, been proposed as a means of reducing physical overuse, enhancing memorization and reducing anxiety (Freymuth 1999).

Previous research suggests that imagery and performance engage many of the same neural regions, but that there are also a number of differences in brain functional organization, alluding to potentially interesting differences in cognitive processing (Lotze *et al.* 2003, Meister *et al.* 2004). Although some of the benefits of imagery have been demonstrated through the empirical and qualitative study of elite musicians (Clark *et al.* in press), more research is needed to examine effective strategy choice and to understand the mechanisms via which imagery reportedly enhances performance.

Figure 1. Musical stimulus used in the study.

The aim of this study was to develop neuroimaging paradigms to investigate multi-modal musical imagery performed by expert pianists.

METHOD

Participants

Healthy volunteer professional and advanced student pianists, with a minimum of 10 years of training, were recruited for the study.

Materials

Participants memorized a novel musical extract prior to scanning (Figure 1) by mentally rehearsing the sound and structure as well as playing the extract on a keyboard (with auditory feedback). Before scanning it was demonstrated that the music could be played and imagined at the correct speed. The extract was limited to a single hand and arm position in order to avoid arm movement during scanning; the unison material was designed to be easy to memorize, with the repeated use of 3rd and 4th fingers at speed presenting a slight motor challenge.

Procedure

We scanned expert pianists during imagery and simulated motor performance of the memorized extract. During both conditions, the sound of the music was imagined. When instructed to "imagine," the participant was asked to mentally recreate the sound of the music and a sense of performing it. When instructed to "play," the participant was asked to mentally recreate the sound, the sense of performance, and to move the fingers as if playing on a real piano.

We used a block design, contrasting either imagined or simulated playing with rest (18 s active blocks interspersed with 18 s fixation rest blocks). Each run lasted for six minutes. During the functional scans, written instructions were presented on a screen. A 3T whole-body scanner (Verio, Siemens, Erlangen, Germany) was used for image acquisition. 118 Functional volumes were acquired using an interleaved EPI gradient echo sequence (TR/TE/flip angle=3000 ms/30 ms/90°, slice thickness=3 mm, 36 slices, FOV=24 cm, matrix size=64×64). All data were analyzed using BrainVoyager QX (Brain Innovation, Maastricht, The Netherlands).

RESULTS

Figures 2-4 show results for a 42 year-old professional pianist who began training at the age of 6. The pianist reported vivid sound imagery throughout, with an accompanying image of finger movements; visual imagery of the keyboard was also present to some extent. With the exception of primary motor cortex (M1), which was activated only during simulated performance, the motor system of the brain was activated similarly for both imagery and simulated performance of the piano extract (i.e. bilateral premotor [BA6], SMA, and cerebellum). Similar regions in the inferior parietal lobe were also activated bilaterally during both tasks. The notable difference between the imagined and simulated performance conditions was that the former produced bilateral activation of the Middle Frontal Gyrus (MFG) whereas the latter produced only left sided activation of MFG.

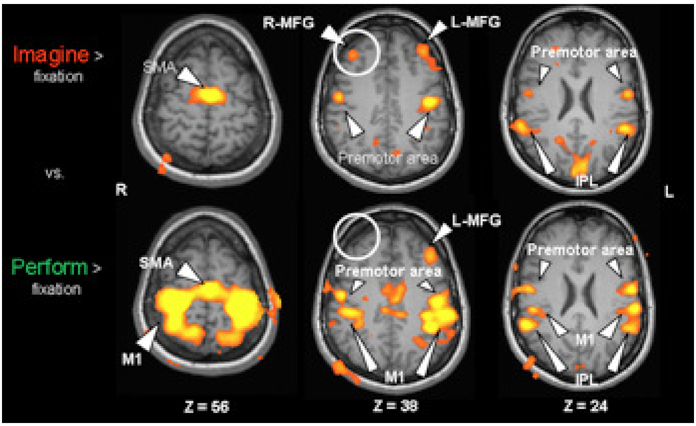

Figure 2. Significantly activated regions for imagery and performance (both versus fixation, N=1, corrected p<0.05, cluster threshold=10 voxels). (See full color version at www.performancescience.org.)

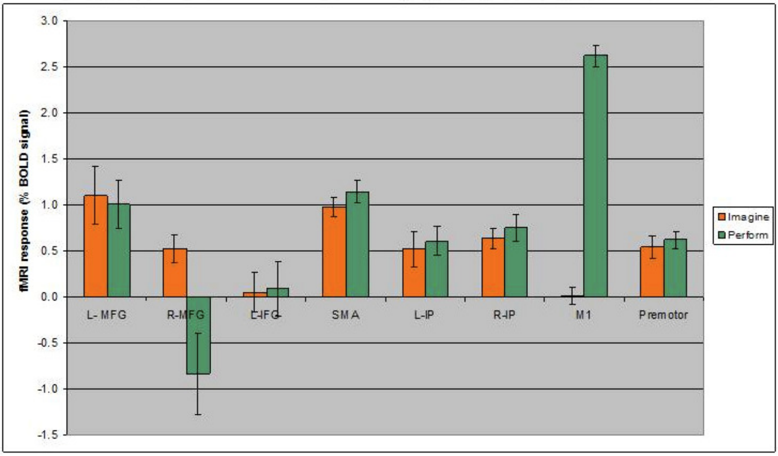

Figure 3. Average % BOLD signal of regions of interest.

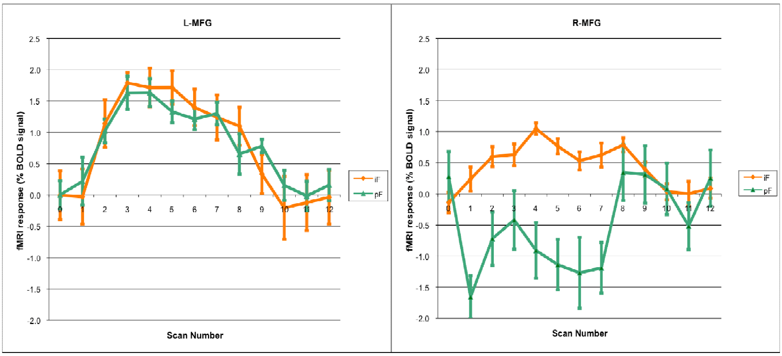

Figure 4. Time course of the BOLD signal: L-MFG and R-MFG. (See full color versions at www.performancescience.org.)

DISCUSSION

As expected for this pianist who reported vivid sound and movement imagery skills, the pattern of activation for performed and imagined piano music was similar, with the motor system of the brain showing similar activation during both conditions. The exception, as predicted, was that the primary motor cortex (M1) was activated only during performance (Lotze *et al.* 2003). In addition, motor performance showed left sided activation of the MFG, while performance imagery showed bilateral activation of the MFG. We interpret this finding in terms of a possible shift, or change in level, of attention to internally generated representations of musical content during imagery as compared with performance. In other words, imagery may engage similar processes to execution but specifically allow access to cognitive processes that are not as readily accessible during performance.

The MFG is thus a potential neural substrate for musical imagery and could provide an index to monitor the effectiveness of imagery as a learning strategy. We are in the process of scanning a cohort of pianists in order to investigate this hypothesis.

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Musical expertise and the planning of expression during performance

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Musicians often say that the ability to imagine a desired sound is integral to expressive performance. Research suggests that musical imagery abilities improve with increasing musical expertise and that online imagery may guide expressive performance when sensory feedback is disrupted. However, the effects of sensory feedback deprivation on online imagery and the relationship between online imagery ability and musical expertise remain unclear. This study tested the hypotheses that imagery can occur concurrently with normal performance, that imagery ability improves with increasing musical expertise, and that imagery is most vivid when auditory feedback is absent but motor feedback present. Auditory and motor feedback conditions were manipulated as pianists performed two melodies expressively using the score. Dynamic and articulation markings were periodically introduced into the score and pianists indicated verbally whether the marking matched their intentions while continuing to play their own interpretation. Preliminary analyses suggest that, as expected, expressive profiles are most accurately replicated under normal feedback conditions but that imagery is most vivid in the absence of auditory feedback. The improvements to online imagery ability expected to co-occur with increasing musical expertise, if observed, will support the idea that enhanced imagery abilities contribute to expert musicians' extraordinary control over expression.

Keywords: musical imagery; expertise; sensory feedback; expression; planning

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Rehearsal away from the instrument: What expert musicians understand by the terms "mental practice" and "score analysis"

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Musicians commonly talk about "mental practice" and "score analysis" in referring to widely used strategies. But these terms may not be universally understood in the same way. Eighty-nine experienced musicians from the UK, Portugal, and Spain were asked what these terms meant to them and how useful they found the strategies. Mental practice was more likely to be considered very useful than score analysis was. Interpretative phenomenological analysis was used to investigate open-ended responses to the two terms. Various underlying themes emerged, including: mental practice and score analysis as a practical activity (e.g. studying the score, where and when this took place); psychological approaches to mental representations of music (e.g. cognitive processing, imagery, consciousness); usefulness of the strategies (e.g. interpretation for performance, identifying technical difficulties); and associations to the music (e.g. structural features, composer's intentions). The findings are discussed in terms of similarities and differences between mental practice and score analysis.

Keywords: silent rehearsal; notated score; score analysis; mental representation; mental practice

In order to become experts, performing musicians, whether instrumentalists, singers, or conductors, must develop a range of musical skills during their training. Most performers (at least of Western art music) are musically literate, and generally rehearse and/or perform with the score. One of the most important skills in developing performance expertise is efficient practice, often called *deliberate practice* (Ericsson *et al.* 1993). However, in addition to practicing at the instrument, one can perfectly well practice away from it, doing so in one's mind. This mental practice is a cognitive strategy conducted prior to performance that complements and enhances physical rehearsal with the instrument (Driskell *et al.* 1994). Moreover, during formal musical training, at least in Western traditions, musicians are often taught to analyze scores formally. This enables them to understand the music and its construction, but perhaps has less to do with performance preparation.

Mental practice is clearly a strategy to assist learning (whether of an instrument or specific piece) and involves the development and enhancement of internal mental representations of the piece. Bravo and Fine (2009) studied mental practice by asking performers when they use it, what information in a notated score they found potentially helpful, and how they use that information. Survey data from Bravo and Fine (2009) suggested that performers use mental practice at all stages, from initial sight-reading to memorization and prior to polished performances. There is a variety of information available in the score to assist performers in their interpretation, understanding, and memorization of the piece.

Much of the mental practice literature in music concerns its effectiveness in improving performance (Coffman 1990, Ross 1985), but little exists on how musicians understand the terms “mental practice” and “score analysis.” They may not mean the same to all performers. The present study discusses the findings from Bravo and Fine’s (2009) survey asking expert performers what they understood by these terms, as well as how useful they find mental practice and score analysis.

METHOD

Participants

Eighty-nine performing musicians in the UK (n=60), Portugal (n=21), and Spain (n=8) completed an online questionnaire. Their mean age was 37.4 years (SD=13.3). Fifty (56%) stated that they were professional, 24 (27%) semi-professional, and 15 (17%) amateur. Forty-six were male, 40 female, and 3 did not state their gender. In all, 65 (73%) completed the questionnaire. The respondents played between 1 and 4 instruments (including conducting), and had done so for an overall average of 19.4 years (SD=13.0). Forty-eight were trained in formal musical analysis, and 17 had not had any such training.

Materials

The questionnaire consisted of 18 questions, both open and closed, providing quantitative and qualitative data. Demographics including age, sex, and musical experience were collected. The questionnaire then asked what respondents understood by the terms "mental practice" and "score analysis," how useful they found these strategies, when they use them and what information from the score they obtain in the process.

Procedure

The online survey was completed on SurveyMonkey® and publicized to groups of expert musicians. Spanish and Portuguese responses were translated into English prior to data analysis. Being of a qualitative nature, the data for the present article were analyzed using Interpretative Phenomenological Analysis (Smith *et al.* 1995, Willig 2008). Survey responses were read through carefully, and organized such that underlying themes emerged. These themes were then grouped into clusters.

RESULTS

The particular questions of relevance to this article concerned what respondents understood by the terms "mental practice" and "score analysis" and how useful they found these strategies. Seventy percent stated that "mental practice" was very useful or vital, whereas only 48% considered "score analysis" to be very useful. Over 90% claimed that they always or frequently re-heard the music in their head. There were both similarities and differences between respondents' understanding of mental practice and score analysis. Emergent themes are outlined in Table 1, and are discussed below.

Mental practice and score analysis as a practical activity

Respondents talked about the task itself in terms of what they do: reading, perusing, studying, looking through the score, etc. Participants disagreed as to whether mental practice took place for them in the presence or absence of the score, the instrument, or a recording. Mental practice took place both for specific pieces and for the instrument itself.

Psychological approaches to mental representations of music

It was generally agreed that "mental" referred to practice "in the head" or "in the mind"; a few pianists talked of practicing fingering in the air or on a table. Visualization and imagery, such as inner hearing or imagining movements, were important in mental practice, though mentioned less often in terms of score analysis. The multisensory nature of mental practice, both of the music and the performance situation, was also mentioned, for instance imagining being in the venue and experiencing relevant emotions and sensations. Some

Table 1. Emerging themes related to strategies of mental practice and/or score analysis.

Mental practice and score analysis as a practical activity	
	the task—reading/practicing/studying
	context—where and when it occurs
	presence/absence of score/instrument/recording
	analysis—seeing patterns/making connections
Psychological approaches to mental representations of music	
	cognitive processing/thinking/mental practice
	imagery/internal representations
	perception—multisensory engagement
	mindfulness—consciousness, deliberation
	analytical approaches—formal/academic vs. practical
Associations to the music	
	structural organization—form/counterpoint
	musical features—harmony/melody/rhythm
	composer's goals/intentions and context
Usefulness of the strategies	
	interpretation for performance
	planning of physical aspects
	clarifying goals/solving technical problems

Table 2. Musical and structural aspects related to score analysis.

Musical	harmony, melody, tonality, key signature, modulations, clef
	tempo, time signature, rhythm, dynamics, movement, accents
	instrumentation, voice leading, phrasing
	genre, expressive content, meaning, style
	word rhythm, text-music relationship
Structural	sections, form, patterns, salient features
	hierarchical levels—whole piece, movement, section, detail
	tone rows and their inversions
	canons, switches, repetitions, counterpoint, interplay of parts

respondents made a distinction between practical analysis (i.e. mental practice), and formal/academic analysis, much more the realm of musicologists. The latter was described as being "drier" and of "limited practical use" (male, 58), but enabling people to "find deeper patterns than initially evident" (male, 29), "know the role of each note" (female, 44) and to try "to see what is going to happen" (male, 31).

Associations to the music

One difference between mental practice and score analysis was that, when speaking about the latter, respondents were much more likely to talk both about the analysis itself and the specific musical and structural aspects of the piece, some of which are listed in Table 2. An awareness of the composer's intentions was also mentioned by some participants as being important.

Usefulness of the strategies

The way that mental practice and score analysis assisted the interpretation of the piece for the purpose of performance was an important theme. Specific aspects of performance such as pianists' fingerings, singers' breathing, the balance between instruments and interactions with others, and the musical direction of phrases, were all mentioned as being considered during mental practice and score analysis. One respondent put it: "so when you play, there are no surprises" (male, 22). Related to this was decision making: "working out what choices as a conductor there are to be made" (male, 44). Except by three people who said they never used mental practice, and five who did not use score analysis, it was generally agreed that mental practice in particular was useful in helping to prepare for performance. Identifying and thinking through technical problems and difficult passages, and planning solutions were noted. Increasing familiarity with the piece and memorization were also mentioned, both for mental practice and score analysis. Mental practice also helped one respondent to "discover the meaning, message, objective of the piece" (male, 57), and another stated that it "seeks to make the study time more profitable to avoid unnecessary muscular effort" (female, 36).

DISCUSSION

Asking musicians what they understand by the terms "mental practice" and "score analysis" yielded a wealth of information. There were both individual differences and similarities in respondents' views. It was generally agreed that mental practice increased familiarity with the piece and aided performance preparation, supporting the literature that mental practice enhances performance (Driskell *et al.* 1994). Although many musicians favored mental practice with the score and away from the instrument, some said that they did so without the score, and some while listening to a recording. This could be investigated in more detail in future. Formal analysis of the score was deemed less useful in practical terms than mental practice. Future research could investigate in more detail how different groups of musicians (e.g. pianists, singers, conductors, musicologists) emphasize different aspects in their understanding of the terms.

Note

Anabela Bravo very sadly died of cancer in July 2010 after a long struggle against the illness. She was well enough to present some of her earlier research in person at ISPS 2009 in Auckland, New Zealand, and was the driving force behind this research.

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Thematic session: Expression and interpretation

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Expression of basic emotion on playing the snare drum

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The motions used when expressing emotion in a musical performance are the target of this study, in which a professional percussionist was asked to play while expressing each of five basic emotions, such as anger, happiness, fear, sadness, and tenderness. The characteristic motions for expressing each of the emotions, such as the velocity and height of a drumstick, were then extracted, and these extracted motions were assumed to be the cues used by a player to express emotion. Finally, synthesized motions expressing each emotion were obtained by introducing a geometric average of the obtained motion data (.trc) as the average motion of each emotion. We then conducted an evaluation experiment to reproduce each of the emotions to be recognized and then confirmed that the motions actually represented a particular aspect of the emotional plane.

Keywords: motion capture system; snare drum; drumming; emotional expression; performance

The motions in musical performances are important as well as its acoustics. In recent years, the myoelectric sensor (Fujisawa and Miura 2010) and the motion capture system have often been used to analyze motion, and studies concerning performance skill have also been conducted (Dahl 2001). However, the motions used when playing with each emotion have not been reported. Therefore, the motions used when expressing an emotion in a musical performance are the target of this study. The motions of a snare drum performance displayed when specified emotion is being expressed were investigated by using a motion capture system. A professional percussionist was asked to play the snare drum while expressing five basic emotions and one non-emotion. The relation between the performed and expressed emotions was investigated by observing motion data synthesized from recorded data. The performance cues, such as tempo, vibrato, etc., that are associated with emotion were reported by Juslin and Sloboda (2001). Reports on the motion cues used when playing with emotion have not yet been presented. In Figure 1, the relation between the emotional space reported by Juslin and Sloboda (2001) and performed motion is shown.

MAIN CONTRIBUTION

Outline of measurement

We conducted a recording experiment in which a professional percussionist was asked to play single strokes while expressing each of five basic emotions. The performance task used in the experiment is shown in Figure 2. The specified tempo was 90 bpm, and the length of the performance was one minute. Eight metronome clicks, meaning the length of two bar-lines, were presented to the player prior to the performance.

Recording environment

The motions of the percussionist were recorded by using a motion capture system at a studio at the College of Art at Nihon University. The motion capture system was a MAC 3D System (Motion Analysis Corp.) recording a frame every $^1/_{200}$ s at a shutter speed of $^1/_{1000}$ s. The number of markers on the player was 30, as shown in Figure 3.

Measuring emotional motion

Extracting motions from one bar-length: To obtain the tendencies of the motions displayed during a performance, the motions for the four strokes in one bar-length were recorded. The geometric average for all the recorded motion in one bar-length was then calculated, meaning the average motion, named "emotional motion", which was represented as a matrix whose size was 90 (30 points with 3 dimensions) x the number of samples (580 in this example). The emotional motions obtained were M_t (for tender motion), M_h (for happy motion), M_s (for sad motion), M_f (for fear motion), M_a (for anger motion), and M_n (for non-emotional motion). Next, by subtracting geometrically the M_n from each of the emotional motions (or in this case, subtracting the .trc data), we then obtained the differentials for each of the emotional motions, which were M_t', M_h', M_s', M_f', and M_a'.

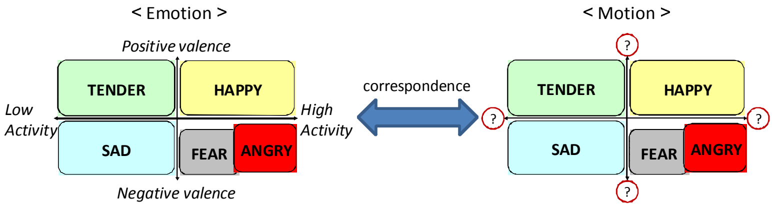


Figure 1. Relation between emotional space and performed motion.

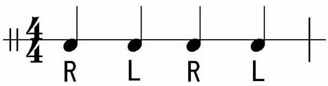


Figure 2. Performance task used in the experiment.

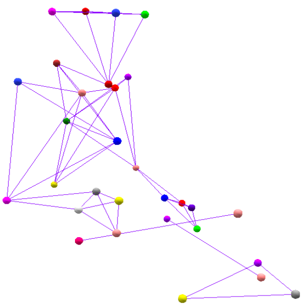
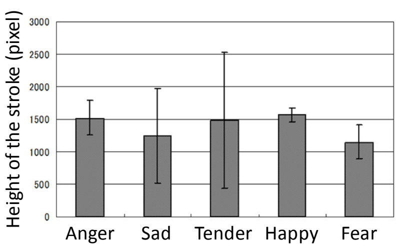


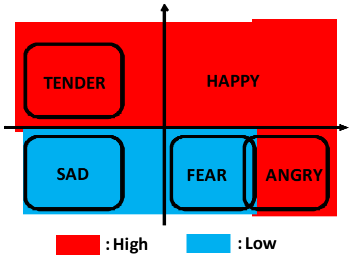
Figure 3. Positions of markers on the player. (See full color versions at www.performancescience.org.)

Comparing emotional motion: To determine the nature of each motion, we obtained an exaggerated version of each of the motions by multiplying each M_t', M_h', M_s', M_f', and M_a' with five and then it adding the result geometrically to M_n, generating exaggerated motion data for each emotional motion. Although these exaggerated motions were unnatural, they enabled us to see the nature of each emotional motion.

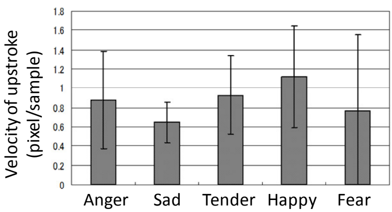
Nature of emotional motion: By observing the differences between the exaggerated emotional motions, we found the tendencies of the differences in the height of a stroke, the velocity of an upstroke, and the velocity of a down stroke, as shown in Figure 4(a), (c), and (e). The height and two velocities were obtained by observing constantly the tip of each drum stick for each



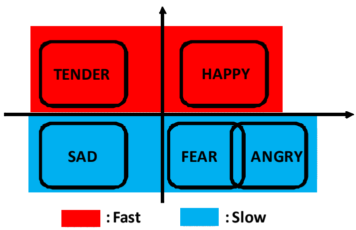
(a) Height of stroke



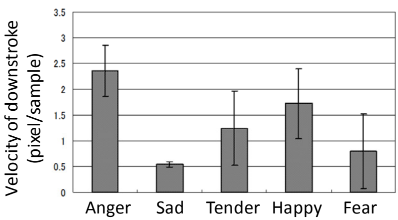
(b) Height of stroke in emotional plane



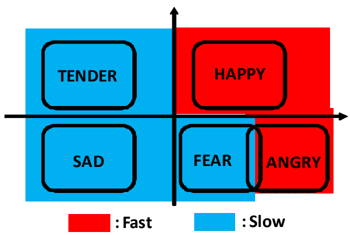
(c) Velocity of upstroke



(d) Velocity of upstroke in emotional plane



(e) Velocity of downstroke



(f) Velocity of downstroke in emotional plane

Figure 4. Nature of each emotional motion for the specified aspects of the drumsticks and the relation of each aspect to the emotional spaces reported by Juslin and Sloboda (2001). (See full color version at www.performancescience.org.)

frame. In addition, the relation between the emotional space reported by Juslin and Sloboda (2001) and each emotion is shown in Figure 4(b), (d), and (f). Since the tendencies were observed, the aspects for each drumstick are referred to as motion cues, which correspond to the axes in the two-dimensional space that represents emotion.

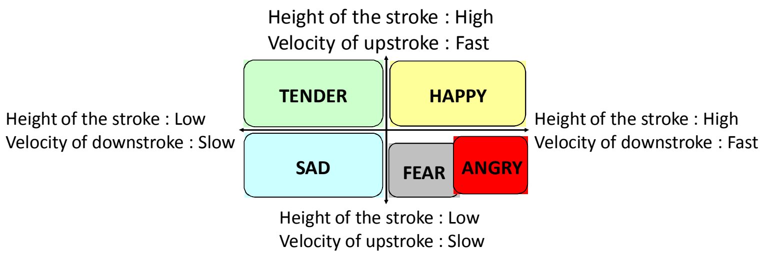


Figure 5. Relation between the combinations of the motion cues and the emotional planes reported by Juslin and Sloboda (2001). (See full color version at www.performancescience.org.)

IMPLICATIONS

Using motion cues when expressing emotion through performance

By comparing obtained motion cues with two axes, activity and valence, we could see that the axis for activity corresponded to the height of the stroke and the velocity of the down stroke and that the axis for valence corresponded to the height of the stroke and the velocity of the upstroke, shown in Figure 5.

Synthesizing motions with specific aspects

We synthesized motions with the specific aspects given in Figure 5. We extracted a motion along with one of the denoted motions on the ends of each of the axes in Figure 5 and then obtained the geometric average of the two motions as *.trc data, named “synthesized motion.” For example, in the case of synthesizing the motion for happiness, we extracted two motions, one with the maximum height of a stroke and the velocity of an upstroke and the other with the maximum height of a stroke and the velocity of a down stroke, so that we could confirm that the motion denoted in Figure 5 actually represented that particular aspect of the emotional plane.

Experiment for subjective recognition

We conducted an experiment to recognize each five of the basic emotions. We used emotional motion without exaggeration, exaggerated emotional motion, recorded video, and synthesized motion, labelled “1x”, “5x”, “Video”, and “Synth.”, respectively. We presented five subjects with 20 patterns of motions (5 emotions x 4 types of stimuli) and asked them to identify an expressed

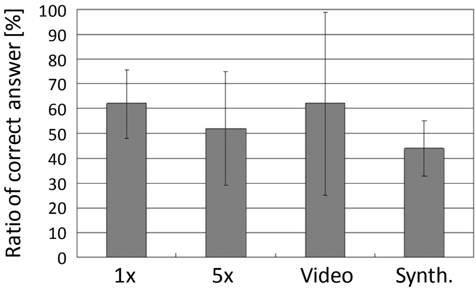


Figure 6. Average and standard deviations of correct ratio of answers by all subjects.

emotion. The average of the correct answer, shown in Figure 6, shows that no significant differences were determined by tests such as Tukey's HSD, Dunnett's T3, and Dunnett's C. We found that the synthesized motions correctly represented an emotion with the same accuracy as other stimuli.

Juslin and Sloboda (2001) stated that several cues for representing emotion are used differently among players but that they are powerful even though they are communicated in an ambiguous way. This study shows that motion cues exist in a professional percussionist on the basis of the relation confirmed by the synthesized motions.

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What can we learn from idiosyncratic performances? Exploring outliers in corpuses of Chopin renditions

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Recent work in expressive timing has resulted in robust models that can predict much of the variance in the durations of events in performed music and generate convincing renditions. Many of these models translate a representation of musical structure into a map of performance decisions. But this translation treats "musical structure" as a ground truth from which performances might be generated or models might be assessed. An unfortunate consequence of this methodology is that idiosyncratic performances might be deemed poor reflections of musical structure. Yet most passages will afford multiple structural descriptions, and idiosyncratic renditions might be understood to widen a piece's interpretative range. In this article I focus on Joseph Stefanits's outlying rendition of the interior of Chopin's Nocturne in B*b* minor, Op. 9, No. 1, attempting to understand it as a novel description of the "structure" of the work. It is not my intention to criticize methods of scholarship that focus on conventional performances (without which Stefanits's rendition could not be called idiosyncratic): my aim instead is to construe performance as a source of knowledge in its own right, rather than just a reflection of musical structure.

Keywords: expressive timing; interpretation; music theory; meter; music performance

The study of expressive timing in performance has flourished in the last three decades, and the development of ever more robust algorithms for extracting performance features from audio may prompt more work in this area. Because of this research we can now claim a number of general statements about the relationship between "musical structure" and performance timing, including the following:

- Performers "curve" phrases through acceleration/deceleration patterns (Todd 1985).
- Timing correlates to meter-specific profiles (Palmer and Krumhansl 1990).
- Timing contains traces of bodily motion, such as large leaps (Widmer 2002).

There are at two commonly used methods for verifying such statements. Some statements about performance timing begin as speculative models that are later shown to be correlative to expert performances (Clynes 1983, Todd 1985). Other statements about performance timing are derived from average tendencies of performers discovered by examining large collections of existing recordings using various statistical and machine-learning techniques (Repp 1992, Widmer and Tobudic 2003).

The study of average tendencies in performance can be justified on both utilitarian and aesthetic grounds. If performance timing reflects a performer's understanding of musical structure (even in an implicit way), then successfully modeling the most common strategies can provide the most complete description of cognitive processes (Clarke 1989). As Bruno Repp has shown, performances that most closely approximate conventional playing are preferred by audiences in certain settings; this finding mirrors reports that, for example, "average" faces are judged most attractive (Langlois and Roggman 1990, Repp 1997).

One issue with this approach is that it assumes a one-directional mapping from musical structure ("the score") onto performance decisions (Cook 1999). As such, a structural description of a piece is taken to be a ground truth that can verify speculative models of performance or explain tendencies evident in corpuses of renditions. But musical structure is not (always) a fixed entity: rather, structure arises at the intersection of musical content "on the page" and individual listeners' experience of that content (Guck 2006). Sometimes there will be wide intersubjective agreement—there is a half cadence in the fourth bar of the first movement of Beethoven's Symphony No. 6. Just as often, no group of listeners, regardless of musical experience, will be able to arrive at a consensus structural description. Because music affords a wide variety of structural descriptions, and because performances can give voice to those descriptions, idiosyncratic performances might be understood as widening the range of known descriptions of a piece, rather than poorly expressing its "structure" through common performance strategies (Dodson 2008).

Below, I discuss the idiosyncrasies of a portion of Joseph Stefanits's rendition of Frédéric Chopin's Nocturne in B*b* minor, Op. 9, No. 1, that is a

Figure 1. Frédéric Chopin, Nocturne in B*b* minor, Op. 9, No. 1, bars 20-27.

rather extreme outlier within a larger corpus of performances (see Figure 1). By highlighting the ways in which it diverges from an average performance, I will argue that Stefanits suggests a novel description of the Nocturne's structure, one given license by the score though not necessarily predicted by it. It is not my intention to criticize methods of scholarship that focus on conventional performances: without those methods (that I myself employ elsewhere) I would be unable to call Stefanits's rendition "idiosyncratic." My aim instead is to construe performance as a source of knowledge about a piece in its own right, not only a vessel that can communicate that knowledge to a greater or lesser extent.

MAIN CONTRIBUTION

The passage in question, from the interior of the Nocturne, is purportedly in D*b* major. The first four bars outline a common tonic-dominant-dominant-tonic progression in that key, resulting in a cadence in the fourth measure. The second four measures shift abruptly to D (natural) major and decorate that pitch with its own tonic-subdominant-tonic progression before moving back to D*b* at the end of the phrase. The passage in D major (i.e. bars 25-26 and its three subsequent) appears as a kind of tonal retreat, growing even softer than the *sotto voce* music at the beginning of the section.

Successful models of expressive timing might suggest two phrase arches for each of these four-measure phrases, and perhaps a slight lengthening on metrically strong positions. An averaged performance of the passage, comprised of 20 renditions, is well explained by such a model, presenting two approximate curves when durations are measured at the dotted half-note

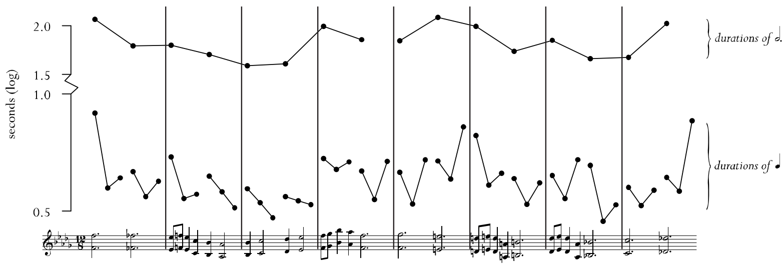

Figure 2. Bars 20-27, durational contour of an averaged performance with durations measured at the dotted half-note level (upper contour) and the quarter note level (lower contour).

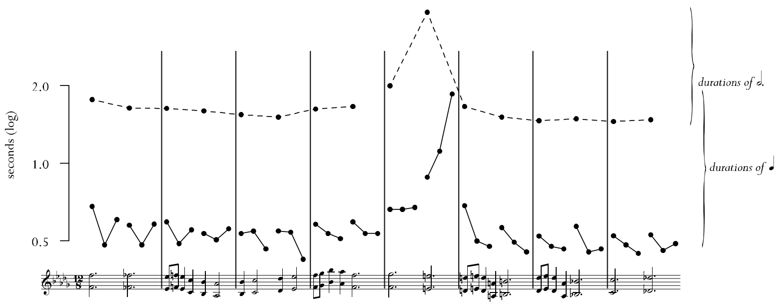

Figure 3. Bars 20-27, durational contour of Joseph Stefanits's rendition, plotted analogously to Figure 2.

level and a number of "v-shaped" contours when durations are measured at the quarter-note level (see Figure 2).

Stefinits's approach to the first four measures are largely similar (see Figure 3); a general curve at the slower rate of measurement is paired with metric accentuations on the first beat of each three-beat group (Stefanits's rendition is available at www.youtube.com/watch?v=ljbXHVCoisE). But in the second phrase Stefanits departs from the average tendency by coming to a near standstill at the end of the fifth bar. If lengthening is a primary means by which performers suggest salient moments in generative grouping or tonal structure, then Stefanits seems to construe the D major chord on the downbeat of the sixth bar as a point of tonal arrival. This decision may have implications for how listeners construe the tonal structure of the passage in question and also the piece as a whole.

In Stefanits's rendition, D*b* major (which begins the passage) is cast as preparation to D major in the sixth bar; in the average performance (and likely in most descriptions furnished by listeners and performers), D major in the sixth bar decorates D*b* major (as its Neapolitan). When listening to Stefanits arrive at D major, one might experience a kind of poignancy that a tonal area apparently so significant is abandoned after just one measure. Since the passage repeats several times in the interior of the movement, the poignancy is magnified as the abandonment recurs. In a larger frame of reference, Stefanits's dwelling on an apparently subordinate tonal area complicates a description of the tonal form of the whole Nocturne. The piece appears to be a relatively common three-part form in minor with a middle section in the relative major, but in Stefanits's rendition, that relative major may not be established as key in one's listening experience. There is little reason for a model of timing to predict this performance strategy since it appears motivated by a unique construal of the piece's tonal structure. Rather than dismissing Stefanits as an outlier who does not conform to successful models, we might be encouraged instead to expand our notion of what this passage of the Nocturne might mean to different performers and listeners.

IMPLICATIONS

In the common methodology for studying the connection between expressive timing and musical structure, the structural description is understood as an objective feature that can be used to predict conventional performances. But this may be an impoverished view of the nature of musical works. Pieces can afford multiple structural descriptions, perhaps even conflicting ones, because these descriptions address the hearing of individuals with unique lived experiences (Kielian-Gilbert 2003, Guck 2006). While we should continue to look to conventional performances as a testing ground for theories of expressive timing, there is room in performance science studies to turn this method around. In addition to investigating how conventional performances verify or challenge particular theories, we should also investigate how idiosyncratic performances might enlarge the collection of meanings we can ascribe to a piece. To take idiosyncrasies seriously, to resist discarding them as outliers or diluting their salience, scholars must also acknowledge the limitations of models of performance. In exchange they may gain a richer understanding of the varieties of experiences a piece can afford.

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Toward a multilevel model of expressive piano performance

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Expressive performance modeling requires different information for each expressive dimension. Most systems, however, rely on a single approach for all dimensions. Further, tempo and timing are mostly treated as one atomic entity instead of being decomposed into elements and treated separately. We propose a performance model that discriminates expressive dimensions with regard to the modeling approach and, additionally, uses separate subsystems to model tempo and timing.

Keywords: expressive piano performance; performance model; support vector machines; probabilistic reasoning; multi-level model

Modeling expressive musical performance is a complex task with information requirements that vary from one expressive dimension to another. For example, dynamics is guided to a considerable extent by annotations in the score, whereas the overall performance tempo is more closely related to phrasing (Todd 1989). Timing and articulation, however, may depend more on local aspects of the score.

Performance modeling systems normally rely on one of three common approaches: (1) probabilistic models (e.g. Grindlay and Helmbold 2006), (2) rule-systems (e.g. Friberg *et al.* 2006), or (3) case-based reasoning (e.g. Widmer and Tubodic 2003). The system we discuss in this study differs from the bulk of performance rendering systems in two significant aspects. Firstly, common to all the systems is that they use the same approach for all performance dimensions. The system we present takes a modular approach that treats dynamics, articulation, and tempo differently. Secondly, with the noteworthy exception of Widmer and Tubodic (2003), most systems view tempo and timing as an atomic dimension of performance. We consider the tempo curve of a performance to be an aggregate of different components which we treat separately: timing of individual notes (*note timing*), phrase-related tempo trends (*local tempo*), and global performance tempo (*tempo markings*).

Our performance model has its roots in the probabilistic rendering system YQX, which won the Rendering Contest RENCON 2008 (Hashida *et al.* 2008). A detailed description of YQX can be found in (Widmer *et al.* 2009). In the original system, a simple Bayesian Network predicted tempo, loudness, and articulation. While the prediction of articulation remains the same in the current system, tempo prediction is replaced by three subsystems, one for each of the components mentioned above. The loudness model is replaced by a model relying on a decomposition of the dynamic annotations in the score (Grachten and Widmer 2011). In this study, we discuss how we handle two of the aspects of performance tempo: local tempo and note timing.

METHOD

Data and score representation

The system is trained using two unique corpora of performances: 13 complete Mozart piano sonatas performed by Roland Batik and the complete works for solo piano by Chopin performed on stage by Nikita Magaloff. All pieces were played and recorded on a Bösendorfer computer-controller grand piano and converted from Bösendorfer's proprietary format to MIDI. All performed notes were aligned to their counterparts in symbolic representations of the score. This resulted in a collection of performances with detailed performance and complete score information for each note.

We describe the score using a combination of local descriptors (rhythmic and melodic) and higher-level features from the Implication-Realization (I-R) model of melodic expectation by Narmour (1990):

- *Duration ratio* describes the ratio between the score duration of a note and its successor.
- *Rhythm context* is an abstract description of a note's duration in relation to its neighbors (e.g. long-short-long).
- *Metrical strength* describes the metrical importance of a note-onset.
- *Pitch interval* measures the distance to the next note in semi-tones.
- *IR-label* is the name of the I-R situation applicable to a note.
- *IR-arch* measures the distance to the next point of strong closure according to an I-R analysis of the score.

Modeling "tempo" as a composite phenomenon

In musical performances, tempo usually refers to a combination of three aspects: (1) *global tempo* refers to the initial tempo prescription at the beginning of a score; (2) *local tempo* describes localized tempo trends which, for example, outline larger musical units (e.g. phrases) and realize annotations in the score; (3) *(local) note timing* refers to local (note-wise) deviations from the local tempo that emphasize single notes through delay or anticipation. In order do make the tempo as observed in a performance independent of *global tempo*, we transform it into a series of logarithmic ratios between score and performance inter-onset intervals (IOIs). We call the result *complete tempo curve* and view it as a composite of local tempo and note timing. More precisely, we associate *local tempo* with the low-frequency content of the complete tempo curve, which we extract by applying a moving average. The residual, the curve that remains after subtracting the local tempo from the complete tempo curve, is associated with *note timing*.

Predicted tempo and timing

Assuming that note timing is a local phenomenon, we model and predict it using the simple Bayesian approach of the original YQX system. The predictions depend only on the immediate score characteristic of each note. With respect to local tempo, we consider two methods: (1) the performance-context-aware Bayesian model presented in Flossmann *et al.* (2009; YQX-global) and (2) support vector machines with and without local performance context (SVM and SVM-C, respectively). The Bayesian network approach is an adaptation of the Viterbi-Algorithm for Hidden Markov Models that results in a tempo prediction that is optimal in the sense that at each point the prediction is the value with the highest probability given the current score characteristics and performance predictions. The SVM we use is a regression model with a Gaussian kernel. To incorporate performance context, we use the previously predicted tempo value as an additional input feature.

RESULTS

In this section, we first discuss the results of experiments using both the Mozart and the Chopin corpora and then inspect qualitative aspects of the different predictions. The experiments were conducted on subsets of the corpora, selected according to stylistic criteria—fast and slow movements for the Mozart sonatas, different categories (ballades, nocturnes, etc.) for the Chopin data—as they might contain different interpretational concepts that could

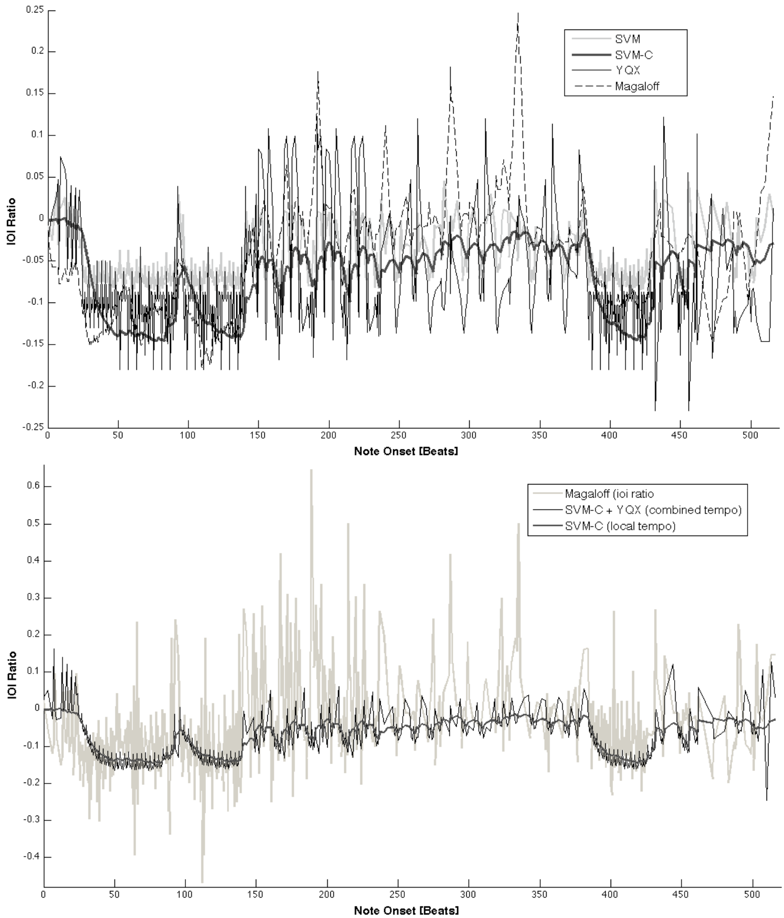

Figure 1. Local tempo predictions by three algorithms for Waltz Op. 34 No. 3 (upper panel) and tempo curves for Waltz Op. 34 No. 3 (lower panel), as observed in Magaloff's performance and combined from separate predictions for local tempo and note timing.

also be reflected in the predictions. As a numerical quality indicator, we use the correlation coefficient that measures the similarity between the predicted and the real tempo curve.

The quality of the results of the different algorithms depends heavily on the selected subset of score features and the tempo aspect they are trained to predict. Their respective best results are based on different sets of features, which suggests that different dimensions of tempo indeed depend on different aspects of the score. Trained with suitable feature sets, the note timing predictions of the different algorithms are numerically comparable, with the context-free algorithms YQX and SVM performing slightly better. For predictions of local tempo it seems beneficial to incorporate the performance context: both context-aware algorithms, YQX-global and SVM-C, outperform the context-free algorithms by roughly 15%.

Qualitative evaluation

Although the quantitative evaluation does not indicate significant differences between the algorithms, the curves they predict exhibit discriminating characteristics. Figure 1 shows tempo curves predicted for Waltz Op. 34 No. 3 by Chopin. The upper panel illustrates a typical situation often found in predictions for local tempo: the prediction made by the context-free Bayesian approach (YQX), while reasonably similar to the original (r=0.37), exhibits sharp fluctuations, which is not a desired characteristic for local tempo. The curve predicted by the context-free SVM is more similar to the original (r=0.49) but comparably unsteady. Both algorithms have only information about the local score context, which explains the similar behavior. Integrating the performance context seems to have the desired effect: the curve predicted by the context-aware SVM (r=0.66) is much smoother with distinctive trends. The lower panel shows a complete tempo curve assembled from a local tempo prediction with a context-aware SVM, and a note timing prediction with the context-free YQX. The resulting curve retains the coherent tempo trends from the local tempo prediction and is enriched by the local variations from the note timing prediction. Compared with the result of a context-aware SVM trained to predict the complete tempo curve directly, the correlation of the combined prediction is slightly lower (r=0.38 and r=0.41, respectively). However, the combined curve is steadier than the directly predicted curve and displays much clearer trends.

DISCUSSION

We have presented a performance model that takes a multi-level approach to tempo prediction: instead of searching for one model for all aspects of tempo, components relating to different levels of locality are modeled by specialized subsystems and afterwards combined to form the tempo. The resulting tempo curves seem to reproduce better the musicality of the performances. This is not always reflected in the numerical similarity, but rather than suggesting an aesthetically inferior result, this casts doubt on the suitability of correlation as a quality indicator. Further research will explore evaluation criteria that are musically more meaningful. Another fundamental problem is the score model: simple score descriptors cannot capture abstract musical concepts such as phrase boundaries, cadences, and harmonic suspensions. We believe that the most promising line of investigation lies in creating a more musically meaningful score model that describes the score at several different levels.

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Thematic session:
The science of string playing

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Mastering the violin: Motor learning in complex bowing skills

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A pilot study is presented comparing the performance of complex bowing patterns of three violinists. Analysis of the movements revealed a subtle coordination between string crossings and bow changes in repetitive bowing patterns across two and three strings. Clear differences between the performances of the three players were found that could be interpreted in terms of consistency and efficiency of movement. The pilot study forms an upbeat to a planned study to characterize the motor learning process in bowing skills from intermediate to expert level.

Keywords: violin; bowing; movement; motor learning; practicing

The violin and other bowed-string instruments are known to be difficult to master. This can for an important part be led back to the critical constraints involved in the sound generation process, which require a precise spatiotemporal control of bowing actions (Rasamimanana 2008, Demoucron 2008, Schoonderwaldt 2009). The development of the necessary motor skills involves many hours of practice under critical guidance by the ear. However, not much is known in any detail about the motor learning processes that take place, in short term during practice, as well as in the long term in the development toward expertise.

Studies of motor control in bowed string performance have mainly been dealing with expert performers (Winold *et al.* 1994, Shan and Visentin 2003). Recent studies have explored the use of modern motion analysis techniques in string pedagogy (Konczak *et al.* 2009, Visenting *et al.* 2008, Larkin *et al.* 2008, van der Linden et *al.* 2011). However, the focus of these studies has mainly been limited to relatively basic bowing skills (e.g. legato playing and the development of a straight bow stroke) and novice performance.

Currently, there is a lack of studies dealing with the learning of complex bowing skills, which form an essential part on the way toward expertise. The main objective of the current study is to address these issues and to gain more insight in motor learning and refinement in a range of complex bowing skills. The focus is on the development from intermediate to expert level. An important aspiration is the generation of pedagogically relevant findings, which in the long term could lead to optimization of practicing and teaching strategies in professional education.

In this article, a pilot study is presented of a particular class of complex bowing patterns. The movements of the bow relative to the violin were recorded using a motion capture system. An analysis is presented of repetitive movement patterns in fast 16th-note passages involving coordinated bow changes (reversal of bowing direction), and string crossings.

METHOD

Participants

Performances of three violinists were analyzed for this study: two advanced music students (player 1 and 2) and one amateur player (player 3).

Materials

A 3D motion capture system was used to measure the position and the orientation (6 DOF) of the bow and the violin. An additional sensor was used for measuring the bow force. This method allowed for a complete measurement of the bowing parameters used by players to control the sound (Schoonderwaldt and Demoucron 2009). The movements of the bow were transformed to the (moving) local coordinate system of the violin.

Procedure

Performances of the first 28 bars of J. S. Bach's *Preludium* from the third Partita for Solo Violin (BWV 1006) were recorded. One of the advanced students (player 1) was familiar with the piece; the other student (player 2) was sight-reading; the amateur player (player 3) was also familiar with the piece. The analysis focused on the spatiotemporal coordination of string crossings and bow changes in two types of complex repetitive bowing patterns (see Figure 1). Both fragments are played *détaché*: in fragment 1 two strings are alternated, fragment 2 is played as an arpeggio across three strings.

Figure 1. Selected passages for analysis of repetitive bowing patterns.

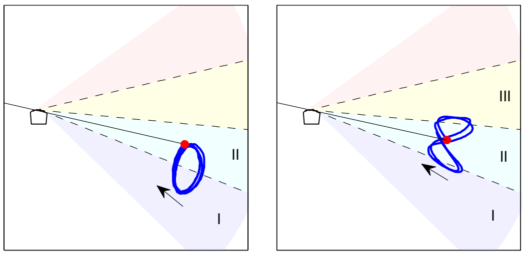

Figure 2. Examples of the bowing patterns corresponding to fragment 1 (circular pattern) and fragment 2 (figure-of-eight pattern) by player 1. The plots show the bowing pattern from the player's perspective. The dashed lines separate the angular zones corresponding to the respective strings.

RESULTS

The two types of complex bowing patterns correspond to spatial trajectories of the bowing hand in the shape of a circle and a figure-of-eight, respectively, as illustrated in Figure 2.

The coordination between bow changes and string crossings in the circular bowing patterns was illuminated by a derivate representation of bow inclination (the bow angle relative to the violin used to select the string) versus bow velocity (velocity of the bow perpendicular to the string). Figure 3 reveals a clear hysteresis in the patterns of all three players, which indicates that the string crossings occur slightly earlier than the bow changes (zero bow velocity). This may seem surprising at first; intuitively one could expect that string crossings and bow changes should co-occur. However, taking the mechanics of the bowed string into account, this behavior could be explained by the fact that a minimum amount of bow force is required for a proper start of a tone (Guettler 2002, Schoonderwaldt 2009). Thus, the lead of the string crossings

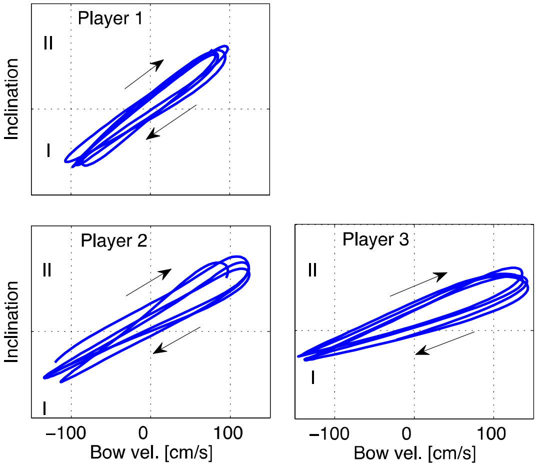

Figure 3. Plots of bow inclination versus bow force showing the performances of fragment 1 (circular bowing pattern) by all three players.

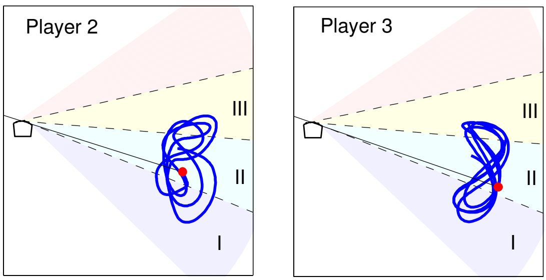

Figure 4. Performances of fragment 2 (figure-of-eight bowing patterns) by players 2 and 3.

represents an optimized strategy related to the transfer of bow force between strings, which is necessary for the production of clean note transitions.

Figure 3 also reveals some subtle differences between the players. The pattern produced by player 1 formed a rather regular ellipse, which indicates a constant phase relation between the two movement components. The sharp cusp visible in the patterns of the other two players, most notably player 3, reveals the presence of variations in the relative phase, which might be an indication of a less efficient movement pattern.

The figure-of-eight pattern, which is considerably more difficult to produce, revealed greater differences between players. Player 1 (see Figure 2) produced the most stable pattern, characterized by a similar lead of string crossings as demonstrated in the circular pattern. The performances of player 2 and 3 are shown in Figure 4. Player 2 (sight-reading) was not able to produce a stable performance at all. Player 3 (amateur) was able to perform the passage but was less consistent than player 1 and had much less control of the coordination between string crossing and bow changes. It could be confirmed by listening to the recording sound that the note transitions were less well defined and noisier. Furthermore, it can be seen that player 3 exhibited a larger amount of "overshoot" on the outer strings (string I and III) compared with player 1, indicating a less efficient movement for making string transitions.

DISCUSSION

The pilot study revealed clear differences between the performances of the three players. The differences could be interpreted in terms of consistency (regularity of the pattern) and efficiency (variations in relative phase between movement components, movement amplitude related to string transitions). Furthermore, it was found that a few features were sufficient to characterize the complex bowing gestures described in this study—namely, the relative phase between two periodic movement components and the amplitude of the movement associated with string crossings.

In the near future a cross-sectional study is planned to describe long-term development of a representative set of bowing skills in violinists during the course of professional music education. Similar sets of features will be defined for an adequate performance characterization, allowing for comparison between individuals and groups. In addition to the movements of the bow relative to the violin, which have a direct relation to the control of the sound, the movements of the bowing arm will be analyzed in order to gain insight in the physical production of tone in bowed string instrument performance. A long-term goal of the studies is to provide a contribution to more effective teaching and practicing strategies.

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BowScribe: Supporting the violinist's performance model

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Musicians often learn about their vision of a piece through practicing it and listening to recordings. However, this does not always free the player to develop his or her own interpretation of the piece, especially when technique is lacking. We have developed software, the *BowScribe* markup language, that supports a violinist in creating a "performance model" of a piece currently beyond his or her playing skills, by allowing the player fine control over tempo, volume, and articulation, including playing of chords, at a level of expressiveness and flexibility that is significantly beyond the MIDI playback modes of popular music notation software. BowScribe has been used by the first author (who was trained as a professional violinist) to create a model of the entire Bach *Chaconne* (edited by Galamian), a long and demanding piece of music for solo violin that has many phrases that span groups of chords as well as melodic passages. The markup language specified chords to be rolled in two classic ways, as well as a wide variety of other strokes, including greater volume for individual notes in long slurs and small but essential variations in tempo.

Keywords: violin; performance; tool; computer; model

String performers spend much time developing their technique. However, unless they grow as interpreters of music, their improved technique will not be sufficient to attain their musical goals. Our thesis is that it is possible to develop a software system that helps a string player to develop their ideal performance model of a piece, using annotations to express fine control over the performance.

There has been significant work done on synthesizing performances using rule-based systems (Frieberg *et al.* 2006) and tuning rule-based systems to create a performance that is similar to that of a particular performer (Zanon and de Poli 2003). These lines of work are significant for our research because they demonstrate that performers have specific styles that are different enough to be worth studying. This is explicitly supported by work on automatically recognizing violinists playing Bach's solo sonatas and partitas (Molina-Solana *et al.* 2008). This has some interesting implications for the student who develops his or her own model. Such a student must abstract away from performances by prominent musicians, or absorb their habits and expressive characteristics. Other work on the importance of learning from a musical model (Rosenthal 1984) and taking the experience of the listener into account when evaluating the success of a performance (Gabrielsson and Juslin 1996) suggests that students constructing their own models would do well to involve the critical ear of others.

MAIN CONTRIBUTION

Our thesis is that software tools can help novice and intermediate players to work on their interpretation concurrently with technical mastery. To demonstrate this, we have developed a combination of notation and computer software that helps the player to create a "performance model" of the piece. The system is called *BowScribe*, and it has been implemented. The system takes music text expressed in the standard Lilypond format. The user then annotates the text file and runs our software application, which outputs a typeset score with the annotations, as well as a MIDI file enhanced by those annotations. The user can listen to the system's MIDI output, analyze it, and refine the annotations. Eventually, this process produces a performance model with which the user is currently satisfied, at which point the user can go back to developing the technique required to achieve the desired interpretation. The BowScribe notation and software are open source.

We have evaluated BowScribe by using it to develop a performer's model of some of Bach's solo works for the violin. Some existing software, such as the commercial Sibelius package, supports simple rolled chords, but more control is needed. In particular, we need a way to stop the roll at the point where the melodic line cuts through the chord. This can occur at the bottom, middle, or top of the chord. Sibelius and Finale support crude tempo changes in playback, indicated by metronome markings or tempo change notation such as *ritardando* etc. However, what is often needed is just a slight tempo change to express rubato on one or two notes within a whole phrase without rubato. Digital audio workstations provide powerful facilities for enhancing MIDI once it is generated by another tool, as does Rosegarden, an open source audio and MIDI sequencer and processor. However, these are designed to treat MIDI just as a stream to be converted to audio.

An initial example

To illustrate BowScribe, consider a simple example. Figure 1 shows four annotated passages from the Bach *Chaconne*. The annotations were added by the violinist while working out an interpretation. The score shown in the figure was typeset by Lilypond, and BowScribe has generated a corresponding MIDI file. The first line gives bars 9 and 10, the second bar 30, the third bar 98, and the fourth bar 122. At the tops of these bars, there are annotations that are combined by our software with MIDI generated from the Lilypond text file.

We start our discussion with the bar 30 (the second line in Figure 1). All annotations start with "$." and the annotation for articulation is "l*n*", where *n* ranges from short to medium (1 to 5), and medium to longer (6 through 9). The default sounds as if the note is slurred.

Looking at the first four sixteenth notes, we see that the first annotation will shorten a stroke with three notes. The second annotation gives a more precise way to identify the shortened note by specifying the part of the slur to be shortened, so for the second slur we write $.x3.l6, meaning that there are three notes which are to have the default articulation, followed by a note that will be shortened.

Figure 1. Excerpt from the score of the Bach *Chaconne* for solo violin. Annotations have been added, as explained in the text. Our software generated MIDI incorporating the annotations, and Lilypond typeset the score shown here.

The annotation for relative note intensity is "i*n*", where *n* ranges from soft to medium (1 to 5) and medium to loud (6 to 9). This is useful when a note within a passage should be relatively loud.

For example, in bar 98 of the Bach *Chaconne*, we want to accentuate the notes at the top of the arpeggiated section and follow them as they descend. There are two annotations: $.i7.i5 and $.i5. The first indicates that the first of two notes will be louder than the second, whereas the second annotation returns the stroke to the default dynamics.

A more complicated example

The next example comes from the Bach *Chaconne* (bars 9 and 10), at the very beginning, and contains chords and bowstrokes of varying lengths (see the top line in Figure 1).

The new annotation we will need is one that indicates the type of chord used. If the notes in the chord are to be broken and one of the notes in the chord is played at the end, then we use "b*n*" where *n* indicates which note of the chord will be played last (1 for top string, 4 for bottom). If the notes of the chord are played simultaneously, or the upper string carries the melody, then we use "u" (which can also be used with single notes to economize on notation needed for passages in which single notes are mixed with chords that finish on the top note).

Notice that in this example several chords are rolled to the note on the top string and then to the bottom note. This is done so that the line of the melody, which is being played on the lower strings of the instrument, is emphasized.

Finally, we show an example (bar 122, the last line in Figure 1) in which a relative change in tempo is inserted. The annotation for relative change in tempo is "c*n*", where *n* is slow to medium (1 to 5) and medium to fast (6 to 9). In the last line of Figure 1, we would like the first note of the bar to be a little longer and louder than usual, to emphasize the contrast between it and the rest of the bar.

Working with the Bach *Chaconne* as a whole

The Bach *Chaconne* is a piece for solo violin which takes 13 pages in the Galamian edition that we used. It is interesting to study because chords are pervasive throughout the piece and because it is composed of variations on a very small theme. In order to handle the chords in a satisfactory way, we must ensure that there is a way to emphasize the melodic line when it runs through a series of chords and a way to specify the articulation of the bow strokes playing the chords. The variations on the theme require careful study because many of them continue on into the next variation without any change in phrasing, but some require substantial *ritardandi*, with emphasis on certain notes.

For example, in bars 1 to 8, the main theme appears in chords, with the melodic line at the top of the chords, and each bow stroke is long, allowing the chords to ring out without stopping the string. We use the annotation $.ul7c4, indicating that the articulation is longer and the tempo is slightly slower than usual. However, the next section, bars 9 through 16, is significantly different because Galamian indicates that the articulations of the strokes are shorter, almost like a dance, and the melodic line is at the bottom. Here, we use the annotation $.b3.l6, which does not specify a tempo change (thus resetting the tempo from the previous annotation, c4), and which indicates that the melodic line is carried at the bottom of the chord. Varied articulation annotations are used to heighten the interest during the rest of the section before bar 89, at which point the first arpeggio section starts.

Here, we emphasize the notes at either the bottom or the top of the arpeggios, and after some parts of that section are completed, we vary the tempo slightly. At the end of the section, the tempo should slow significantly to prepare for the later re-entry of the theme, again in chords. The rest of the piece is annotated in a similar way.

IMPLICATIONS

The BowScribe notation allows a violinist to express subtle aspects of the performance, and the software tools typeset the music and generate MIDI output. The system allows a string player to experiment with various choices in interpretation, and to listen to the result, even before their technique has reached the level required to play that interpretation. The system also makes it possible to achieve greater control over audio generated from MIDI.

As can be seen from our examples, writing Lilypond and annotations can be a job that requires precision. The current system demonstrates the capabilities of such a detailed notation and software tools, but it is not easy to use. In future work, we plan to experiment with an interactive WYSIWYG music editor that automatically generates the textual notations, while allowing the performer to use annotations that are as intuitive and expressive as possible.

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Designing a didactic tool to facilitate the integration of improvisation in the teaching of violin: Content of the final prototype

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The goal of this study was to create a pedagogical tool to facilitate the integration of improvisation in the curriculum of violin lessons. Following a methodological approach specific to *development research*, the topics of the tool were determined according to the needs expressed by three violin teachers. Theoretical analyses linked to these topics were selected from literature specific to improvisation along with Tardif's Strategic Teaching Model and basic violin technique parameters and then developed into a series of practical pedagogical activities and strategies. The tool's prototype—a paper document including two DVDs—was evaluated by the researcher and the three participant teachers in collaboration with some of their pupils corresponding to the population target.

Keywords: improvisation; violin pedagogy; teaching material; creativity; teaching strategies

The traditional approach of western classical music education entails a teacher-centered context (Young *et al.* 2003) that leaves very little decisional latitude to the pupil (Persson 1995). The integration of creative activities, such as improvisation—which leaves place for decision-making by the pupil—into teaching seems a relevant way to improve the violin teaching-learning context. However, violin teachers do not have access to suitable material allowing for the integration of improvisation within the framework of their individual lessons (Azzara 2002). Our research aimed at filling this gap by designing a pedagogical tool to help teachers integrate improvisation to their individual classes in the first three years of learning.

MAIN CONTRIBUTION

The methodological process used for the creation of the tool followed the five steps of Van der Maren's (2003) model regarding educational tool development: (1) the analysis of the demand, (2) the scope statement, (3) the tool's conception, (4) the technical preparation and prototype's construction, and (5) the fine tuning of the tool.

The first stage of the process was the *analysis of the demand*. We scrutinized the improvisation teaching material within the classical western curriculum. We noted that no material concerned with the integration of improvisation in violin teaching was available on the current market especially in the francophone environment. Then, to shape the functions of our pedagogical tool, we realized the second stage of the process, the *scope-statement*. To do so, we interviewed three violin teachers, expert with beginner level. The analysis of the teachers' needs and queries helped to clarify the pedagogical tool's contents. It should map out for the teachers how to: acquire the basic theory of improvisation, to think up strategies to integrate improvisation into their lessons, to progressively build up their students' improvisation skills, and to acquire strategies to guide the students' learning. Some other concerns would have to be taken into consideration when designing this tool: the teachers' lack of experience with improvisation, the lack of time available during lessons, and the teachers' personal pedagogical approach.

The third stage of the process, the *tool's conception*, was initiated with a literature review that helped us to collate the foundational knowledge necessary for the tool's conception. An in-depth analysis of a wide array of documents enabled us to define the multiple constituents of improvisation. More specifically, we clarified our idea of its definition, its practice inherent abilities, and notions related to both the teaching and the learning experiences. We used the objectives of the first three levels taken from Laval University's Anne-Marie Globensky music preparatory school's violin program (Robidas and Masson-Bourque 2007) and Tardif's Strategic Teaching Model (2007) in order to strengthen the knowledge already acquired through the literature review. We specifically chose Tardif's (1997) Strategic Teaching Model because it takes into account cognitive psychology and places the student at the center of the learning process making him/her more autonomously able to assimilate processes and information and use it in diverse contexts. Strategic teaching divides knowledge into three categories: declarative, procedural, and conditional. This model also defines the teacher's role and the strategies that may be used to enable the student to master his/her acquired knowledge.

Tardif's Model also groups the different steps of strategic teaching into three fundamental phases: (a) Preparation to the training; (b) Content's presentation; (c) Application and transfer of knowledge. We adapted the different phases of this model in order to suit the objectives of our teaching context. These objectives are the acquisition and integration of technical, musical, and improvisation abilities with the violin.

Through the fourth stage of the methodological process, the *technical preparation* and the *prototype's construction*, we designed and evaluated multiple variations of the tool according to their feasibility and functionality. This stage was linked to the fifth and last stage of the process, the *fine tuning* of the tool, completed in three phases. Initially, the researcher tested the material on her pupils as it was being designed. Subsequently, once the prototype was completed, the researcher tried out the complete pedagogical material with four other students that matched the target population. Then, the three violin teachers that were interviewed at the early stage of the research validated the prototype with some of their pupils corresponding to the population target (6-11 years old, 3 first years of lessons). The data generated by trials *in situ*, video captions, and semi-structured interviews were submitted to qualitative analysis and used to improve the prototype.

The validation process showed positive results. The majority of the tool's constituents were deemed adequate in terms of content as well as presentation. Furthermore, each of the three teachers experimented with some of the improvisation activities with their pupils and noted that their responses were very positive. Overall, the three teachers brought up many favorable comments about the tool's prototype, and following their advice, we made slight modifications to the tool. Thus, we considered that this tool answers the needs of the population.

The tool's content

The tool is divided into four sections. The first section provides necessary information for teachers who desire to teach improvisation. The content intends to answer the teachers' and researcher's initial inquiries: Why improvise? What is improvisation? Which knowledge and skills must the student learn in order to improvise? What is the developmental process of the improvisator? How should improvisation be taught? That's to say: Which activities should be offered? Which progression should be favored? Which teaching strategies should be used? What attitude should the teacher adopt? The answers to those questions were framed by information gathered through our literature review. This is not discussed in this article. However, it is relevant

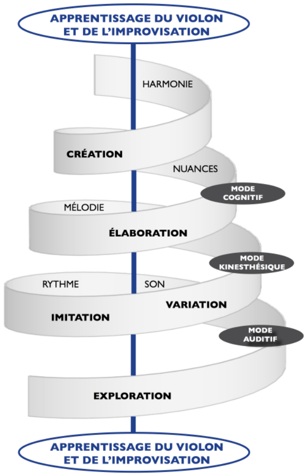

Figure 1. Gradual development of a musical and technical vocabulary specific to violin and improvisation abilities.

to display a schema that synthesizes the main ideas of improvisation teaching advocated by our approach (see Figure 1).

This schema shows the gradual development and integration of a musical and technical vocabulary specific to violin and improvisation abilities. It is based on Skidmore's (2002) ideas, which advocates a spiral pattern of development for improvisation activities. This progression favors the revision every lesson of the musical parameters and the usage of multidimensional activities—auditory, cognitive, and kinesthetic—in order to diversify the pupil's ways of learning. Further, the spiral's progression takes into account Brophy's (2001) ideas suggesting that more and more space should be left for the student's musical ideas. To do so, activities are proposed in order at first to imitate a musical stimulus, then to create a variant of or a response to the musical stimulus. Ultimately, the aim is to create musical novelty.

Furthermore, the tool's first section also introduces the principles, phases, and stages of Tardif's (1997) Strategic Teaching Model.

The tool's second section comprises 25 activities presented as games that are divided into three categories: (a) *Targeted improvisation activities* that aim at the development of a technical ability or at the use of specific musical parameters. These games mainly use imitation, variation, and "question and answer" strategies; (b) *Repertoire improvisation activities*, which are activities built around components of the pupil's known musical pieces. These games mainly use strategies of variations and elaborations; (c) *Explorative improvisation activities* give a lot of room to the student's creativity. These games mainly use creative strategies.

These activities involve the standard class curriculum (scales, technical exercise, repertoire, etc.); however, they are altered to encompass all of the necessary faculties to improvisation. Because we focused our approach on beginner violinists, the suggested activities do not try to comply with a specific style, but rather to integrate elements common to all musical forms—namely, the rhythm, the melody, sound attributes, and some harmonic parameters. The activities were inspired by several authors' work and by general games widely played by children (for example, disguising oneself, memory games, ping-pong, treasure hunt, mimicking, etc).

The tool's third section wishes to help the transfer of the knowledge acquired in the first two sections. It presents five pedagogical scenarios that describe improvisation and teaching situations. Those scenarios are linked with the main musical and technical objectives of the three first levels of the violin curriculum as well as the principles, phases, and stages of the Strategic Teaching Model (Tardif 1997). Furthermore, the tool's fourth and final section comprises two DVDs exemplifying the 25 improvisation games, the developed abilities, and the phases of Tardif's (2007) Strategic Teaching Model through several short videos. Several modeled situations of teaching are laid out in those videos. In order to facilitate the creation of a bond between theory and practice for any future teacher, subtitles were used to emphasize the phases of the Strategic Teaching Model as well as specific teaching and learning strategies.

Research limitations

Like any research, this one has its limitations. Only a limited number of teachers participated in the demands analysis and the fine tuning of the tool. Another limitation was that no criteria were used in the teacher's selection process specific to their improvisation experience or improvisation teaching experience: this may have influenced the results. Another limitation constitutes the participation of the researcher to the research as a teacher, which might have influenced the choices of the tool's components.

IMPLICATIONS

Based on a rigorous methodological model, this research put together a well-built tool for improvisation instruction. While many sources came from scientific literature, this research also gives value to practical knowledge. By promoting the usage of pedagogical strategies involving the student and stimulating creativity, the tool answers a significant need of the Western classical music context. More specifically, Tardif's (2007) model allows us to offer an organized pedagogical process that structures the teacher's role and the pedagogical strategies to be used in order to help the integration of various types of knowledge. In short, this tool suggests a guideline to the teacher which, while it contributes to the musical development of the pupil, wishes to stimulate an internal motivation of the pupil that will lead him/her to pursue musical exploration for the rest of his/her life.

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Thematic session:
Memory and attention in performance

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Attentional foci in piano performance

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Studies investigating the influence of the learner's focus of attention suggest that, in general, directing performers' attention to the *effects* of their movements (*external* focus of attention) is more beneficial than directing their attention to their own movements (*internal* focus of attention). It has been shown that different attentional foci are associated with different motor control processes, and internal focus may act as interference in the maintenance of a highly automated motor coordination. As an example of highly automated motor coordination, the present study aimed to investigate the effect of different attentional foci associated with expert piano playing. To this end, both the external focus (auditory feedback) and internal focus (fingering) were manipulated in order to explore their possible effects on piano playing. The main finding was the timing irregularity brought by manipulating the external focus (auditory feedback), but not the internal focus (motor pattern).

Keywords: attentional foci; pianist; auditory feedback; motor pattern; scale analysis

Studies investigating the influence of the performer's focus of attention suggest that, in general, directing one's attention to the *effects* of the movements (*external* focus) is more beneficial than directing their attention to their own movements (*internal* focus) (for a review, see Wulf and Prinz 2001). It has been shown that different attentional foci are associated with different motor control processes (McNevin *et al.* 2002), and internal focus may act as interference in the maintenance of a highly automated motor coordination. The beneficial effect of external focus is also supported by common-coding theory: if an action is planned based on an external focus, the action is planned on the basis of distal events that are more similar to this common representation.

The current study aims to examine the external and internal foci of professional pianists by manipulating the distal effect of movement (auditory feedback) and the movement itself (fingering). We therefore designed an experiment with variation either in internal focus or external focus. As a paradigm, we selected scale playing in highly skilled professional pianists. Here, we expect, on one side, a high degree of automaticity and, on the other, various susceptibility to interfering variables such as variation in finger or auditory feedback.

METHOD

Participants

Twenty-five healthy professional pianists (13 men, 12 women, mean age=25.8 years) participated in this study. Twenty-four were right handed, and one was left handed, according to the Edinburgh inventory (Oldfield 1971).

Materials

Participants were instructed to play two octaves of C major scales (from C4 to C6) in legato-style at a tempo of 80 beats per minute with sixteenth notes (four notes per beat, inter onset interval=187.5 ms), same as in the scale-paradigm (Jabusch *et al.* 2004).

Procedure

Participants completed a questionnaire on music expertise and musician's health before the experiment started and then were informed that the task was to play repeatedly both upward and downward scales on a MIDI digital piano as accurate as possible according to the metronome. There were three types of auditory feedback (normal, silent, and delayed feedback of 200 ms) and there were two types of designated motor patterns (conventional fingering and new fingering). Therefore, there were six conditions in the study:

- Normal feedback x conventional fingering
- No feedback x conventional fingering
- Delayed feedback x conventional fingering
- Normal feedback x new fingering
- No feedback x new fingering
- Delayed feedback x new fingering

Conventional fingering

New fingering

Figure 1. New fingering designed for the experiment. The fingering 1-5 refer to thumb, index, middle, ring and little finger, respectively.

The participants were allowed to try out the delayed auditory feedback and the new fingering for five times at most. In each condition participants had to play at least 25 times of complete upward and downward scales. The order of conditions was randomized, and all playing was synchronized to the metronome indicating a tempo of 80 beats per minute. In the third and sixth conditions, the participants were explicitly instructed to synchronize the piano sound to the metronome, not the movement. The onset, offset, and the velocity of each key depression was recorded, and video recording was made during the performance.

Data analysis

The analysis aimed to evaluate the evenness of scale playing. Four parameters were analyzed: velocity of each key depression (VEL), duration of each key depression (DUR), the inter-onset-interval between two consecutive key depressions (IOI), and the overlap between two consecutive key depressions (OVL). The last key depression of every scale was not analyzed because it was frequently delayed according to the pianist's expressive playing. In each condition, the medians and the standard deviations of all four parameters for each key were computed from at least 25 sets of upward and downward scales, and then the median of these standard deviations were calculated to indicate the irregularity of timing and loudness of a condition. Finally, the medians of all four parameters of different conditions from 25 pianists were analyzed with multivariate analysis with PSAW SPSS Statistics v.18.

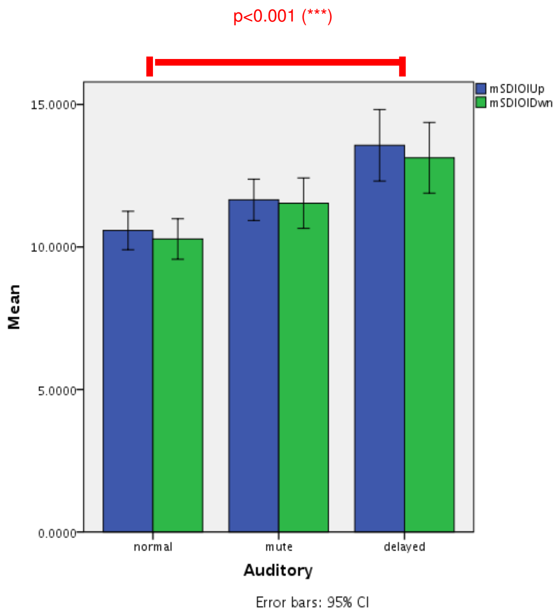

Figure 2. Mean variability of inter-onset-intervals (IOIs) under different auditory feedbacks. The blue bars represent the IOIs of upward scales and the green bars represent the IOIs of downward scales.

RESULTS

Multivariance analysis revealed a highly significant main effect of auditory feedback on all the variables (F_{18}=1.93 [Pillai's Trace], p=0.018), especially the effect of auditory feedback on IOIs (F_2=10.68 for upward scales and F_2=8.60 for downward scales, p<0.001 for both), disregarding the type of fingering. Pairwise comparisons for IOIs between normal and delayed auditory feedback (p<0.001 for both upward and downward scales), between muted and delayed auditory feedback (p=0.004 for upward scales and p=0.022 for downward), and between normal and muted auditory feedback (p=0.103 for upward scales and p=0.07 for downward) showed that this highly significant main effect was based on the effect of delayed feedback (see Figure.2). There was no significant effect brought by different fingerings (F_8=1.37, p=0.213), and pairwise comparisons did not show any significant difference between two types of fingering (all p>0.05) under any kind of auditory feedback.

DISCUSSION

Altered auditory feedback can cause different types of disruption to several dimensions of music performance (Pfordresher 2006). The deprivation of auditory feedback in this study had negligible influence on the evenness of scale playing, which is in accordance with the conclusion of previous studies (Repp 1999, Pfordresher 2006). As for the delayed auditory feedback used in this study, it created a profound effect on participants' timing, which is also in line with the results of previous studies.

While one might reasonably think that the long-trained motor pattern for scale playing would manifest its advantage by showing much lower deviations, the result of the present study showed that professional pianists are in fact very flexible in terms of motor planning and re-planning. This is the first study demonstrating the flexibility of motor programs in order to obtain a hierarchically higher, specific motor goal. It should be noted, however, that altered fingerings of fragments of the C-major scale playing may be part of daily life pianistic literature playing.

Previous studies showed that for both expert performers and novice learners, paying too much attention to one's own movement instead of the effect of movement may decrease the quality of certain well-practiced skills (Wulf and Prinz 2001). The advantage of external focus of attention is that it facilitates self-monitored, low-level, automatic processes required to achieve the motor control for the desired effect at a higher level, thus results in fast movement adjustments and enhances performance and learning. This effect is especially pronounced during the performance of relatively challenging tasks that require a greater degree of automaticity in movement control (Wulf *et al.* 2007). Being arguably one of the most challenging tasks, piano playing is suitable for examining the effect of different attentional foci. In the present study, in the fourth and sixth conditions (see Method), although the participants' attention was directed to the internal focus while playing with an unfamiliar fingering, the auditory feedback still existed as a powerful reminder of the external focus. Therefore, it was possible for the participants to perform the task by utilizing both internal and external foci concurrently. The utmost priority of external focus in expert musicians comes from the extensive auditory-sensorimotor training that enables musicians to have a reorganized neural network highly efficient in performing motor control over the acquainted musical instrument. This well-established, automatic co-activation of both the auditory and the motor cortical representations is likely to be on the top levels of motor control hierarchies, and only by disrupting the crucial properties (e.g. timing between action and auditory feedback) of this network can the motor control be disrupted. Unlike the facile adaptation to an unfamiliar motor pattern, this automatic auditory-sensorimotor co-activation is so robust that it cannot be easily modified according to the new association of movement and effect of movement, as in the third and sixth conditions. Moreover, the complete deprivation of auditory feedback in the second and fifth conditions can be regarded as tasks based solely on internal focus because of the lack of external focus. Since the performance did not deteriorate for these conditions, it can be explained that internal focus serves at lower levels of modules, as a prerequisite for further performance refinement.

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Annotation and the coordination of cognitive processes in Western Art Music performance

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This paper examines the role of performance annotations in coordinating Western Art Music (WAM) performance. Annotations are classified by their function in supporting cognitive and meta-cognitive processes of performance in relation to the printed score (visual salience, repair/correction, and anchoring). The classification supports theory in distributed cognition by demonstrating a clear functional relation between the annotated score and both internal and external performance processes.

Keywords: music performance; distributed cognition; coordination devices; annotation; instrumental case study

Cognition in ensemble performance is many-layered and multi-faceted, including processes that have internal and external, individual and group, cognitive and meta-cognitive components. This paper presents an analysis of annotations on a performance score drawn from a case study of ensemble performance in the Western Art Music (WAM) tradition. The observational case study consisted of nine videotaped rehearsals and a performance of Torû Takemitsu's *Masque for Two Flutes* (1959-60). A prior analysis of the conversation, body motion, and instrumental play revealed four domains of coordination in music performance (Kaastra 2008). This paper presents a detailed exploration of one of those domains, annotation, using theory drawn from the field of distributed cognition. For this analysis, every pencil mark on the rehearsal score has been studied in the context in which it was made, though only a summary of the analysis appears here.

In the most comprehensive ethnographic study of music annotation to date, Winget (2008) collected over 25,000 annotations created by chamber and orchestral musicians at a range of skill levels. Through an examination of rehearsal scores and some accompanying interview data, she analyzed the characteristics of the annotations, the purpose for making the annotations, and the knowledge required to use the annotations in context. She classifies annotations by mode (text, symbol, number) and function (technical, conceptual, technical-conceptual). This organization of the performance world is built upon the notion of the musical score as a *standardized-type boundary object*. The boundary object holds information in a standard form for communication across diverse communities. This implies a linear transfer of musical information from composer→ (conductor→) performer→ audience. The score is viewed as an object of communication, and the annotations are viewed as evidence of breakdowns or clarification in the communicative event.

In order to delve more deeply into the cognitive processes of performing music, I propose studying the score as a *coordination device* rather than a communicative artifact. This shifts the unit of analysis from the contents of the score to the relation between the score and the performers. In this work, I am interested in how a mark is used in performance, rather than its abstract musical value. The emphasis on *the dynamic interaction* between the score and the performers comes from the field of distributed cognition (Hollan *et al.* 2000, Kirsh 2005), an area of research in cognitive science that extends the unit of analysis for cognitive activity beyond the brain of an individual to the functional relations between an individual and her tools and environment. From this systems perspective, the score is not just a storage device for musical content, but a *persistent external representation* (Kirsh 2010) functionally tied to cognitive processes in music performance. Thus, the annotations help to make the internal processes of performing (i.e. counting) easier, *and* they provide external visual anchors for placing expressive sound in the context of a live performance of the work. The implications of that shift of perspective are made clear in the discussion that follows.

Finally, Winget's (2008) study demonstrated that skilled instrumentalists tend to annotate more than less-skilled players. This finding corresponds with Kirsh's (2010) theory that external representations increase and enhance cognitive processes by providing a persistent external representation of internal cognitive processes. The more advanced performer, this suggests, uses more external support because she is engaged in more complex performance activity. Based on these findings, we would expect to see many annotations on a performance score for a complex or novel piece of music like *Masque*. In fact, the first movement contains a total of 128 pencil marks. Out of 37 bars, only 11 are free of markings. The second movement contains a total of 65 pencil marks. Out of 40 bars, only 17 have no markings. I have classified the marks by their function in supporting cognitive processes of musical coordination in relation to a printed score: visual salience, repair/correction, and anchoring.

MAIN CONTRIBUTION

A musical score, from the point of view I am taking in this article, is not just a storage device for musical information. It holds links to cognitive processes required for performance. Viewed this way, every aspect of the printed page signals some process or state through which performance is coordinated. The most obvious link from the score to an internal cognitive process lies in the numerical indications for subdivisions of the beat. The rhythms (especially in Mvt. 1, *Continu*) are very uneven, the tempo is constantly shifting, and the pulse is deliberately obscured. Each measure has a different time signature ($^2/_8$, $^5/_{16}$, $^5/_8$, etc.), and within each measure, subdivisions of the beat layer duple and triple and sometimes quintuple (or other uneven) counts between parts. Numerical cues indicate how uneven divisions of the beat should be counted (e.g. 3, 5, 6, 7, 5:4, 3:2). A "3" over a combination of notes indicates a triplet subdivision (see Figure 1). A "5:4" over a sixteenth note rest, one eighth note, and two sixteenth notes indicates that there are five sixteenths to be counted in the space of four (bar 8 not shown). These precise numerical cues establish a link between the internal process of counting and the external coordination of sound. Indeed, every aspect of the score can reveal a connection between a performance process and the page. *Masque* is a precisely notated, very detailed example of modern Western Art Music. Every note has an indication for articulation, dynamics, timbre, and shape (as well as, of course, pitch and rhythm). The likelihood of this score being memorized is small, solidifying its role as a persistent external representation.

A classification of performance annotations

I observed each annotation as it was made in the rehearsals, including the playing, stoppage of play, and conversation that accompanied each mark. I then classified the marks based on the reason they were used. The annotations fall into three categories:

- Class 1: Visual salience
- Class 2: Repair/correction
- Class 3: Performance anchors

The first group of annotations make existing aspects of the score more *visually salient* for performance. These include widening dynamic wedges (top of staff, bar 20 in Figure 1), adding existing markings (e.g. dynamics, tempo) to the second staff, circling something, or translating a verbal cue into English. The intent behind these marks is not to revise the content of the music but to assist the performers in accomplishing a performance goal already indicated in the score. Only nine such marks appear on the rehearsal score for *Masque*.

The second group of annotations *repairs or corrects* some aspect of the score, or a cognitive process implied by the score. For example, bars 20, 23, and 32 are presented with time signatures that are uneven: $3\frac{1}{2}/8$, $2\frac{1}{2}/8$, and $2\frac{1}{2}/8$. The uneven time signatures appear to require subdivision at a unit below what is written. To correct the undesired outcomes from counting in such a lop-sided manner, the flutists revised the measures to $7/16$, $5/16$, and $5/16$, respectively. For the purposes of making music, it is much easier to count in equal units to 7 than to count to 3 and add a half-beat. The flutists *revised* the score to indicate the required subdivision. Other Class 2 annotations include verbal cues that try to mitigate negative performance outcomes. For example, "go→" indicates "keep moving" in a passage that has a tendency to slow down; "SLOW" in block letters serves as a red flag to slow down; note names written in an attempt to prevent note errors; and words like "fast," "slower," "more time," "accel. molto" (+ wavy line) all try to drive the musical activity away from natural outcomes that were determined to be undesirable by the flutists.

The third group of annotations I call, *performance anchors* because they hold and link internal and external performance processes. This group comprises the vast majority of annotations on this score, due to the rhythmic complexity of the music. Beat marks were used extensively in early stages of rehearsal. The marks form a visual "click track" so that the flutists can *see* (while they count, listen, and play) how the beats line up. Other anchors include triangles to indicate the count in an uneven bar (e.g. $7/16$ with a triangle over the last part indicates 1234-123 count). In addition, arrows are used to coordinate motion or pitch. For example, curved arrows over the end of the staff means that the flow of the music should continue into the next line. Straight arrows indicate motion (forward=faster; backward=slower) or pitch (up or down). Not surprisingly, most Class 3 annotations are symbols, although some of these symbols are also accompanied by words (e.g. "go→"). This annotation combines marks from Classes 2 and 3.

While this article presents only a summary of the annotations, it may be helpful to view a few heavily annotated bars from the score. Figure 1 presents an excerpt of the score that shows some annotations from all three categories. Note the expanded dynamic wedge in bar 20 (Class 1), the revised time sig-

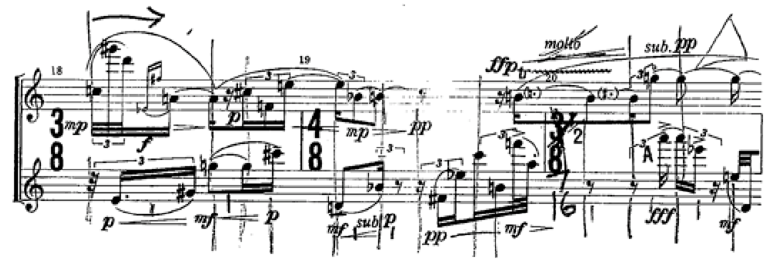

Figure 1. Rehearsal score bars 18-20 from Movement 1, *Continu*, of Takemitsu's *Masque for Two Flutes* (© Editions Salabert France, used by permission).

nature and arrow (Class 2), the short and long beat marks, and triangle (Class 3).

IMPLICATIONS

This classification of annotations supports the notion of the score as a persistent visual representation (Kirsh 2010). Perhaps the most persuasive case comes from Class 3, the Performance Anchor. The flutists used beat marks to line up their parts in the early stages of rehearsing the work. The flutists used the marks to coordinate the main beats *and* to coordinate their subdivision between beats, bridging internal and external coordination domains. Similarly, the wider dynamic wedge (see Figure 1) is not a revision of the composer's intention, but a signal to perform the dynamics. While Classes 1 and 3 support the notion of the annotated score as a persistent visual representation linking internal and external domains of coordination, Class 2 annotations more obviously link metacognitive processes (i.e. of monitoring, repairing, and/or correcting performance outcomes) with a mark on the score. The arrow in Figure 1, for example, is a reminder to push the tempo. The flutists will monitor the tempo and make adjustments to their performance of it based on the presence of the arrow. The beat marks, on the other hand, allow the flutists to anchor the flow of notes as they work through the passage.

In the dress rehearsal, the flutists forgot the performance score and used a substitute score with no annotations. I observed a noticeable increase in the volume of bodily gestures in that rehearsal (Kaastra 2008). The flutists also reported that they were more attentive to the "other cues" that they used to coordinate performance in that rehearsal. Therefore, we cannot say, for example, that the beat marks were solely responsible for coordinating the rhythms in the performance of *Masque*, but we can say that they present one layer of coordination within a domain. WAM performance is coordinated by a combination of counting, marking, listening, watching, and moving. Instrumentalists attend to multiple cognitive processes and representational systems, sometimes leaning more on one than another, depending on the needs for performance. Future work will continue to compare cognitive processes between domains (e.g. annotation and gesture) to further examine the coordination of cognitive processes in music performance.

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Slow down and learn: Pianists and memory

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This multi-disciplinary pilot study compared two groups of eight undergraduate pianists in a 3-week, 17-session experiment of a previously unknown 4-voice fugue (C. Schumann, Op. 16/2). The experimental group (EG, n=5) used adapted *Superlearning*™ techniques, which involved relaxation and controlled breathing with music chunking and a strong auditory-visual component. The control group (CG, n=3) was left free to study as desired. Both groups were asked to study only 30 minutes daily and to keep a practice journal during the 3.5-week experiment. Three trials were done. Prior to and after each trial, a battery of psychological tests was administered (stress, anxiety, life orientation, personality), as well as stress level monitoring through heart-rate variability through the use of a non-invasive T-shirt (*VitalJacket*®) and non-invasive cortisol saliva swabs. After the Trial 1 performance, the participants considered the study completed. A surprise Trial 2 was given 3 months later, followed by a Trial 3 performance two weeks after that. The results confirmed that the accelerated learning techniques functioned, but instead of having the desired effect of relaxation, the EG was more stressed. Another surprising result was the success of the male pianists over the females, although this was not one of the objectives of the study.

Keywords: memory; stress; anxiety; Superlearning; pianists

Historically, performance levels in many areas have been increasing (Palmer 2006). As a system of accelerated learning and hypermnesia, the *Super-*

learning™ method has been used to enhance performance and acquisition in foreign languages and other areas (Ostrander and Schroeder 1979), although is rarely used in music study (Alberici 1999). The method uses 20-minute daily learning sessions that are divided into two 10-minute sessions in which the participant looks at the material being presented, then closes the eyes while listening to the same material. The presentation of the material is given in 4 s intervals of new information (spoken in various modalities of normal voice, whispered, authoritative—e.g. *le chat,* the cat) followed by 4 s of silence, then 4 s of new material, followed by 4 s of silence, and so on. During the listening part, music (preferably Baroque Adagio string movements at 60 M.M.) is played underneath the spoken material and pauses. Breathing is coordinated by exhaling and inhaling during the silence and holding during the presentation of new material. The *Superlearning*™ method espouses the side benefits of improved health and retention rates. Contrary to *Superlearning*™ claims, studies have shown that free recall in music performance has been poor (Segalowitz *et al.* 2001) and that gender is a factor in the memory-stress relationship (Wolf *et al.* 2001). The main aim of this pilot study is to see if the accelerated learning techniques of the *Superlearning*™ system, which combine relaxation, controlled breathing, and chunking, work equally well through learning, memorizing, performing, and free recall of complex music acquisition—in this case, a previously unknown 4-voice fugue—by higher level pianists (Welch *et al.* 2008, Chaffin *et al.* 2002, Connolly and Williamon 2004, Ginsborg 2004).

METHOD

Participants

Eight undergraduate pianists, aged 18-25 years old who were all enrolled in the same discipline were placed into two groups: experimental group (EG) of five pianists (three female) and control group (two female). From questionnaires, the EG had more years of piano study than the CG (12.67 years vs. 9.80 years), practiced more on a daily basis (5.40 hours vs. 4.67 hours), and required less time to memorize a fugue (EG=6.8 weeks vs. CG=10.67 weeks). The majority of the pianists said that the most difficult type of music to memorize was a fugue (EG=80%, CG=100%).

Materials

The materials consisted of (1) the musical score of the Fugue in E*b*, Op. 16, No. 2 by Clara Schumann (1845) for both groups, (2) an altered version of a commercial recording of the fugue (Jozef de Beenhouwer 2001, CPO Records, B00005MAV1, normal time=107 s), slowed to 60 M.M, for the EG (*Bias Peak Pro 6*), (3) musical chunks or fragments of the fugue separated by an equivalent amount of silence, plus a chunking map for each day's practice, for the EG (the musical chunks were determined by the fugue theme, musical phrases, and hands-together coordination), (4) a practice journal, for both groups, (5) pre-/post-questionnaires plus standardized psychological tests (state and trait anxiety [STAI-1, STAI-2], perceived stress scale [PSS], life orientation [LOT], personality [EPQ]), (6) *VitalJacket®* (VJ) during performances, and (7) test tubes and processors for cortisol analyses during performances. A description follows: (1) The use of the psychological tests permits the characterization of the psychological make-up of the groups (anxiety, stress, dispositional optimism, and personality dimensions) and understanding of the psychological effects of the presence or absence of the *Superlearning™* method during the different performance moments. (2) The VJ consists of a T-shirt and a small electronic device box using miniaturized components placed in a pocket that allows continuous non-invasive monitoring of the heart wave up to five days (see www.biodevices.pt); it permits a transthoracic interpretation of the electrical activity of the heart, or ECG reading, in real time via skin electrodes with storage in its internal memory or wireless transmission via Bluetooth technology; the cortisol salivary testing by competitive immunoassay is non-invasive and has been used in studies of memory, stress, and gender. (3) Cortisol, also known as hydrocortisone, is a steroid hormone or glucocorticoid produced by the adrenal gland or adrenal cortex as part of the hypothalamic-pituitary-adrenal (HPA) axis regulation. It is released in response to stress and to a low level of blood glucocorticoids. Despite its pathological effects on the context of long term exposure to stress factors, cortisol is relevant to cognitive performance such as memory.

Procedure

Before starting the study, the students were given an orientation session, asked to sign a consent form, and respond to a pre-test questionnaire to ascertain their pianistic profile. Each group then had 3.5 weeks in which to learn the Fugue and was asked to use their respective techniques for only 30 minutes daily for a total of five days per week, registering the time of practice, local of practice, and their observations about practice. The EG used the altered *Superlearning™* techniques, while the CG was free to learn as they chose. Once a week, both groups met briefly with the project leader, who then proceeded to work for 30 minutes with the EG using relaxation and controlled breathing techniques before advancing to the techniques of music chunking coupled with the breathing sequences (an altered version of *Superlearning*™ techniques). At the end of the 17 sessions, the students were filmed in a live performance (Trial 1) of the fugue. At this point, the pianists thought that the study had finished. Three months later, a surprise performance test (Trial 2) was given. Two weeks after that, the students were asked to repeat the performance (Trial 3), with only one week of preparation using their respective study techniques. All performances were filmed. Before and after all sessions, psychological tests were given and a salivary control for cortisol rating was done by oral swabs of saliva samples from each participant to test cortisol levels by a competitive immunoassay. Before and during the sessions, VJ monitoring of the heart rate was carried out.

RESULTS

Performance results of the 3 trials were different than expected. In Trial 1, 40% of the EG (2 males) successfully performed the fugue, while 33% of the CG (1 male) was successful (time: EG=70.6 s, CG=47 s). In Trial 2, there was little difference between the groups, although EG was slightly better in memory recall (EG=15.0 s, CG=14.3 s). Both groups showed improvement in Trial 3 compared with Trial 1 (EG=79 s, an 11% improvement; CG=69 s, a 32% improvement). In Trial 3, the three male pianists again performed successfully, and the female pianists also showed improvement.

For state and trait anxiety, the EG had a dramatic rise from the pre-test to Trial 1 and was only slightly higher in Trial 3 in trait anxiety. There was little difference between the groups in Trial 2. The EG was overall more optimistic and less anxious than the CG. Using statistical analyses (SPSS 17.0) the following results were found. For state anxiety, the EG had a significant rise from the pre-test to Trial 1: $t_4=-3.27$, $p<0.05$ (Pre- mean=34.80, SD=2.78; Trail 1 mean=47.60, SD=5.77). In other words, the EG was more anxious in Trial 1, which could be related to the novelty of the adapted *Superlearning*™ method and the fact that Trial 1 was the first evaluation of the students with this method. The CG also had a dramatic rise from the pre-test to Trial 1, showing that the performance assessment was also stressful. However, this difference was not statistically significant. Statistical analysis showed no significant differences between groups in anxiety (trait and state) levels; however, CG perceived stress was significantly higher: $t_6=-2.54$, $p<0.05$ (CG mean=30.33, SD=3.06; EG mean=22.60, SD=4.83). Trials 2 and 3 showed no significant differences between groups, and in Trial 3, in both groups, identical averages are detected to those of the pre-test. No significant differences

Table 1. Mean heart rate variability (HRV) or ECG for the experimental (EG) and control groups (CG).

Trial 1: Mean HRV Not play/play	*Trial 2: Mean HRV Not play/play*	*Trial 3: Mean HRV Not play/play*
EG (n=5; 3 females)= 105/139	EG (n=5; 3 females)= 107/105	EG (n=4; 2 females)= 87/115
CG (n=3; 2 females)= 93/125	CG (n=3; 2 females)= 94/84	CG (n=3; 2 females)= 87/116

Table 2. Mean cortisol levels for the experimental (EG) and control groups (CG).

Trial 1: Concentration of Cortisol (µg/dl): Before/after	*Trial 2: Concentration of Cortisol (µg/dl): Before/after*	*Trial 3: Concentration of Cortisol (µg/dl): Before/after*
EG=0.62/0.61	EG=0.29/0.33	EG=0.59/0.44
CG=0.33/0.37	CG=0.26/0.26	CG=0.36/0.30

were found in either inter- or intra-participants in the LOT and EPQ tests. These results show that both groups were more anxious in Trial 1, as would be expected. However, as the intra-participant analyses show that the EG was significantly more anxious in the Pre-test, we can infer that the *Superlearning*™ adapted method explains this increase in the anxiety levels of the students by being a new and demanding method.

The heart rate variability (HRV) found the EG group to be more anxious in Trials 1 and 2 than CG but less than CG in Trial 3. Overall rates declined in both groups between the first and last trials (Table 1).

Contrary to the desired effect of relaxing while learning and performing, the EG was consistently more stressed than the CG (Table 2), according to cortisol presence in their saliva.

DISCUSSION

From this multi-disciplinary pilot study we conclude: (1) the *Superlearning*™ techniques adapted for complex music acquisition (i.e. fugue learning by pianists) function but cause stress in the participants and should therefore be refined because their long-term results are positive; (2) the study was gender-specific with all male pianists having 100% learning rate in less time than normal, a surprising finding requiring further study; (3) the EG and all male participants were most successful in free recall (Trial 2); (4) musical performance has to be practiced if security is to be attained, a finding that is supported by both EG and CG and one which every good pedagogue inculcates in his/her students.

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Thinking about performance: Memory, attention, and practice

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Performers must trust their memories to work reliably under the pressures of the concert stage. So, the performance must be thoroughly automatic. At the same time, it must be fresh and spontaneous in order to communicate emotionally with the audience. To learn how musicians resolve this dilemma, I have conducted longitudinal case studies of concert soloists preparing for performance. Our studies track memory development through practice to public performance and beyond. Like expert memorists in other domains, experienced musicians use highly practiced retrieval schemes. The retrieval organization provides a mental map of the piece that tells the performer what comes next—a series of landmarks, hierarchically organized by the sections and subsections of the music. The musician attends to these *performance cues* (PCs) in order to ensure that the performance unfolds as planned. PCs are established by thinking about particular features of the music during practice so that they later come to mind automatically. PCs help the musician to monitor the unfolding performance and adjust its rapid, automatic motor sequences to the needs of the moment.

Keywords: memory; attention; practice; performance cues; spontaneity

Performers are faced with a dilemma. On the one hand, performances in the Western art music tradition are usually highly prepared, but mindlessly relying on the automaticity of well-practiced motor sequences, is both risky and unlikely to produce an aesthetically satisfying performance (Chaffin *et al.* 2006, 2007; Ericsson 2002). On the other hand, thinking too closely about a highly practiced skill is a sure way to disrupt it (Beilock and Carr 2001). Experienced performers resolve this dilemma by training themselves during practice to attend to specific features of the music. These *performance cues* (PCs) come to mind automatically during the performance, providing a series of landmarks that the performer can use to monitor progress through the piece and direct attention as needed—to technical issues, interpretation, or expressive gestures. PCs provide the performer with a safety net that allows recovery if something goes wrong and provide points of flexibility at which the performer can introduce spontaneous variation into a highly prepared performance.

MAIN CONTRIBUTION

Experts in any domain memorize with a facility that often seems superhuman (Gobet and Simon 1996). Musicians are no exception. Their biographies are full of tales of amazing memory feats, such as the story of the young Mozart writing out Allegri's *Miserere* from memory (Cooke 1999) or Jorge Bolet's memorization of Liszt's *Mephisto Waltz* in 75 minutes (Noyle 1987). These feats of memory can be explained in terms of three principles: meaningful encoding of novel material, use of a retrieval organization, and extended practice in its use (Ericsson and Kintsch 1995).

It is not obvious that principles of expert memory, which were derived from studies of memory for chess boards, digit strings, and dinner orders, would apply to music performance. Motor and auditory memory, that play a central role in performance, are minimally involved in these other, very different fields. Despite the differences, the principles do apply (Chaffin *et al.* 2002, Chaffin and Logan 2006, Krampe and Ericsson 1996). First, experts' knowledge of their domain of expertise allows them to encode new information in terms of ready-made chunks already stored in memory (Miller 1956, Tulving 1962). For a musician, these include familiar patterns like chords, scales, and arpeggios, whose practice forms an important part of every musician's training (Halpern and Bower 1982). Second, experts develop a retrieval scheme that provides access to the chunks of information in long-term memory (Ericsson and Oliver 1989). For a musician, the formal structure of the music provides a convenient, ready-made organization (Chaffin and Imreh 2002, Williamon and Valentine 2002). Third, prolonged practice is required to bring the speed and reliability of memory retrieval up to the point that it becomes useful (Ericsson and Kintsch 1995). For musicians, this means that extended practice is necessary for memory retrieval to operate reliably at performance speeds.

Some musicians appear to disagree with this last claim. In published interviews, many performers describe memorization as "very simple" (Walter Gesiking), a "subconscious process" (Harold Bauer), that "just happens" (Andre-Michel Schub), "like breathing" (Jorge Bolet). Others, in contrast, compare the "terror of forgetting" (Janina Fialkowska) to "tortures…of the inquisition" (Anton Rubenstein), suggesting that "every performer…always thinks about the possibility of memory slips…[and] has to work at memorizing" (John Browning; all citations from Chaffin *et al.* 2002, Chapter 3).

These disagreements reflect the fact that performance normally involves two different kinds of memory, at least for experienced musicians. *Serial chaining* develops automatically, without deliberate effort, during practice, providing a type of implicit, procedural memory that is remarkably accurate (Chaffin *et al.* 2009, Rubin 2006). However, relying on serial chaining is problematic. First, it can only be accessed by playing the piece. The uncertainty of whether the memory will be there when needed on stage is a source of anxiety for many performers. Second, if something does go wrong in performance, the serial chain can only be restarted by going back to the beginning. This unfortunate staple of student recitals is something that more experienced performers generally manage to avoid.

Experienced performers provide themselves with a safety net. *Content addressable access* allows a musician to start at different points in a piece (e.g. "2nd return of the main theme"). This provides a way to recover if something goes wrong. Establishing the necessary retrieval cues is easy enough. Just think of a location and start playing. Do this a few times and the thought becomes a retrieval cue, eliciting memory for the music. This kind of retrieval works well enough in ordinary conversation. In music performance, however, retrieval has to keep pace with the pulse of the music. Getting retrieval up to speed is what makes memorization such hard, slow work. As pianist Gabriela Imreh put it in talking about learning the *Italian Concerto (Presto)* by J.S. Bach: "My fingers were playing the notes just fine. The practice I needed was in my head. I had to learn to keep track of where I was. It was a matter of learning exactly what I needed to be thinking of as I played, and at exactly what point…" (Chaffin *et al.* 2002, p. 224). She was talking about performance cues (PCs).

PCs are landmarks in the mental map of a piece that an experienced musician maintains in working memory during performance. Because they can be accessed both by serial cuing and directly, by address, they provide a backup if serial cuing breaks down. By carefully preparing PCs, soloists are able to reliably perform challenging works from memory on the concert stage. By repeatedly paying attention to PCs during practice, the musician ensures that they become an integral part of the performance, coming to mind effortlessly as the music unfolds. The performer remains mindful of these aspects of the performance while allowing other aspects to be executed automatically. When things go smoothly, PCs are a source of spontaneity and variation in highly polished performance (Chaffin *et al.* 2007). When things go wrong, they provide places at which the soloist can recover and go on.

PCs point to different types of memory according to which aspect of the music they address. *Structural* cues are critical places in the formal structure, such as section boundaries. *Expressive* cues represent musical feelings (e.g. excitement). *Interpretive* cues refer to musical gestures, such as changes of tempo or dynamics. *Basic* cues point to motor memory for critical details of technique (e.g. a fingering that sets the hand up for what follows). Musicians are likely to agree on the musical structure of a piece. They are likely to differ about other cues, those that are more specific to the performer or instrument. For example, basic PCs for a cellist include decisions about intonation are not relevant for a pianist. For ensemble work, shared PCs may also be needed to coordinate with the other musicians (Ginsborg *et al.* 2006, Ginsborg and Chaffin 2011).

With musician colleagues, I have examined the development of PCs in a series of longitudinal case studies of concert soloists preparing for performance. During practice, musicians constantly make decisions about technique, interpretation, and performance. The behavioral record of starts and stops provides a window into the cognitive processes involved. Figure 1 shows practice data from a study in which an experienced cello soloist learned the *Prelude* from Bach's *Suite No. 6*, for cello solo, BWV 1012 (Chaffin *et al.* 2010, Lisboa *et al.* in press). The figure shows a 1.5-hour practice session during which the cellist polished the piece for a public performance. The graph reads from bottom to top. Each horizontal line represents the uninterrupted playing (practice segments) of the corresponding half-bars shown on the horizontal axis. The vertical lines represent the locations of the main section boundaries (darker) and the interpretive PCs (lighter) that the cellist reported. The graph shows that the cellist worked through the piece in sections, starting at the end. The session concludes with an uninterrupted performance of the entire piece, represented by the horizontal line at the top of the graph. The many places where vertical lines intersect with starts and ends of horizontal lines are occasions on which playing started or stopped at a PC. This is how PCs are created, by establishing automatic links between thought and action. Data of this sort have allowed us to track the development of PCs across practice sessions.

Music practice provides a rich source of information about many aspects of expertise that are of interest to psychologists and of value to musicians. The changes in a musician's goals that take place as learning progresses are reflected in where playing starts and stops (e.g. Chaffin *et al.* 2002, see Chapters 8-9). Experienced performers start out by forming a "musical im-

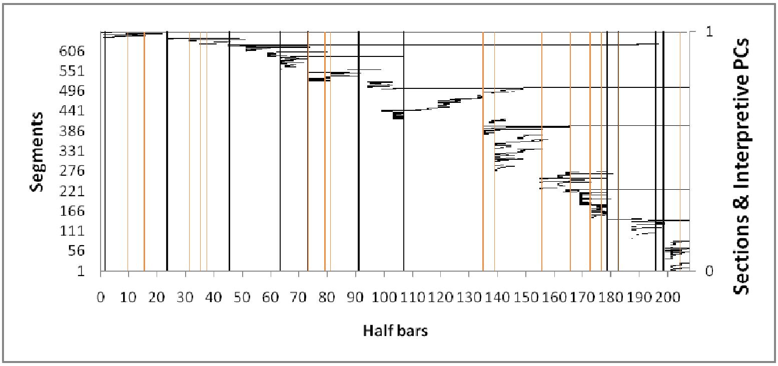

Figure 1. Practice in session 58 showing location of section boundaries (dark vertical lines) and interpretive PCs (pale vertical lines; reproduced from Lisboa *et al.* in press). (See full color version at www.performancescience.org.)

age" of a new piece, before working on technical issues (Chaffin *et al.* 2003, Lisboa *et al.* in press, Neuhaus 1973). Strategic alternation between section-by-section and integrative practice is reflected in the varying length of practice segments, both within and across sessions (Chaffin *et al.* 2002, 2010; Miklaszewski 1989; Williamon *et al.* 2002). Level of concentration is reflected in time spent in micro-pauses, as the musician makes decisions while playing (Chaffin and Lemieux 2004, p. 25; Chaffin 2007). Large scale body movements, not strictly necessary for note production, reflect the musician's mental organization of the music (Ginsborg 2009).

PCs guide playing during performance, as well as in practice. We can see their influence in the fluctuations of tempo and dynamics that reflect a performer's musical interpretation and style. Figure 2 shows the mean half-bar-to-half-bar tempo of 27 polished performances of the *Prelude* by the cellist whose practice of the same piece is shown in Figure 1. There were dips in tempo at places where the cellist reported expressive PCs. A factor analysis of the performances yielded two factors, which we identified, on the basis of external evidence, as more versus less relaxed/expressive performances (Figure 2 shows the factor scores). The momentary decreases in tempo at expressive PCs were more pronounced in the more expressive performances (Lisboa *et al.* 2007). The cellist modulated the size of her musical gestures, making them larger in some performances and smaller in others. This suggests that the PCs may have provided her with points of control where her automatic

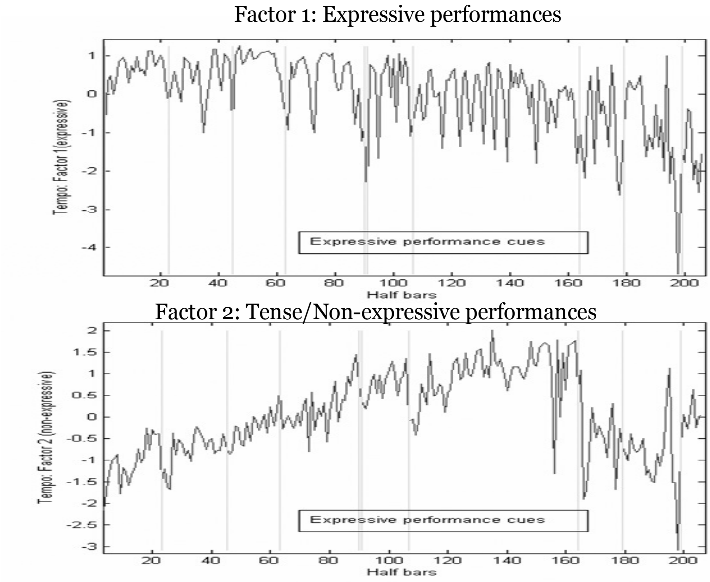

Figure 2. Normalized tempo (per half-bar) for more expressive/relaxed (Factor 1, top panel) and less expressive/relaxed (Factor 2, bottom panel) performances, with vertical lines showing the location of expressive PCs (reproduced from Lisboa *et al.* 2007).

motor sequences could be modified from one performance to another (Chaffin *et al.* 2007).

If PCs function as retrieval cues, then their effects should be reflected in recall. Figure 3 shows mean probability of correct recall of bars before and after expressive features (including expressive PCs). The data are from a study in which a singer wrote out the score of the first Ricercar from Stravinsky's *Cantata* six times over a period of five years after performing the piece (Ginsborg and Chaffin 2009). The figure shows a sharp increase in accuracy in bars containing expressive features (located at serial position [SP] =0). This serial position effect suggests that the singer had direct, content addressable access to her memory for the piece at these locations. The stepwise decrease in successive bars before and after SP=0 suggests that their recall was a product of serial cuing. Recall declined because at each link in the associative chain, there was a non-zero probability that retrieval of the next link in the chain would fail. Content addressable access at expressive features provided renewed access to the associative chain, resulting in the sharp increase in recall observed at SP=0.

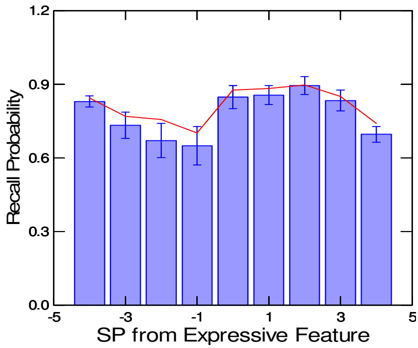

Figure 3. Accuracy of recall as a function of serial position (SP) of bars before and after expressive features (at SP=0). Red line shows fit of model to data (Ginsborg and Chaffin 2009). (See full color version at www.performancescience.org.)

In other studies, we have examined the potential role of PCs in recovering from disruptions to performance. We cued musicians to start playing in the middle of a piece that they had memorized by playing them brief passages cut from recordings of their own performances. The tests were conducted months, and in some cases, years, after the musicians had last performed the works. The musicians were instructed to continue playing when the auditory cue stopped, trying to make it sound as much as possible like an uninterrupted performance (Begosh *et al.* 2010). Responses were faster for cues that ended at expressive PCs. These PCs provided the best content addressable access to the musicians' memory.

The musicians in these longitudinal studies were asked to talk to the camera about what they were doing during practice, whenever they felt able to do so. They rarely mentioned PCs, and then only obliquely. The one exception was pianist Gabriela Imreh, during her learning of Bach's *Italian Concerto (Presto)*. On three occasions, she went through the score, describing the "map of the piece in [my] mind…[where I] focus on certain places" (Chaffin *et al.* 2006, pp. 205-208). In session 12, after playing the piece through from memory for the first time, her description was exclusively about the musical structure (e.g. "that's the second time"). In session 17, after the piece was thoroughly memorized, she talked mostly about technique (e.g. "the fingering in bar 65, the left hand divided"). In session 24, right before the first public performance, she talked mostly about interpretation (e.g. "In [bar] 77, I'm trying to bring out the *C*s…and *F* in the left hand"). The pianist's descriptions show how her PCs developed over the course of learning the piece.

The changes in the pianist's descriptions of her PCs were also reflected in changes in practice (Chaffin *et al.* 2006). The mapping of word and action is not, however, generally one-to-one. Sometimes word and action are in agreement; sometimes they are at odds. For example, in the early practice sessions of the *Prelude* study, the cellist talked almost exclusively about technical issues (e.g. decisions about fingering and bowing; Lisboa *et al.* in press). In later sessions, she talked increasingly about interpretation. Her practice, however, showed the opposite pattern. She started and stopped more at interpretive features and PCs in early sessions and at more technical difficulties in later sessions. The explanation is to be found in a single remark in practice session 3, in among hundreds of comments about technique. The cellist commented, "I have to decide musically what I want, and then I can choose a fingering." It is only in hindsight, and with the help of the practice record, that we are able to see that this one, isolated remark provides the key to her learning strategy.

IMPLICATIONS

The rapid starts and stops of musicians' practice reflect their strategies and goals. By itself, however, the behavioral record of practice is relatively uninformative. We need the first-person perspective of the musician (Chaffin and Imreh 2001). Experienced musicians can provide detailed and insightful self-reports about their practice and memorization strategies (Hallam 1995). But self-reports alone are not sufficient. Musicians must rely on intuition and are not always aware of why they do things (Ericsson and Simon 1980). However, when their reports are validated by the behavioral record of their practice and performances, the objective record is illuminated by the musical understanding and insight of the performer. When approached in this way, practice provides a valuable, natural laboratory for studying the development of the complex skills required in performance.

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