The effects of music playing on cognitive task performance

by

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Abstract

Numerous music cognition studies have demonstrated the cognitive benefits of both long-term and short-term musical training. Whereas a great number of these studies deal with the short-term benefits for the music listener or the longer term benefits for the novice or accomplished musician, our study examines the short-term effects of music playing for the advanced performer. For our pretest-posttest design, we recruited advanced classically/score-based trained pianists. The participants started by completing a creative exercise (alternative uses task) or detail-oriented exercise (proofreading task). They then performed a piano piece for ten minutes. The performances were followed by completion of the second cognitive task (whichever task they were not given in the pretest condition). No significant pretest-posttest differences in creativity were reported. However, we found that participants performed significantly worse in the posttest detail-oriented task. Our results suggest that performance in tasks involving attention to detail—specifically, a proofreading task involving the visual detection of errors—may be hindered immediately following a short period of score-based music playing when the piece is already familiar to the performer.

Preface

Procedures and protocols for this project were approved by the Behavioral Research Ethics Board at the University of British Columbia: Certificate Number H09-03293.

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1 INTRODUCTION

1.1 Music Cognition Research

The musician's brain presents an ideal model for investigating experience-driven neuroplasticity at the behavioural and cortical levels in auditory and motor domains (Schlaug, 2001; Munte, Altenmuller & Jancke, 2002). As such, within the fields of music and psychology, there has been a great deal of interest and exploration in clinical studies—namely, the use of music therapy as a way to facilitate changes in areas such as social development and motor skills. For example, the benefits of music therapy have been demonstrated with patients suffering from autism (Wigam & Gold, 2006; Walworth, 2007), epilepsy (Sidorenko, 2000), depression (Guetin et al., 2009) and Alzheimer's disease (Witzke et al., 2008); the use of music has been shown to improve gait function in Parkinsonian patients (Satoh & Kuzuhara, 2008); and benefits from melodic intonation therapy have been found with patients suffering from apraxia of speech (Keith & Aronson, 1975) and aphasia (Keith & Aronson, 1975; Naeser & Helm-Estabrooks, 1985; Belin et al., 1996), just to name a few. Importantly, these results also demonstrate that music can have an impact on learning and cognitive development.

There is also a growing number of studies examining the non-musical cognitive skills associated with music experience—whether that experience be through formal lessons or simply through listening. From these studies, we can infer two lines of research: first, the long-term cognitive effects where training in the musical domain transfers over to specific skills in non-musical domains; and second, the short-term cognitive effects of musical exposure as a result of neural priming. As might be expected, the cognitive implications of long-term music training versus short-term music listening are distinct (Schellenberg, 2003).

1.2 Long-Term and Short-Term Studies

For many studies investigating the cognitive implications of long-term musical training children are often used as the study population. Compared with adults, children's brains display a higher plasticity and ability to adapt to changing experiences (e.g. Dawson, Ashman & Carver, 2000; Ho, Cheung & Chan, 2003; Norton et al., 2005; Takeuchi & Hulse, 1993; Taylor & Alden, 1997). Studies with children have investigated the relation between long-term music training and non-musical abilities such as literacy (Barwick et al., 1989; Douglas & Willatts, 1994; Gardiner et al., 1996), prereading/writing skills (Standley & Hughes, 1997; Register, 2001), verbal memory (Ho, Cheung & Chan, 2003), math (Gardiner et al., 1996; Graziano, Peterson & Shaw, 1999) as well as spatial and spatial-temporal reasoning (Bilharz, Bruhn & Olson, 2000; Costa-Giomi, 1999; Graziano, Peterson & Shaw, 1999, Gromko & Poorman, 1998; Hassler, Birbaumer & Feil, 1985; Hetland, 2000a; Rauscher et al., 1997; Rauscher & Zupan, 2000). Long-term effects of at least six years of music training have also been shown for adults in areas such as verbal memory (Chan, Ho & Cheung, 1998). In terms of music and IQ, it has been found that music training results in greater increases in full-scale IQ although the effect is relatively small (Schellenberg, 2004). It was also found that IQ and academic ability were positively correlated with duration of music lessons for children six to eleven years of age; similar associations, albeit weaker ones, were also found between intellectual functioning among undergraduates and childhood music playing (Schellenberg, 2006). It is important to note, however, that for these studies musical training did not yield stronger associations with specific cognitive abilities such as math, spatial-temporal or verbal skills compared with other skills. Nevertheless, these results seem to demonstrate that musical training during childhood can result in small, long-lasting effects.

In contrast to the long-term effects of childhood music lessons, the short-term implications from music listening can be most notably found in numerous studies investigating the Mozart effect—a term originally coined by Alfred A. Tomatis (Tomatis believed that listening to the music of Mozart at different frequencies aided in brain development). Rauscher & Shaw found that adults who listened to ten minutes of Mozart's Sonata for Two Pianos in D major improved on spatial reasoning tasks (1993) when compared with those who listened to a relaxation tape or silence; however, the effect did not last beyond the ten to fifteen minute period in which the participants were working on the spatial tasks. They also found that listening to Mozart resulted in the short-term enhancement of spatial-temporal reasoning (1995). As a result of media hype—"listening to Mozart actually makes you smarter"—and researchers' attempts to replicate their results, Rauscher clarified that they had made no such claim with regards to Mozart's intelligence-enhancing capabilities—and that "the effect is limited to spatial-temporal tasks involving mental imagery and temporal ordering".

There are many other studies that continue to examine as well as challenge the short-term effects of listening to Mozart. Whereas support for the Mozart effect has been found for music listening and spatial-temporal reasoning (e.g. Hetland, 2000b), there have also been findings to the contrary: that participants demonstrate better performance in a paper folding task after listening to pop music versus Mozart (Schellenberg & Hallam, 2005); that the Mozart effect is actually due to the short-term effects of music on arousal and mood (if the music possesses a positive emotional quality and is energetic) (Thompson, Schellenberg & Husain, 2001); and that the Mozart effect is due to "enjoyment arousal"—meaning that task performance is improved if participants enjoy what they hear, whether it be music or a story (Chabris, 1999), pop music or Mozart (Schellenberg & Hallam, 2005)—and that these effects generalize across cultures and age groups (Schellenberg et al, 2007).

1.3 Cognitive Effects of Piano Training

Several studies have shown that musical training specific to piano performance can affect one's success in cognitive task performance. For example, Graziano, Peterson & Shaw (1999) found that in contrast with control groups, preschool children who received six months of piano keyboard lessons showed dramatic improvement with spatial-temporal reasoning. From this finding, they sought to demonstrate that the enhanced spatial-temporal reasoning from the piano training could also lead to enhanced learning of specific math concepts. As such, they found that children who received piano and math video game training scored much higher in proportional math and fractions compared with children who were given only a control training along with the math video game.

In a similar vein to the Graziano study, Bugos et al. (2007) showed that individualized piano instruction versus no training enhanced executive functioning and working memory in older adults. Over a period of six months, the piano instruction included musical performance (Alfred All-In-One Basic Piano Course Level 1), technical motor and dexterity exercise (basic chord progressions, rhythmic exercises, scales, arpeggios, primary triads and Hanon exercises), as well as music theory (basic note reading, intervallic and key relationships, and basic tertian harmony). The results of the study suggested that individualized piano instruction could serve as an effective cognitive intervention for age-related cognitive decline.

Ragert et al. (2004) ran a study measuring spatial tactile acuity, in which highly trained pianists and non-musician controls were presented with either one or two needles in eighty single trials. Participants were required to touch the needles and report immediately afterwards if they felt the sensation of one or two tips. In the case of two needles, the needles were separated in distances ranging from 0.7 to 2.5 mm in 0.3 mm steps for each trial. The trained pianists, compared with non-musician controls, showed significantly lower discrimination thresholds on the tips of their right and left hand index fingers. Furthermore, a significant relationship between the mean discrimination thresholds for the right and left index fingers and the amount of daily piano training for both fingers was also found—in other words, better discrimination performance resulted from extensive use of the fingers and increased duration in daily practice.

Finally, Piro & Ortiz (2009) demonstrated the effects of piano training on language and literacy. One group of second-grade students was given formal piano instruction that included music theory, ear training, playing and practicing of scored pieces as well as improvisation. The students in the control group were not given any music lessons, whether private or in school. After three consecutive years of training, the music group produced significantly better vocabulary and verbal sequencing scores.

1.4 Summary

The studies specific to piano training provide a useful demonstration of its effects on long-term brain plasticity at several stages of musical experience, whether it be after a structured period of learning for the child or older adult beginner or after many years of training for a professional musician. In light of our current study, however, what short-term plasticity effects, if any, arise from musical priming for the experienced pianist? My thesis will examine the cognitive effects of long-term piano training and short-term performance priming on non-musical skills as determined by tasks measuring participants' creativity and attention to detail.

2 THE SHORT-TERM EFFECTS OF SCORE-BASED PLAYING ON COGNITIVE TASK PERFORMANCE

2.1 Introduction

Playing a musical instrument is one of the most complex of motor tasks (Palmer, 1997). A musician must seamlessly integrate fast-paced sequential hand movements with purposeful expression and rhythmic accuracy, and it can take many years of practice to reach this level of musical fluency.

The musical styles in which a musician may undertake training can be—for the sake of simplification here—broadly categorized into two genres: improvisation (generally associated with jazz, baroque or experimental performance practice) or the performance of previously-practiced musical sequences that are normally learned (and frequently reiterated) with reference to a musical score (as generally occurs with classical music).

Since, for the current study, we are looking at the effects of music playing on cognitive task performance, we wanted to ensure that the cognitive results would not be confounded by mixing these two different kinds of performance—since they involve different kinds of neural activity. That different musical training and playing can activate different parts of the brain is supported by neuroimaging evidence. Functional magnetic resonance imaging (fMRI) studies examining the underlying neural circuitry of musical production have shown that when a musician is taking part in score-based musical sequences versus spontaneous musical improvisation, distinct patterns of neural activation are produced (Limb & Braun, 2008; Berkowitz & Ansari, 2008). As such, we restricted the category of performers to score-based / classically trained musicians in order to control for the effects of neural priming on task performance.

To reiterate, our study examines the influences of musical playing on the non-musical aspects of cognition; as such, an example of influence on task performance can be found in an experiment showing that the colour of a computer desktop can affect cognition in several different ways, depending on the specific colour. Whereas red backgrounds improve accuracy in task performance and attention, blue backgrounds stimulate greater creativity in problem solving (Mehta & Zhu, 2009). Furthermore, distinct neural activations have also been found to occur as a result of differing cognitive tasks. For instance, during problem solving exercises in which participants worked on anagrams (which can be solved deliberately or with sudden insight), an electroencephalography (EEG) study demonstrated that different cortical activity occurs between creative problem solving and analytical problem solving (Kounios & Beeman, 2009).

As indicated by the studies mentioned above, the neural effects of creative versus over-learned or detail-oriented actions are evident; however, the cognitive consequences of these different activities have not, to our knowledge, been experimentally examined musically thus far. In our study, we predicted that due to the nature of advanced score-based playing—where challenging note patterns and musical details such as pedaling, phrasing, dynamics, quality of sound, weight of the hands, controlling of the fingertips, and the conveying of meaning and expression are often extensively practiced and rehearsed—pianists would, immediately after a brief performance, demonstrate significantly better posttest detail-oriented task scores but show no significant change in posttest creative task scores.

2.2 Methods

2.2.1 Participants and Musical Screening

A total of 46 participants (36 females and 10 males, age range of 17 to 37 years, mean age 22 years) took part in the study based on a self-report during recruitment of advanced piano playing experience. To confirm their playing status, several targeted questions were asked at the completion of the study: (1) "Were you formally trained or self-taught? What grade/level did you reach in your training?" (2) "How many years of experience do you have playing this instrument?" Results showed that (1) All participants received advanced formal piano training and (2) Participants reported 7 to 31 years of playing experience with a mean number of 14.41 years.

The study took place in the Sound Studio of the Institute for Computing, Information and Cognitive Systems at the University of British Columbia. Participants received $10 in exchange for taking part in the study. All procedures and protocols were approved by the Behavioral Research Ethics Board at UBC, and all participants gave their informed consent.

2.2.2 Conditions

Participants were randomly assigned to two conditions in our between-groups experimental design: Pre-Post condition or Post-Only condition.

Pre-Post Group

In the Pre-Post group, pianists completed cognitive tasks both prior to and following the performance of a piano piece. Serving as a baseline measurement, participants completed an exercise that was either creative or detail-oriented in nature; following their musical performance, participants were given the second cognitive task—those who completed the creative exercise before playing were now given the detail-oriented exercise and vice versa. Participants' performance results on the second task were then compared with the baseline performance results of the same task. Within this condition, the order of creative or detail-oriented exercises was randomly assigned.

Post-Only Group

In the Post-Only group, pianists completed a cognitive task only after their performance of a piano piece. The rationale for including this condition was to control for any confounding effects that the pretest task may have had on participants' musical performances in the Pre-Post group. This ensured that if any significant effect of music performance on posttest tasks were to be found in the Pre-Post condition, and similar posttest task results were also found in the Post-Only condition, the effect could be attributed solely as a result of the musical performance.

2.2.3 Procedures

As mentioned above, the experimental paradigm consisted of three phases: Cognitive Task 1 (for the Pre-Post group only), Performance Phase, and Cognitive Task 2.

Cognitive Task 1

In this phase, participants completed a cognitive task that was either creative or detail-oriented in nature; these tasks were randomly assigned.

Creativity Task: To parallel the colour studies conducted by Mehta and Zhu (2009), participants completed an alternative uses test—an exercise that has been shown to be a good measure of creativity (Martindale & Hines, 1975). Here, they were required to generate as many creative uses as they could think of for two household items (a brick and bucket) and to refrain from listing typical uses or those that are virtually impossible. Participants were given a time limit of one minute for each item. The order in which the household item questions were given was randomly assigned.

Detail-Oriented Task: A proofreading exercise, often used to assess focus and attention to detail (Kaplan, 1995), served as the detail-oriented task. Participants were asked to compare two passages of a fictional language (Klingon) in which one passage contained spelling and punctuation mistakes. They were given two minutes to find as many mistakes as possible.

Performance Phase

Following the first cognitive task, participants performed a score-based piece of their choice on a Yamaha C3 MIDI Grand Piano. As it would have been impossible to have all participants perform the same piece, pianists were asked to perform a musical work of their choice, thus more adequately controlling for overall piece familiarity and experience.

Participants were instructed to play for ten minutes. If they finished their piece before the allotted time, they were to repeat the performance until time was complete. The rationale for asking them to play the same piece throughout was to, once again, minimize fluctuations in piece familiarity and experience, as well as overall changes in musicality and technicality that would more easily occur in the case of performing several different musical pieces within a given timeframe.

The performances were digitally video recorded in order to assess performance expertise off-line; at the time of playing, however, no feedback was given to participants as to the quality of their performances. The videos were also used to obtain independent ratings of how creative or detail-oriented a performer appeared to be. In order to preserve anonymity, the videos only included the hands of the musicians while they performed on the piano.

Cognitive Task 2

For the Pre-Post group, those who completed the Creativity task before the piano performance would now complete the Detail-Oriented task and vice versa. Those in the Post-Only group completed only one of these two cognitive tasks; the tasks for the Post-Only group were randomly assigned.

2.3 Results

The statistical results reported here are based on a one-way ANCOVA analysis using PSAW Statistics 18.0. All results were controlled for the effects of how well participants knew their pieces and how difficult they found their pieces to play.

2.3.1 Cognitive Tasks

Creativity Task

For the alternative uses task, a total of 243 unique uses were produced by all participants. Fifteen independent coders rated each of these uses for creativity based on a 9-point Likert scale, with 1=Very Uncreative, 5=Neither Creative Nor Uncreative and 9=Very Creative. In keeping with Mehta and Zhu's study, responses for the creative task were coded according to the total number of uses generated, the total number of creative uses and a mean creativity score. The total number of uses generated was simply the total count of uses given by each participant; the total number of creative uses was the total number of uses per participant that received mean creativity scores greater than five; and the mean creativity score was calculated by summing the mean creativity scores for each of the uses given by a particular participant, and then dividing that amount by the total number of uses generated by that participant. Examples given by subjects for creative uses of a brick included using it as a 'laptop cooler' or to 'sustain a piano's pedals'; examples of creative uses of a bucket included 'demonstrational centripetal force' or to 'fend off wild animals'.

In the Pre-Post group, 12 participants completed the Creativity task pretest and 11 participants completed the Creativity task posttest. No significant differences were found between the pretest and posttest results for total number of uses ($F(1, 19) = .612$, $p = .444$), total number of uses with mean creativity scores greater than five ($F(1, 19) = 1.888$, $p = .185$), or mean creativity scores ($F(1, 19) = 2.127$, $p = .161$).

As reported, no significant differences between the pretest and posttest creativity scores were found; however, we still compared the posttest scores of the Pre-Post and Post-Only groups to ensure that the tasks completed before the musical performances in the Pre-Post group did not affect the musical performances themselves or the subsequent tasks. As a result, 11 participants from the Pre-Post group completed the Creativity task posttest and 12 participants in the Post-Only group completed the Creativity task posttest. Here as well, no statistically significant differences were found for total number of uses ($F(1, 19) = .554$, $p = .466$), total number of uses with mean creativity scores greater than five ($F(1, 19) = .121$, $p = .732$), or mean creativity scores ($F(1, 19) = .062$, $p = .807$).

Detail-Oriented Task

Participants' performance for this task was coded by the number of errors made (e.g. any missed spelling or punctuation mistakes in the passage; incorrectly identified 'mistakes'), the number of words that were proofread (indicated by a vertical double bar-line marking the last word that was proofread), and the number of words per error.

In the Pre-Post group, 11 participants completed the Detail-Oriented task pretest and 12 participants completed the Detail-Oriented task posttest. No significant effects were reported for number of errors ($F(1, 19) = 3.353$, $p = .083$), number of words ($F(1, 19) = 2.713$, $p = .116$), or number of words per error ($F(1, 19) = .534$, $p = .474$).

Once again, we compared the posttest scores of the Pre-Post and Post-Only groups. 11 participants from the Pre-Post group completed the Detail-Oriented task posttest and 12 participants in the Post-Only group completed the Detail-Oriented task posttest. No significant differences were reported in number of errors ($F(1, 19) = .488$, $p = .493$), number of words ($F(1, 19) = .504$, $p = .486$), or number of words per error ($F(1, 19) = .102$, $p = .752$).

2.3.2 Further Analysis

Given our non-significant results for both the Creative and Detail-Oriented cognitive tasks, we wanted to examine the possibility that our findings were due to the number of participants in each group. With no significant differences found between the pretest and posttest scores within the Pre-Post group or between the posttest scores of the Pre-Post and Post-Only groups, the data suggests that the pretest did not effect piano performance; therefore, to increase power, we collapsed the two posttest groups, increasing the number of participants in the overall posttest condition to 23 participants for the Creativity task (with 12 in the pretest group), and 23 participants for the Detail-Oriented task (with 11 in the pretest group). The statistical analyses reported are based on one-way ANCOVAs using unweighted means to account for the unequal sample sizes between the pretest and posttest groups.

Creativity Task

After controlling for the effects of how well participants knew their pieces and how difficult they found their pieces to play, no significant effects were found for total number of uses ($F(1, 31) = .499$, $p = .485$), total number of uses with mean creativity scores greater than five ($F(1, 31) = 2.212$, $p = .147$), or mean creativity scores ($F(1, 31) = 2.938$, $p = .096$).

Detail-Oriented Task

Again, controlling for the effects of how well participants knew their pieces and how difficult they found their pieces to play, a significant effect was found for number of errors ($F(1, 30) = 4.517$, $p = .042$) with the mean number of errors nearly twice as high in the posttest condition (12.585) compared with pretest (6.323) (Figure 2.1). However, no significant effects were found for number of words ($F(1, 30) = 3.027$, $p = .092$), or number of words per error ($F(1, 30) = .986$, $p = .329$).

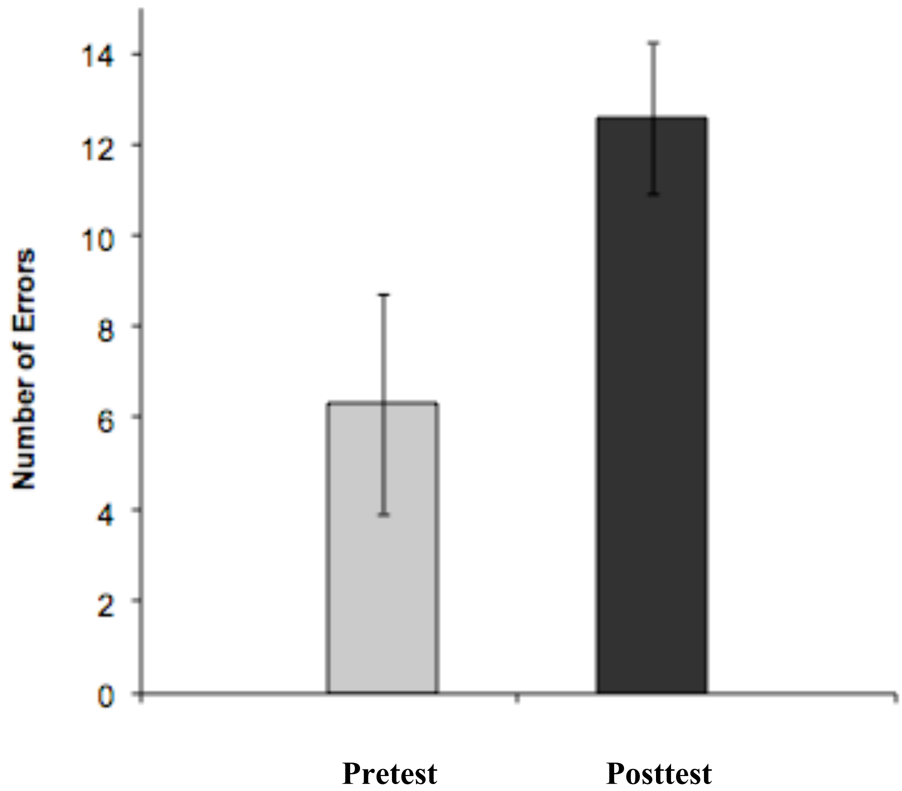

Figure 2.1. The mean number of proofreading errors for the Detail-Oriented task for Pretest and Posttest groups. Vertical bars indicate S.E.M.

2.3.3 Control Analysis

Questionnaires

In addition to answering the questions concerning years of piano training and experience, as outlined earlier, participants also completed the Creative Achievement Questionnaire (Carson, Peterson & Higgins, 2005) and provided subjective reports based on their piano performance.

Creative Achievement Questionnaire: The Creative Achievement Questionnaire (see Appendix A) measures general creative ability and is a self-report test that measures prior achievements in a number of creative domains such as visual arts, music, dance, architecture, creative writing, humour, inventions, scientific discovery, theatre and film, and culinary arts. After additionally controlling for participants' general creative ability scores (i.e. including these scores as an additional covariate in the ANCOVA analyses), no significant results were found for total number of creative uses ($F(1, 30) = .199$, $p = .659$), total number of creative uses with mean scores greater than five ($F(1, 30) = 1.793$, $p = .191$), or mean creativity scores ($F(1, 30) = 2.620$, $p = .116$).

Participants' Subjective Reports: Participants were required to provide subjective reports of thoughts or feelings they experienced during the performance phase of the experiment (e.g. were you thinking about specific notes, intervals, melodies, harmonies, chordal structures, etc.; were there any thoughts unrelated to the study). Two independent raters coded the subjective reports into four main categories: Related Internal Thoughts (R-I): muscle memory, emotional/mental state, visual/aural memory, visual/emotional/sound imagery; Related External Thoughts (R-E): score-reading, technique, the piano, instructor teachings; Unrelated Internal Thoughts (UnR-I): emotional/mental state, bodily sensations, imagery; and Unrelated External Thoughts (UnR-E): study/experimenter curiosity, study environment, past learning/performances, daily/social activities, physical, other music. Where participants indicated instances of mind-wandering but were unspecific as to whether these thoughts were Internal or External, the data was excluded from the analysis as we did not want to speculate on the type of mind-wandering that took place. The total scores for the average number of subjective reports for each category of R-I, R-E, UnR-I and UnR-E are outlined in Table 2.1. The table is categorized by participants who performed on the piano prior to the posttest Creativity task and by those who performed prior to the posttest Detail-Oriented task.

Table 2.1

Performers' Subjective Reports For Posttest Creativity and Posttest Detail-Oriented Groups. Outlined are the totaled group scores (23 participants per group) for the mean number of reports for each of the categories: Related Internal (R-I), Related External (R-E), Unrelated Internal (UnR-I) and Unrelated External Thoughts (UnR-E).

Posttest Creativity Group				
Category	R-I	R-E	UnR-I	UnR-E
Total Reports	63	173.5	4	30.5
Posttest Detail-Oriented Group				
Category	R-I	R-E	UnR-I	UnR-E
Total Reports	57	132.5	6.5	36

For the Creativity task, Pearson correlation analyses revealed no significant correlations between subjective reports and posttest task performance: between R-I and total number of uses (r = .176, n = 23, p = .421), total number of uses with mean creativity scores greater than five (r = .306, n = 23, p = .155), or mean creativity scores (r = .170, n = 23, p = .437); between R-E and total number of uses (r = .045, n = 23, p = .840), total number of uses with mean creativity scores greater than five (r = .129, n = 23, p = .556), or mean creativity scores (r = .202, n = 23, p = .355); between UnR-I and total number of uses (r = -.191, n = 23, p = .382), total number of uses with mean creativity scores greater than five (r = -.187, n = 23, p = .392), or mean creativity scores (r = -.021, n = 23, p = .923); and between UnR-E and total number of uses (r = -.308, n = 23, p = .153), total number of uses with mean creativity scores greater than five (r = -.245, n = 23, p = .259), or mean creativity scores (r = -.094, n = 23, p = .670).

For the Detail-Oriented task, Pearson correlation analyses also revealed no significant correlations between subjective reports and posttest task performance: between R-I and number of errors (r = .076, n = 23, p = .729), number of words (r = .069, n = 23, p = .753), or number of words per error (r = -.043, n = 23, p = .844); between R-E and number of errors (r = -.103, n = 23, p = .641), number of words (r = .012, n = 23, p = .955), or number of words per error (r = -.049, n = 23, p = .823); between UnR-I and number of errors (r = .322, n = 23, p = .134), number of words (r = .155, n = 23, p = .480), or number of words per error (r = -.117, n = 23, p = .594); and between UnR-E and number of errors (r = -.059, n = 23, p = .790), number of words (r = -.074, n = 23, p = .739), or number of words per error (r = -.047, n = 23, p = .832).

Independent Ratings of Participants' Piano Performances

We recruited twenty-five additional participants to watch short video clips of the piano performances, and to rate the pianists on an 8-point Likert scale according to how creative or focused on task they appeared to be. Of interest was any possible correlation between the subjective ratings of the videos and the pianists' subsequent task performance. Due to the practical constraints of the amount of information raters needed to make an evaluation, and based on the concept of thin-slicing—the idea that we are able to find patterns in behaviour based on thin slices of experience (Ambady & Rosenthal, 1992; Gladwell, 2007)—the videos presented were ten seconds in length; also, we decided to present the last ten seconds of music playing (as opposed to any other ten-second segment) with the idea that the pianists would be in any given state maximally at the end of their performances. All raters were recruited based on a self-report of having no prior piano playing experience; as such, we screened out one participant who indicated having piano training, leaving us with a total of twenty-four raters (twelve of the participants rated the pianists on perceived creativity, and the other twelve participants rated the pianists on their level of focus). Our rationale for recruiting raters with no piano experience was that training may presuppose ways in which certain behaviours and actions are measured and we did not want to predetermine what was deemed as creative or focused; thus, recruiting participants with no piano training allowed for more natural or sensitive measures. Furthermore, no specific guidelines were given to the raters as to how performers' level of creativity or focus should be interpreted; this allowed for some freedom and fluidity—the level of commonality or differences—in participants' evaluations. All videos were presented in random order using the stimulus presentation software SuperLab 4.5 by Cedrus.

As a significant effect was found for the number of errors participants made in the posttest Detail-Oriented task, a Pearson correlation coefficient assessing the relationship between these results and the average Focus ratings for the last ten seconds of piano performance was calculated. No significant correlation was revealed ($r = -.177$, $n = 23$, $p = .418$). Additionally, no significant correlation was found between number of errors and average Creativity ratings for the last ten seconds of piano performance ($r = -.188$, $n = 23$, $p = .390$).

Furthermore, we were interested in finding out how the participants judged creativity and focus—thus, we were interested in learning about the perception of playing in addition to the playing itself. As such, at the end of each rating session, the participants gave subjective reports detailing the methods they used to assess pianists' "creativity" or how "focused on task" they were. An outline of the subjective report categories can be found in Appendix B.

2.4 Discussion

The current study was designed to determine the short-term effects, if any, of advanced piano playing on cognitive task performance in different domains. As anticipated, we found no significant difference in posttest Creativity task scores. However, contrary to our prediction, participants performed significantly worse in the Detail-Oriented task immediately following their piano performance. In an attempt to understand the issues driving these effects, research investigating the neural correlates shared by advanced piano performance and the carrying-out of detail-oriented tasks will be discussed.

A common route to learning a musical instrument is to acquire the ability to read notes presented on a musical staff—a skill that, most certainly, all of our participants possessed. Note-reading involves translation from a visuospatial domain—the positioning of notes on the staff and their relation to one another—to a representation which informs the musician of such specifics as rhythm, pitch, patterns, musical textures and positioning of finger sequences (Sergent, 1993). Specifically with pianists, it has been shown that music reading reshapes spatial mapping until eventually, musical notation is automatically processed (Stewart, Walsh & Frith, 2004; Stewart, 2005). This provides evidence of the long-term neural modifications music training can produce.

Furthermore, as earlier discussed, neuroimaging studies have also demonstrated that distinct cortical activity results from different styles of musical training and playing (i.e. score-based versus improvisational). Since our participants are primarily classically trained, we are interested in the areas of the brain that are (or are not) activated during advanced score-based piano performance.

Several imaging studies have investigated the neural activity that is associated with higher-level score-based piano playing. A near-infrared spectroscopy study showed that piano tasks of higher complexity and appropriate to the level of each performer primarily activated the frontal lobe (Hashimoto et al., 2006). A study using O-water emission tomography demonstrated that bimanual performances of scales and concerto performances activated the primary motor cortex, corresponding somatosensory areas, inferior parietal cortex, supplementary motor area, motor cingulate, bilateral superior and middle temporal cortex, right thalamus, and anterior and posterior cerebellum (Parsons et al., 2005). These studies included only participants with piano training. Therefore, in order to get a better idea of brain activity unique to those with advanced performance skills, we will look at several studies comparing the neural activity of pianists to non-musicians.

Studies investigating neural circulation during actual piano performance are rare due to restrictions on space and motion (e.g. during fMRI). For this reason, several experiments utilized bimanual key-pressing tasks in an attempt to emulate typical movements generated by pianists during performance. For example, in an fMRI study using such tasks, Haslinger et al. (2004) found that musically naïve controls recruited an extensive motor network (mesial premotor, rostral cingulate and right dorsal premotor cortex, bilaterial cerebellar hemispheres, as well as activations within prefrontal cortex bilaterally, left ventral premotor cortex, inferior parietal cortex bilaterally and right striatum) to a greater degree than professional musicians. Also utilizing bimanual key-pressing tasks, Jancke, Shah & Peters (2000) found similar fMRI results with professional piano players showing considerably smaller activation in the primary and secondary motor areas (primary motor cortex, supplementary motor area, pre-supplementary motor area and cingulate motor area) compared with control subjects; in fact, the professional pianists showed very little activation in the pre-supplementary motor area and in the cingulate motor area. Again, during an overtrained complex finger movement task, Krings et al. (2000) also reported smaller activation clusters in the primary motor cortex, supplementary motor area, premotor cortex and superior parietal lobule for the professional pianists versus control subjects.

However, in an fMRI study in which participants were prompted only to randomly press keys on a mute MRI-compliant one-octave segment of a grand piano keyboard (Bangert et al., 2006), professional pianists demonstrated activity in the premotor and supplementary motor area whereas for the non-musicians, there was none. Greater activation was also detected in the bilaterial dorsolateral prefrontal cortex for the pianists with almost no activity for the non-musicians. In the right hemisphere, neural activity for pianists was also found in the dorsolateral and inferior frontal cortex (including Broca's area) and the superior temporal gyrus (Wernicke's area).

If we compare the results of the Bangert study with those of the aforementioned fMRI experiments above, we can see that the musicians in Bangert's study show increased activity in the supplementary and premotor areas whereas musicians in the Haslinger, Jancke and Krings studies clearly reveal decreased activity. What is the reason for these conflicting results? Bangert suggests that these neural differences can be ascribed to differences in the complexity of tasks—that the decrease in neural activity for participants in the Jancke and Krings studies is due to the higher level of complexity of their motor tasks.

Since the complexity of the tasks presented in the Haslinger, Jancke and Krings studies more closely parallel the advanced level of performance skill required of the participants in our study, we will focus on their experimental findings—that is, the comparatively considerable reduction in anterior cingulate and pre-supplementary motor activity (as well as the reduction in activity for other regions within the primary and secondary motor areas) for the professional piano players versus control subjects.

Now that we have examined the neural activity that takes place during skilled motor performance for pianists, of interest is whether there are any neural correlates shared by this activity and the carrying out of detail-oriented tasks. As our study employed a proofreading task as a measurement of participants' level of detail-oriented behaviour, it follows that the neural correlates involved with error detection tasks must be discussed.

For error processing, the anterior cingulate cortex is believed to play an important role (Bush, Luu & Posner, 2000), and this is most notably demonstrated in studies involving the Stroop task (Posner & DiGirolamo, 1998); specific to music, this same area has also been shown to be involved in the detection of wrong notes for pianists (during deliberately fast performances—in order to induce error production—of selected right-hand sequences from Preludes V, VI, and X of the Well Tempered Clavier, Part 1, by J.S. Bach and the Piano Sonata No. 52 in E Flat Major by J. Haydn) (Ruiz, Jabusch & Altenmuller, 2009). In addition to the anterior cingulate cortex, neural generators in action-monitoring have also been found in the pre-supplementary motor area and supplementary motor area (Dehaene, Posner & Tucker, 1994; Carter et al., 1998). As mentioned earlier, these are the same areas of the brain that show very little activation for advanced pianists during complex bimanual tasks. It appears that, for pianists, the neural underpinnings of error monitoring are minimally activated during higher-level motor performance. What are the possible reasons for this occurrence?

Piano playing requires a high degree of controlled, sequential individual finger movements and bimanual coordination. As a result, through long-term motor practice, musicians develop cognitive representations of these finger movements (Pantev et al., 2001). For the novice piano learner, the use of visual, proprioceptive and auditory feedback is essential whereas the now-advanced pianist no longer needs to rely on these external cues and now possesses a high level of manual dexterity and polish in his or her performance (Pascual-Leone et al., 1995; Pascual-Leone, 2001). Due to this long-term training and practice, pianists develop an increased efficiency of the motor system for complex bimanual motor activity, thereby requiring fewer number of active neurons in order to carry out pre-determined individual finger actions—allowing them to focus on the artistic aspects of playing and enlarging their capacity to engage in a wider and more diverse range of movements. In the same respect, the number of errors during an advanced musical performance is often minimal despite the rapid rate of music production. Thus, it is possible that during piano performance the decreased neural activity in these specific areas inhibits the ability for participants to perform optimally in any immediate subsequent task requiring error monitoring ability.

3 CONCLUSION

3.1 Summary

Our findings show that advanced score-based piano playing can have a short-term effect on detail-oriented task performance. More specifically, while no change in posttest creativity was found with the alternative uses task, participants demonstrated significantly worse scores in the posttest proofreading task. That piano playing may hinder performance on a cognitive skill seems to contrast with the results of many studies demonstrating beneficial cognitive effects of short-term musical priming (in the form of music listening). Several reasons for our findings are explored.

3.2 Subjective Reports Support Neural Activity

We discussed earlier the neural effects of advanced motor activity in pianists—namely, that the extent to which primary and secondary motor areas are activated is significantly less compared with control participants. Here, the idea is that as the level of playing expertise increases, the recruitment of motor areas becomes increasingly efficient, allowing the performer's cognitive functions to focus on higher-order aspects of aural tracking and tactile response in connection with the performer's aural image and conception of the music. Furthermore, even with a familiar score in view, the performer no longer needs to rely on it for music reading during performance. They are still monitoring their performance continuously however—only now, instead of scrutinizing their scores and correcting errors in the visual domain, they are noticing and correcting errors in the aural and tactile domains.

The idea that participants were not dependent on their scores is supported by their subjective reports: although no significant correlations were found between subjective reports and task performance, if we look specifically at the 42 participants who commented on their use of score and/or muscle memory during their performances, 22 of them reported using primarily muscle memory, 5 of them reported using primarily their score and 15 of them reported using both muscle memory and score. It is clear that although the pieces were score-based, a large number of the pianists employed muscle memory to carry out their performances. This arguably demonstrates that many participants knew their pieces well enough whereby they were no longer entirely dependent on the details of their musical scores.

3.3 Priming

The learning of a musical work may initially be score-based; however, once the music is learned to a certain degree, the performance is no longer entirely score-based. At this stage, score reading involves recognition and not the full cognitive process of reading something unfamiliar; performers merely need to refer to the score, if needed, in order to see a familiar pattern—no longer is there a need to continuously check the musical page for errors or discrepancies. Hence, due to the high level of familiarity with their individual pieces, the participants in this study were not actually being primed for visual accuracy—which resulted in decreased scores in error monitoring for the posttest Detail-Oriented task.

3.4 Creativity: Convergent vs. Divergent Thinking

If the pianists were fluent with their pieces and possessed the freedom and ability to engage in the higher-order aspects of performance, then presumably this could translate—or prime them—into thinking in a more innovative manner for any creative task immediately following their performance. However, we found no significant difference between the pretest and posttest creative task results. An explanation for this outcome could be the type of creative task that we used.

Research in creative problem solving is generally defined by two specific types of thinking: divergent and convergent thinking. For our creative exercise we used the alternative uses task which falls under the category of divergent creative problem solving—that is, participants were asked to generate new ideas or solutions in coming up with novel uses for everyday household items. This style of cognitive processing is predominately used in the early stages of problem solving (Vincent, Decker & Mumford, 2002). Convergent thinking, however, occurs when several possible solutions are evaluated before the best solution is settled upon. The Remote Association Task (Mednick, 1962) is an exercise commonly used to test convergent thinking wherein participants are presented with three words and are then required to come up with a word that is associated with the other three (e.g. what is the fourth word that relates to: Rock, Ware, Steel?). In contrast to divergent thinking, convergent thinking takes place in the later stages of problem solving (Brophy, 2000). It has also been found that people engage in either divergent or convergent thinking, rather than a combination of both, and that these two manners of problem solving present distinct cognitive processes (Brophy, 2000). Given this, we will examine some of the thought processes taking place during our musicians' performances via their subjective reports, and how these thoughts may relate to a more convergent style of creative thinking.

Subjective reports given by our participants revealed several accounts of self-criticism ("I could have done better", "I thought occasionally about errors and unsuccessful musical phrases, articulation, etc."), comments about execution of their performance ("I tried to remember what techniques I had used in the past to play this piece well, i.e. strong fingers, relaxed wrists, sweeping elbows"; "I imagined what it would be like to play this piece perfectly, as I heard it in my mind's ear"), opinions about the piano ("I was thinking about the sound of the piano—which is much better than the one I was playing yesterday"; "I thought about the piano and how different it was from my own, how I had to press the notes just a little harder to play softly"), the study environment ("I thought about the acoustic of this room and how dry the sound was"; "I thought about tone quality and adjusting to the environment so the sound is created with more resonance") and thoughts concerning instructors' teachings ("I recalled advice teachers of the past have given me"; "I remembered how my teacher emphasized certain parts…to bring out the dynamics of the piece"). These reports reflect participants' use of evaluation, adaptation and reasoning—cognitive processes associated more with convergent, rather than divergent, methods of thinking. As is the case, perhaps testing the effects of score-based playing on convergent creative thinking skills would in turn, yield significant results.

3.5 Limitations

3.5.1 Sample Homogeneity

Participants were asked to perform a musical work of their own choice as it would have been impossible to get an adequate sample size of pianists performing the exact same piece. This was the best way to control for piece familiarity between participants; asking everyone to perform the same piece would undoubtedly have resulted in discrepancies between performance expertise levels. Still, as described within the analyses section, we controlled for the effects of how well participants knew their pieces and how difficult they found their pieces to play in order to further ensure optimal sample homogeneity. However, having participants perform different musical works presented other challenges such as mood variance amongst pieces. Since mood has been shown to influence task performance (Thompson, Schellenberg & Husain, 2001), the differences in the musical character of pieces between subjects could potentially have influenced task performance outcomes.

3.5.2 Performance Repetition

Since pianists' individual pieces varied in length, they were asked to play the same piece repeatedly—as opposed to a selection of different pieces—until the performance phase was complete. This was to keep variation in technical ability, mood and other musical factors to a minimum within the performance phase (although, understandably, variation of these musical factors would occur within nearly any single performance). In the case where some of the pieces were shorter, resulting in a higher number of repeated performances, participants may have experienced boredom or higher instances of mind-wandering which in turn, could have affected the results of their cognitive task performance.

3.5.3 Bimanual Key-Pressing Tasks vs. Piano Playing

A high level of bimanual coordination is essential for piano playing (Haslinger et al., 2004). As such, bimanual key-pressing and complex finger movement tasks have been used to examine the neural representations of piano performance; however, these tasks are far from the true nature of piano playing. Aside from the obvious physical differences between acoustic pianos and the shortened keyboards used in experiments (or complete lack thereof), key-pressing tasks offer no—or in some cases, unnatural—auditory feedback. Furthermore, the performer is not engaged in the same manner—emotionally, mentally, physically or musically—during bimanual key-pressing tasks as they would be in a natural performance setting.

3.6 Further Directions

Due to the level of familiarity with their pieces, participants reported minimal use of their scores. Since they were not actively using visual cognition while playing, they were not primed to perform well on a visually detail-oriented posttest task. But what if players were presented with, and asked to perform, an unfamiliar musical piece—thus requiring them to more actively monitor their performance for any errors or discrepancies? Perhaps an expansion of this study could involve measuring participants' performance on a visual proofreading task immediately following a brief period of sight-reading from simple musical scores.

The final issue regarding the cognitive effects of musical playing concerns the style of the musical playing itself. For our study, all of the participants were screened specifically for having advanced score-based piano training. Of interest though is whether professional improvisational pianists (e.g. jazz musicians), would demonstrate different results (i.e. greater creativity) in the posttest creativity phase. To support this hypothesis—at least from a neural standpoint—we return to the fMRI study conducted by Limb & Braun, (2008) which showed that keyboard improvisation, compared with a control condition (memorization), resulted in a complete shut down of the dorsolateral prefrontal cortex—the part of the brain largely responsible for monitoring one's performance. Conversely, the medial prefrontal cortex—involved in self-initiated behaviours and thoughts—increased in activity. Thus, the idea here is that musicians already engaged in the spontaneous generation of novel musical ideas may be inspired and neurally primed to carry on those creative impulses into the completion of a cognitive task. As such, another proposed expansion to this study may involve testing creativity task performance—measuring both divergent and convergent thinking—of improvisational musicians.

3.7 Significance of Research

Does listening to music or partaking in music lessons make you smarter? It makes sense that involvement in musical activities translates to higher *musical* intelligence. This can be seen in the quality of children's drawings and invented symbols for musical sound as their musical perception and intelligence increasingly develops (e.g. Bamberger, 1982, 1991; Davidson & Scripp, 1988, 1989; Domer & Gromko, 1996; Gromko, 1994; Poorman, 1996).

But what about the extramusical effects of music education? We have briefly examined the results of active participation (e.g. instrumental lessons) versus passive music listening (e.g. the Mozart effect). Many studies have detailed the benefits of music training on cognitive abilities such as spatial talent—a skill that is unarguably important for professions such as architecture and engineering, or for fields of study such as mathematics and the natural sciences. Conversely, other studies have demonstrated that factors other than music account for changes in cognitive capability (mood and arousal, rather than Mozart, influence task performance). In the case of our experiment, we have shown that participants' error detection rate significantly suffers immediately following a familiar score-based musical performance.

Furthermore, there have been plenty of studies outlining the neural responses elicited by musical engagement and although there is evidence that music training can generate instant plasticity in the cortex (Bangert & Altenmuller, 2003), the question of whether long-term or short-term music exposure can uniquely and reliably produce effects on nonmusical aspects of cognition remains to be settled.

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Appendices

Appendix A: Creative Achievement Questionnaire

CREATIVE ACHIEVEMENT QUESTIONNAIRE
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I. *Place a check mark beside the areas in which you feel you have more talent, ability, or training than the average person.*

__visual arts (painting, sculpture)
__music
__dance
__individual sports (e.g. tennis, golf)
__team sports
__architectural design
__entrepreneurial ventures
__creative writing
__humor
__inventions
__scientific inquiry
__theater and film
__culinary arts

II. *Place a check mark beside sentences that apply to you. Next to sentences with an asterisk (*), write the number of times this sentence applies to you.*

A. Visual Arts (painting, sculpture)
__ 0. I have no training or recognized talent in this area. (Skip to Music).
__ 1. I have taken lessons in this area.
__ 2. People have commented on my talent in this area.
__ 3. I have won a prize or prizes at a juried art show.
__ 4. I have had a showing of my work in a gallery.
__ 5. I have sold a piece of my work.
__ 6. My work has been critiqued in local publications.
*__ 7. My work has been critiqued in national publications.

B. Music
__ 0. I have no training or recognized talent in this area (Skip to Dance).
__ 1. I play one or more musical instruments proficiently.
__ 2. I have played with a recognized orchestra or band.
__ 3. I have composed an original piece of music.
__ 4. My musical talent has been critiqued in a local publication.
__ 5. My composition has been recorded.
__ 6. Recordings of my composition have been sold publicly.
*__ 7. My compositions have been critiqued in a national publication.

C. Dance
__ 0. I have no training or recognized talent in this area (Skip to Architecture)
__ 1. I have danced with a recognized dance company.
__ 2. I have choreographed an original dance number.
__ 3. My choreography has been performed publicly.
__ 4. My dance abilities have been critiqued in a local publication.

__ 5. I have choreographed dance professionally.
__ 6. My choreography has been recognized by a local publication.
*__ 7. My choreography has been recognized by a national publication.

D. Architectural Design
__ 0. I do not have training or recognized talent in this area (Skip to Writing).
__ 1. I have designed an original structure.
__ 2. A structure designed by me has been constructed.
__ 3. I have sold an original architectural design.
__ 4. A structure that I have designed and sold has been built professionally.
__ 5. My architectural design has won an award or awards.
__ 6. My architectural design has been recognized in a local publication.
*__ 7. My architectural design has been recognized in a national publication.

E. Creative Writing
__ 0. I do not have training or recognized talent in this area (Skip to Humor).
__ 1. I have written an original short work (poem or short story).
__ 2. My work has won an award or prize.
__ 3. I have written an original long work (epic, novel, or play).
__ 4. I have sold my work to a publisher.
__ 5. My work has been printed and sold publicly.
__ 6. My work has been reviewed in local publications.
*__ 7. My work has been reviewed in national publications.

F. Humor
__ 0. I do not have recognized talent in this area (Skip to Inventions).
__ 1. People have often commented on my original sense of humor.
__ 2. I have created jokes that are now regularly repeated by others.
__ 3. I have written jokes for other people.
__ 4. I have written a joke or cartoon that has been published.
__ 5. I have worked as a professional comedian.
__ 6. I have worked as a professional comedy writer.
__ 7. My humor has been recognized in a national publication.

G. Inventions
__ 0. I do not have recognized talent in this area.
__ 1. I regularly find novel uses for household objects.
__ 2. I have sketched out an invention and worked on its design flaws.
__ 3. I have created original software for a computer.
__ 4. I have built a prototype of one of my designed inventions.
__ 5. I have sold one of my inventions to people I know.
*__ 6. I have received a patent for one of my inventions.
*__ 7. I have sold one of my inventions to a manufacturing firm.

H. Scientific Discovery
__ 0. I do not have training or recognized ability in this field (Skip to Theater
__ 1. I often think about ways that scientific problems could be solved.
__ 2. I have won a prize at a science fair or other local competition.
__ 3. I have received a scholarship based on my work in science or medicine.

__ 4. I have been author or coauthor of a study published in a scientific journal.
*__ 5. I have won a national prize in the field of science or medicine.
*__ 6. I have received a grant to pursue my work in science or medicine.
__ 7. My work has been cited by other scientists in national publications.

I. Theater and Film
__ 0. I do not have training or recognized ability in this field.
__ 1. I have performed in theater or film.
__ 2. My acting abilities have been recognized in a local publication.
__ 3. I have directed or produced a theater or film production.
__ 4. I have won an award or prize for acting in theater or film.
__ 5. I have been paid to act in theater or film.
__ 6. I have been paid to direct a theater or film production.
*__ 7. My theatrical work has been recognized in a national publication.

J. Culinary Arts
__ 0. I do not have training or experience in this field.
__ 1. I often experiment with recipes.
__ 2. My recipes have been published in a local cookbook.
__ 3. My recipes have been used in restaurants or other public venues.
__ 4. I have been asked to prepare food for celebrities or dignitaries.
__ 5. My recipes have won a prize or award.
__ 6. I have received a degree in culinary arts.
*__ 7. My recipes have been published nationally.

K. Please list other creative achievements not mentioned above.

III. *Place a check mark beside sentences that apply to you.*
__ One of the first things people mention about me when introducing me to others is my creative ability in the above areas.
__ People regularly accuse me of having an “artistic” temperament.
__ People regularly accuse me of being an “absent-minded professor” type.

Appendix B: Subjective Report Categories for Video Ratings

Subjective Reports for Performance Creativity. Reported is the total number of ratings for each of the categories used to measure pianists' level of creativity during their musical performance.

Subjective Report Categories - Creativity	*Total number of ratings*
Recognition	7
Tempo	6
Intensity	6
Complexity	6
Feelings	4
Fluidity	4
Confidence	1
Comfortable to the ear	1
Body posture	1

Subjective Reports for Performance Focus. Reported is the total number of ratings for each of the categories used to measure pianists' level of focus during their musical performance.

Subjective Report Categories - Focus	*Total number of ratings*
Fluidity	7
Experimenter's Presence	7
Complexity	6
Error rate	4
Fidgeting	3
Body posture	2
Feelings	1
Number of hands	1