From Music to Medicine:
Transfer of Motor Skills from Piano Performance to Laparoscopic Surgery

by

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Table of Contents

Abstract

Background: Due to the deficit of knowledge on fine motor skill far transfer from one domain of expertise to another, piano performance and surgical training serve as a relevant, interdisciplinary context in which to study the transfer of motor skills given both have relatively well-established levels of performance and require complex fine motor skills. Musicians tend to demonstrate greater ease in all aspects of procedural knowledge which are known to contribute to the early stages of motor learning. Previous research in the Piano Pedagogy Research Laboratory (PPRL) found that extensive piano training was correlated with faster learning of surgical knot-tying skills. However, the short-term two-day timeline was a limitation of the study. **Objective:** Our project has built on previous work in the PPRL to address the short-term nature of previous studies by measuring a long-term performance curve as well as retention of surgical training and also expanded on the previous project by focussing this time on laparoscopic tasks. This study compared performance curves of two participant groups (pianists and controls) over five consecutive days and retention one week later, as measured by speed and accuracy of task completion. Laparoscopic training consisted of six tasks repeated at every session. Since laparoscopy involves a variety of abilities concurrently, we also administered a battery of ten psychometric tests to isolate and measure specific aspects of non-motor and fine motor skills. **Results:** There was no statistical difference between participant groups on the majority of laparoscopic training and psychomotor assessments based on two-way mixed ANOVA and Mann-Whitney U test analysis, respectively. There were also little to no significant correlations between abilities and laparoscopic performance. The only significant confounding variable was that the control group was significantly more interested in surgery than the musician group ($p = .037$). **Conclusion:** Overall, these results demonstrate that piano performance training did not far transfer to laparoscopic surgery. This is relevant to the debate on far transfer of motor skills given this study's robust design which addressed previous shortcomings by including a longer timeline and more specifications of musicians' characteristics. Our findings indicate that fine motor skills are domain specific to music and surgery, respectively.

Keywords: motor learning, skill transfer, piano performance, laparoscopic surgery, fine motor skill, psychometric tests, visuospatial ability, depth perception, dexterity, ambidexterity, hand-eye coordination

Résumé

Contexte : En raison du déficit de connaissances sur la motricité fine, très éloigné d'un domaine d'expertise à un autre, l'interprétation pianistique et la formation chirurgicale constituent un contexte interdisciplinaire pertinent pour étudier le transfert de la motricité étant donné que les deux ont des niveaux de performance relativement bien établies et nécessitent une motricité fine complexe. Les musiciens ont tendance à démontrer une plus grande facilité dans tous les aspects des connaissances procédurales qui sont connus pour contribuer aux premiers stades de l'apprentissage moteur. Des recherches antérieures au laboratoire de recherche en pédagogie du piano (LRPP) ont révélé qu'une formation approfondie au piano était corrélée à un apprentissage plus rapide des techniques chirurgicales de nouage. Cependant, le délai à court terme de deux jours était une limite de l'étude. **Objectif :** Notre projet s'est appuyé sur les travaux antérieurs du LRPP pour aborder la nature à court terme des études précédentes en mesurant une courbe de performance à long terme ainsi que la rétention de la formation chirurgicale et a également élargi le projet précédent en se concentrant cette fois sur les tâches laparoscopiques. Cette étude a comparé les courbes de performance de deux groupes de participants (pianistes et témoins) sur cinq jours consécutifs et la rétention une semaine plus tard, telle que mesurée par la vitesse et la précision de l'exécution des tâches. La formation laparoscopique consistait en six tâches répétées à chaque session. Étant donné que la laparoscopie implique une variété de capacités simultanément, nous avons également administré une batterie de dix tests psychométriques pour isoler et mesurer des aspects spécifiques des habiletés motrices non motrices. **Résultats :** Il n'y avait pas de différence statistique entre les groupes de participants sur la majorité des évaluations laparoscopiques et psychomotrices basées sur l'analyse bidirectionnelle mixte ANOVA et Mann-Whitney U, respectivement. Il y avait également peu ou pas de corrélations significatives entre les capacités et les performances laparoscopiques. La seule variable de confusion significative était que le groupe témoin était significativement plus intéressé par la chirurgie que le groupe musicien (p = 0,037). **Conclusion :** Dans l'ensemble, ces résultats démontrent que l'entraînement au piano n'a pas transféré à la chirurgie laparoscopique. Ceci est pertinent pour le débat sur le transfert lointain des habiletés motrices étant donné la conception robuste de cette étude qui a corrigé les lacunes précédentes en incluant une chronologie plus longue et plus de spécifications des caractéristiques des musiciens. Nos résultats indiquent que la motricité fine est spécifique aux domaines de la musique et à la chirurgie, respectivement.

Mots-clés : apprentissage moteur, transfert de compétences, performance au piano, chirurgie laparoscopique, motricité fine, tests psychométriques, capacité visuospatiale, perception de la profondeur, dextérité, ambidextérité, coordination œil-main

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List of Tables

List of Figures

Introduction

There is little knowledge on fine motor skill transfer from one domain to another. Of the existing research, results were mixed with some suggesting fine motor skills positively transfer, while others suggest there is no transfer at all (Green & Bavelier, 2008). Our study aims to investigate this topic further by selecting two domains of expertise that have well-established levels of performance and require complex fine motor skills: piano performance and surgical training. Both domains involve many years of fine motor skill training to reach a high level of expertise. In order to understand what is involved, the following discussion provides background information regarding current accepted theories in motor skill acquisition and transfer which functions as a lens through which we conducted our study. The subsequent review of literature lists motor skills associated with piano training, motor skills required in surgical performance, and summarizes the literature to date on whether motor skills far transfer from music performance to the surgical domain while highlighting the need for more research.

Nomenclature

This section provides a brief overview of cognitive psychology and neuroscience theories regarding motor skill acquisition and transfer in five parts. The first part describes procedural learning and its components. The next discusses motor skill learning and acquisition. The third part considers retention. The fourth and fifth parts describe domains of expertise and motor skill transfer, respectively. Altogether these sections provide the theoretical framework and nomenclature for understanding motor skill acquisition and transfer.

Procedural knowledge

Historically, it was the convergence of theories from cognitive neuroscience (habit learning) and cognitive neuropsychology (implicit learning and automatic processing) that gave rise to a more unified theory known as **procedural learning**, which is a type of non-declarative knowledge inaccessible to the conscious mind (Seger & Spiering, 2011). Procedural learning is multifaceted and can be divided into two skill sets (hereafter referred to as 'skill faculties'): non-motor and motor. The non-motor skill faculty includes cognitive and perceptual skills whereas the motor skill faculty stands alone (Squire & Zola-Morgan, 1988; Green & Bavelier, 2008). The **cognitive faculty** involves language processing of instructions and visual attention to complete a given task (Evans, 2008). The **perceptual faculty** involves perception of given stimuli, which is closely intertwined and often considered a sub-set of the cognitive faculty. The final faculty concerns motor skills. It is important to distinguish between motor skills and motor abilities. **Motor skills** are generally learned activities requiring voluntary movements of the body to accomplish a task; they can be categorized as fine or gross (Magill & Anderson, 2016; Adams, 1987). **Fine motor skills** are the high-precision control of small musculature in hands and fingers in conjunction with hand-eye coordination to accomplish a task, whereas gross motor skills consequently require engagement of larger muscles (Magill & Anderson, 2016). In comparison, **motor ability** involves non-learned individual differences in performing a motor skill; these can also be categorized as fine or gross. These key terms are the foundation for understanding motor skill learning and transfer.

Motor skill learning and acquisition

Motor skill learning, also known as the process of motor skill acquisition, is the difference between initial and final performance of a task in any field, where the final performance occurs after a training period (Ackerman, 1987). Repeated measures of performance throughout the learning process can generate a performance curve with its slope representing an individual's **learning rate** (Schmidt & Lee, 2005; Ackerman, 2007). In parallel, cognitive and perceptual faculties are strongly involved in the early stage of learning through the use of cognitive and visuospatial abilities (Fitts & Posner, 1967; Fleishman, 1972; Fleishman & Rich, 1963; Spruit et al., 2014). An increase in factors such as motivation (Fitts &

Posner, 1967; Lee, 1998; Green & Bavelier, 2008) and aptitude (Cronbach & Snow, 1981) often result in higher learning rates. **Motor skill acquisition** is the final stage reached in learning to the point of automatization or autopilot, requiring little to no cognitive involvement (Fitts & Posner, 1967; Logan, 1988; Ackerman, 2007; Spruit et al., 2014; Halsband & Lange, 2006). In a performance curve, this is typically represented by a **performance plateau** (Schmidt & Lee, 2005).

Retention

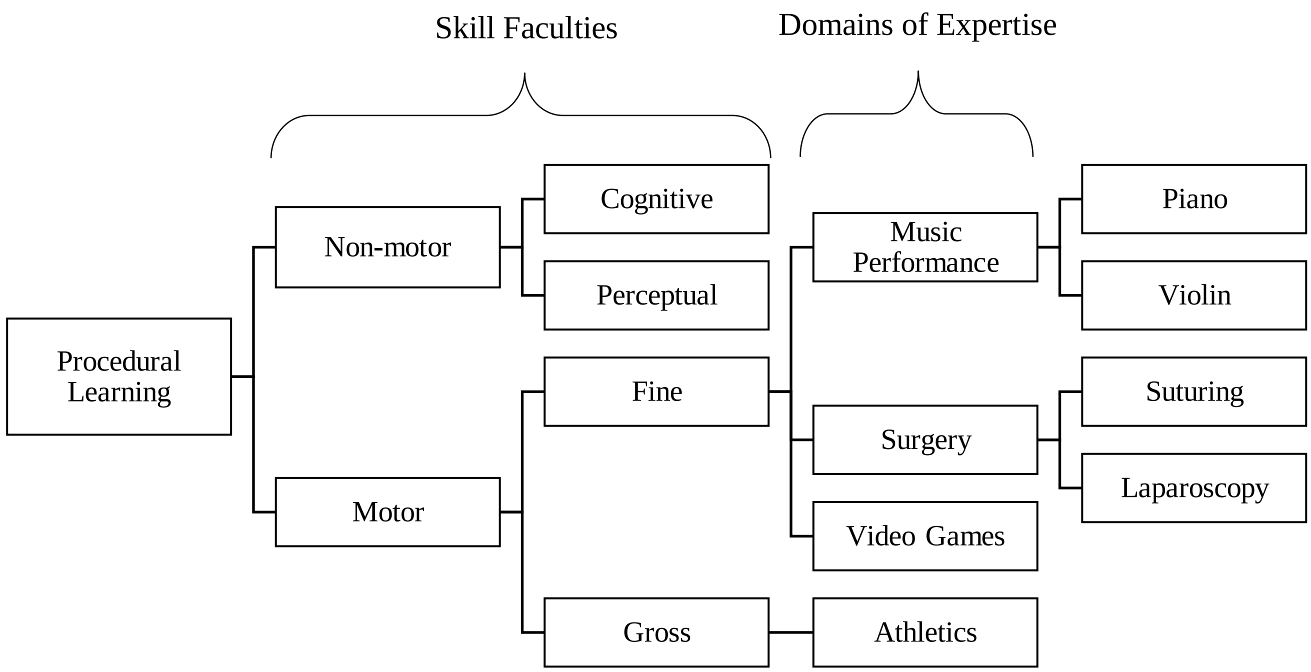
Once a new motor skill has been learned, it is also questioned as to how long this skill is retained or remembered. Retention can be categorized as either short-term or long-term. **Short-term retention** generally takes place over minutes, hours or days, whereas **long-term retention** takes place over weeks, months or years, though the precise time interval is relative to each other and the topic being researched (Adams, 1987). For example, a study by Massetti and colleagues (2018) found there was a short-term retention of five minutes after pediatric patients with Duschenne Muscular Dystrophy practiced a virtual target reaching task. In comparison, another study by Smith (2002) found that newly acquired snowboarding skills were retained after a one-week-hiatus from practice, suggesting long-term retention.

Domains of expertise

It is no surprise that experts have acquired several motor skills in a given domain of expertise. A **domain of expertise** (referred to as 'domain' in short form) is defined as an area of specialization typically associated with a specific career or hobby at a high level of expert performance (Ericsson, 1997). It is widely accepted that greater amounts of time engaged in **deliberate practice** (focused, purposeful rehearsal) generally leads to higher levels of performance compared to those who invested fewer hours (Ericsson et al., 1993). Domains of expertise pertaining to fine motor skills include music performance, surgery or other activities requiring fine movement of the hands and fingers. On the other hand, domains pertaining to gross motor skills include athletics, rehabilitation or occupations requiring movements of larger limbs such as the arms and legs. See Figure 1 below for a diagram summarizing procedural learning.

Figure 1

Tentative skill learning taxonomy.



Note. This taxonomy highlights and provides a road map of the main domains of expertise discussed throughout this work. It is not an exhaustive list. Procedural learning is divided into non-motor (includes cognitive and perceptual) and motor skill faculties (Squire & Zola-Morgan, 1988; Green & Bavelier, 2008). We have termed these skill sets as *faculties* to avoid confusion with "domains of expertise" used later (Ericsson, 1997). The motor skill faculty branches into either fine or gross. The fine motor skill faculty includes but is not limited to music performance, surgery and video game domains. The gross motor skill faculty includes but is not limited to athletics. Subdomains within the domains of music performance (piano and violin) and surgery (suturing and laparoscopy) are listed.

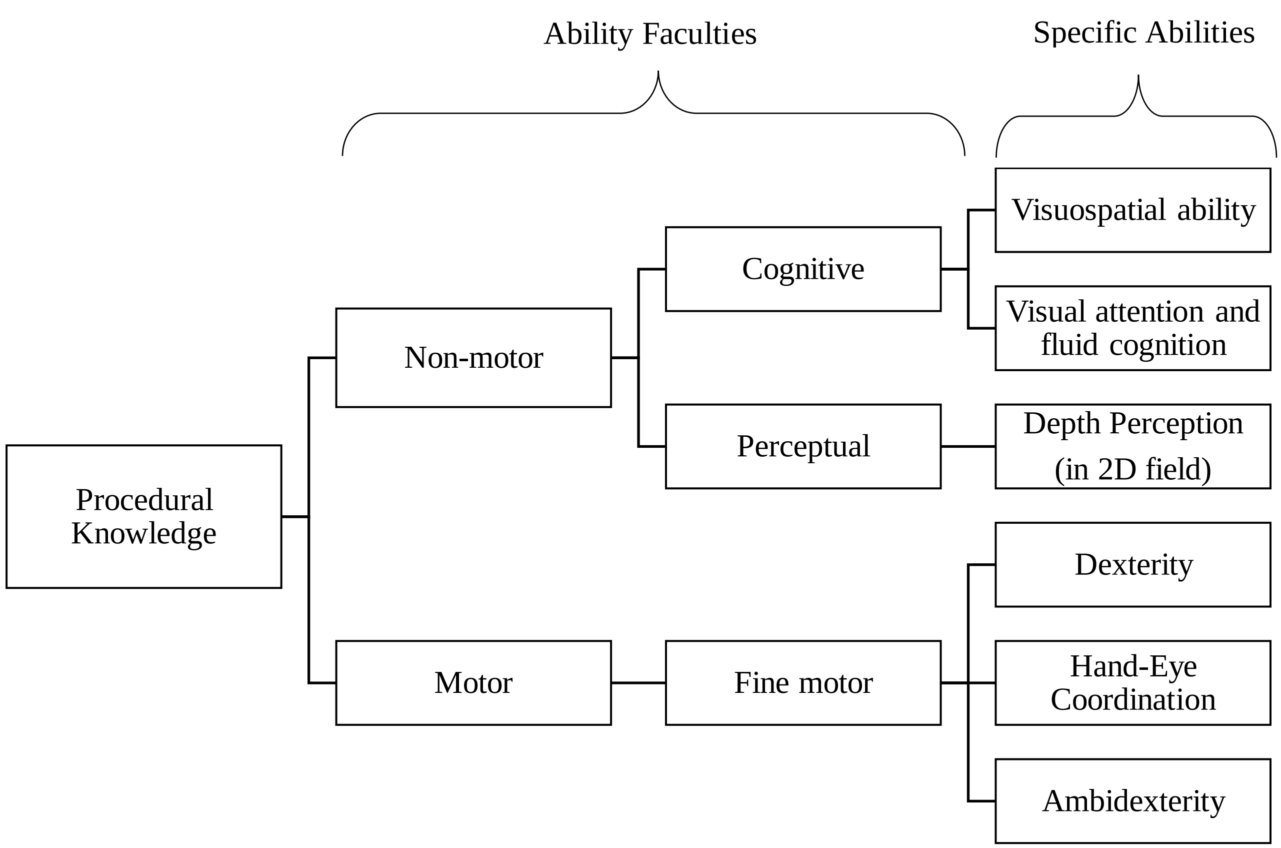
Motor skill transfer

The study of skill transfer is a controversial topic in various fields as it is not yet fully understood. From a cognitive neuroscience perspective, it is believed that engagement in certain activities promotes **neuroplasticity** (known as the brain's potential to adapt to learning and experiences by reorganizing its neural networks) thus facilitating a certain degree of skill transferability to new and different tasks (Altenmüller & Gruhn, 2002). Generally, there seem to be two main dimensions to classifying skill transfer which we shall refer to as **effect** (positive, negative or zero) and **distance** (near or far). Transferring skills between domains can either have a positive, negative or no effect (Issurin, 2013; Perkins & Salomon, 1992). **Positive transfer** occurs where previous experiences improve learning a new skill, whereas **negative transfer** is the opposite – previous knowledge interferes or undermines the performance (Fitts & Posner, 1967). A study by Pau and colleagues (2013) found that experienced pianists were superior at learning new finger sequences compared to controls, suggesting positive transfer of previous music training to new tasks. Negative transfer on the other hand is rare, though has been speculated in athletic training of gymnastics and swimming techniques (Sands, 2018; Dixon, 2015). No transfer or zero transfer occurs where there is no visible correlation between previous experience and learning a new skill in another domain (Issurin, 2013). A thesis study by Nelson (1957) found no transfer of gross motor skills between basic swimming, volleyball and hurdle skills. With respect to distance, the transfer can either be near or far. The previously mentioned positive transfer study also illustrates near transfer given that playing the piano and performing finger sequences are similar tasks within the same domain (Pau et al., 2013). **Near transfer** tends to be more common, within the same domain of expertise, and easier to verify (Nozaki et al., 2006; Seidler, 2004; Yokoi et al., 2017; Pau et al. 2013; Palmer & Meyer, 2000). Conversely, **far transfer** seems to be precarious for researchers to actually confirm from one domain to another (Hyde et al., 2009; Sala & Gobet, 2020). There is some evidence of near transfer of gross motor skills (Issurin, 2013; Kelso & Zanone, 2002), however we will exclude most detailed consideration of gross motor skills moving forward in order to focus mainly on far transfer of skills developed through piano training.

In summary, the taxonomy of procedural learning was presented with a particular emphasis on the fine motor skill faculty since it is less researched. See Figure 2 for the tentative ability taxonomy. Based on theories of motor learning, a motor skill is considered acquired once an individual reaches an autopilot stage in task performance. This occurs at high levels of performance and is accompanied by a plateau in their performance curve. Skill transfer can be described by effect (positive, negative or zero) and distance (near or far). Short-term and long-term retention were also discussed. While there is evidence to support near transfer of motor skills, our knowledge on far transfer of motor skills is particularly lacking.

Figure 2

Tentative ability taxonomy.



Note. Summary of the specific abilities within the two main non-motor and motor ability faculties. This diagram does not include piano performance or laparoscopic surgery since these are a mix of both trained non-motor and motor skills.

The general purpose of this research is to study far transfer of fine motor skills. There are limited domains of expertise in which to study fine motor skill transfer since a high level of performance is needed in order to ensure acquired motor skills in the starting domain. Music performance and surgical training are a good interdisciplinary context in which to study far transfer of fine motor skills. The procedural learning concepts, particularly motor skills, are valuable in consideration of the subsequent review of literature which is divided into three main sections. The first section describes motor skills associated with piano training. The second section outlines motor skills required in surgical training. The third section summarizes the literature to date on tentative skill transfer from music performance to surgical training and features areas lacking more knowledge on far transfer of fine motor skills.

1. Review of Literature

1.1 Motor skills associated with piano training

High levels of piano performance require precise and timely fine motor movements which develop over years of rigorous training (Altenmüller & Schneider, 2009). Motor skills associated with piano training are thought to include fine motor dexterity (FMD), hand-eye coordination and ambidexterity (Rui et al., 2018; Schlaug et al., 1995). See Figure 2 for summary taxonomy. Based on neuroimaging studies, there are five important characteristics of music training that studies should specify in order to have a well-defined musician group: (1) level of performance, i.e. expert, amateur or novice (Gaser & Schlaug, 2003; Haslinger et al., 2004; Hund-Georgiadis & von Cramon, 1999); (2) frequency of training, i.e. hours per week or similar (Karni et al., 1998); (3) age of onset music training (Watanabe et al., 2007; Amunts et al., 1997); (4) instrument type, i.e. piano, violin or other (Vollmann et al., 2014; Elbert et al., 1995) and; (5) total years' experience (Amunts et al., 1997; Bermudez et al., 2009; Meister et al., 2005). The following studies were selected because they investigated motor skills in musicians and their results were consistent with the limited literature available on this topic (Christman, 1993; Furuya & Altenmüller, 2015; Kimoto et al., 2019).

In his doctoral dissertation, McCoy (1970) compared musicians and controls' motor abilities. Participants consisted of undergraduate students from Louisiana State University and were divided into one of two groups. The first group consisted of music students (n = 100; age above 18 years; 46 females) performing any classical music instrument. The second group consisted of non-music students (n = 100; age above 18 years; 46 females). Participants were required to perform a battery of four psychometric tests (i.e., standardized neuropsychological measures), in particular psychomotor tests measuring motor abilities. These tests included Minnesota Rate of Manipulation Test (MRM), Groove Type Steadiness Test (GTST), Purdue Pegboard (Purdue) and MacQuarrie Test for Mechanical Ability (MTMA). Results showed that the music students performed better on all psychomotor test administered. However, these results were not statistically significant. Interestingly, pianists and flautists appeared to perform best on nearly all psychomotor tests, with the flautists scoring higher than the pianists (except GTST). The authors concluded that musicians that performed better on certain psychomotor tests required those same abilities to perform on their instrument. However, the non-significance of this result suggested limited potential for transfer.

With great improvement in technology since then, and the invention of MIDI (musical instrument digital interface) technology, it became possible to more accurately assess pianists' FMD and hand-eye coordination (Wilson, 1992). A study by Minetti and colleagues (2007), compared pianists' precision in executing scales at various tempi and dynamics. Participants consisted of pianists (n = 14; range 14-73 years) who ranged from novices to professionals (n = 2). All participants were asked to play single-hand C major scales (5 octaves; ascending and descending in 16th notes) at three different tempi (♩ = 60, 72 and 88 BPM). In addition, they were asked to play at five different dynamics, starting with their mean dynamic (*md*) before playing fortissimo (*ff*), mezzo forte (*mf*), then pianissimo (*pp*) and mezzo piano (*mp*). Results showed that the lowest precision corresponded to the softest dynamic (*pp*) as measured by velocity and time interval between keys. Interestingly, among all pianists, the two professional pianists scored the best in terms of precision suggesting that higher levels of piano training result in enhanced FMD and hand-eye coordination.

Jäncke and colleagues (1997) evaluated ambidexterity (hand skill asymmetry) and performance skill in professional musicians using different psychometric tests. Participants consisted of professional classical musicians (n = 31) on either keyboard (n = 17), string (14) or both; as well a non-musician control group (n = 93). All musicians were right-handed, and the overall musician group had a mean age of onset of music training at 5.7 years. The controls were divided into three groups (n = 31 in each sub-group) composed of consistent right-handers (CRH), consistent left-handers (CLH) and mixed handers (MH). The three control sub-groups were matched for sex, age and socioeconomic status. All participants completed the Annett handedness questionnaire and ambidexterity was calculated using a laterality quotient $\frac{(R-L)}{(R+L)}$ where 'R' represents the right-hand and 'L' represents the left-hand. Hand skill performance was tested using (1) a hand-dominance test (HDT) on paper with pencil (15 second per sub-section) and (2) an index finger tapping test (TAP) where participants tapped as quickly as they could on the spacebar of an Apple keyboard for 20 seconds. Results showed that despite musicians being right-handed, they had significantly increased ambidexterity compared to CRH controls. Pianists performed significantly better on TAP compared to string players, however there was no difference in ambidexterity between musician groups. Interestingly, increased tapping ambidexterity was found to be significantly linked to age of onset rather than years of overall music training experience. However, this final finding has been contested by Kopiez and colleagues (2010) who conducted a similar speed tapping paradigm study but found that age of onset of musical training and overall music training experience had no correlation with increased ambidexterity based on the TAP speed between hands, despite extensive bimanual training. Furthermore, Kopiez and colleagues (2010) attributed the findings of increased ambidexterity amongst musicians to the unusually high proportion of left-handed musicians. As such, both studies highlighted the importance of measuring handedness as a potentially confounding variable when considering ambidexterity amongst musicians.

Since non-motor skills are important in the early stages of motor skill learning, we also considered abilities in the cognitive and perceptual faculties, particularly visuospatial (VS) and perceptual abilities, respectively. See Figure 2 for summary taxonomy. Piano training may inadvertently develop VS ability in musical sight-reading due to relative pitch perception (determining relationships of intervals in sound space) required in music reading and conceptualizing music (Sergent et al. 1992). Most research on VS ability in musicians was extrapolated from neuroimaging studies (Sluming et al., 2007; Gaser & Schlaug, 2003; Bangert & Altenmüller, 2003; Barrett et al. 2013; Herholz & Zatorre, 2012; Bianco et al., 2017), however this is not necessarily conclusive with respect to performance. As such, psychometric studies of musicians' non-motor skills were selected because they investigated VS and perceptual abilities in musicians compared to controls and their results were consistent with the limited literature available on this topic (Catterall & Rauscher, 2007; Pietsch & Jansen, 2012).

Brochard and colleagues (2004) conducted a study to see the effects of musical expertise on VS ability via reaction times and mental imagery. Participants (n = 20 students; mean age: 23.3 years; 14 females) were divided into two groups. The musician group (n = 10) consisted of students in music or musicology with minimum 8 years of formal music lessons, sight-reading ability and practiced min. one musical instrument for at least 4 hours per week. Meanwhile, the non-musician control group (n = 10) consisted of ten psychology students with no formal music training and who could not play nor read music. Participants were asked to report which side of a reference line a small target dot appeared on a screen in front of them. There were two experimental conditions. In the first, the reference line disappeared before the target dot appeared. In the second, the line stayed on screen as the target appeared. Participants performed one condition per block of 80 trials in counterbalanced order for a total of 240 trials (with 20 practice trials in between test blocks) lasting about half an hour. Results showed that reaction times were significantly shorter for musicians in all conditions. In the imaging condition especially, musical experience seemed to benefit participants which suggests better sensorimotor integration in musicians compared to controls.

The final study in this section pertaining to non-motor skills examined perceptual skills in musicians. Helmbold and colleagues (2005) conducted a psychometric study investigating musicians' primary mental abilities, which included verbal comprehension, word fluency, VS ability, flexibility of closure, perceptual speed, reasoning, number, and memory. Participants consisted of music students (n = 70; mean age: 22.6 years; 37 females) and age-matched control students (n = 70; mean age: 22.4 years; 37 females). The musicians were students at the University of Music and Drama in Hannover, Germany and had a mean musical training of 17 years. The controls were students of various subjects (except music) at the University of Göttingen and none of them had any experience playing a musical instrument. All participants completed a battery of thirteen psychometric assessments of their intelligence (cognitive abilities) which lasted about 1.5 hours. The first five tests were from a German intelligence test (Leistungsprüfsystem) measuring verbal comprehension, word fluency, VS ability, flexibility of closure and perceptual speed. The following four tests were a shortened version of Cattell’s Culture Free Intelligence Test Scale 3 measuring Series, Classification, Matrices and Topologies. The final four tests were from the Berliner Intelligenzstruktur-Test measuring numerical thinking and memory (verbal, numerical and spatial). Results showed no significant differences for any of the tested cognitive abilities except flexibility of closure and perceptual speed. These results suggest that long-term music training may improve perceptual skills.

In summary, both motor and non-motor skills seem to be associated with music training. Most of the studies outlined in this section described advanced level musicians performing significantly better on certain motor and non-motor skills compared to controls, except for McCoy (1970) who found no statistical significance on psychomotor evaluations. Most psychometric tests were applicable to both musicians and controls; however, MIDI technology cannot be used to directly compare performance between musicians and controls since it is a task that is highly specific and trained among most musicians. Overall, there were unfortunately few psychometric studies conducted specifically on musicians’ FMD, hand-eye coordination and ambidexterity. Similarly, there was little psychometric research conducted on musicians' non-motor skills which are required in the early stages of motor skill learning. In order to clarify whether musicians truly excel in these skills, further empirical research is recommended.

1.2 Motor skills required in surgical training

Specific motor and non-motor skills deemed important in surgeons seem to overlap with those observed in musicians. That is, FMD, ambidexterity and hand-eye coordination (Cuschieri et al., 2001; Rui et al., 2018; Causby et al., 2014; Hughes et al., 2014; Tsai & Heinrichs, 1994) as well as VS and perceptual skills (Gallagher et al., 2003; Cuschieri et al., 2001) are valued in the surgical domain. Furthermore, psychometric assessments are employed to evaluate abilities or learned skills and correlated with performance in the surgical domain as well (Causby et al., 2014). This section of the literature review concentrates on studies investigating novice surgeons (i.e., medical students and junior surgical residents) with no experience learning a particular task in order to best evaluate the learning rate of surgical skill acquisition.

FMD is considered one of the most important factors in surgical performance according to expert surgeon opinions (Cuschieri et al., 2001; Hofstad et al., 2017). The following study was selected because it investigated in great detail how FMD affects surgical skill acquisition and their results were consistent with the literature (Van Herzeele et al., 2010; Tsai & Heinrichs, 1994; Hughes et al., 2014; Datta et al., 2002). Previous studies were variable in their results likely due to flawed methodology with respect to omitted inter-rater reliability (Bann & Darzi, 2005; Lee et al., 2012; Panait et al., 2011; Wanzel et al., 2003; Figueiredo et al., 2016). Masud and colleagues (2012) investigated FMD in novices performing small bowel anastomosis. Participants consisted of senior medical students (n = 36) with limited surgical experience. None had ever completed a small bowel suturing. All participants completed psychomotor testing measuring FMD (Purdue Pegboard) as well as surgical training. They were then taught surgical knot-tying followed by small bowel suturing on a bench model. Participants had one attempt per day over eight days. Their performance was evaluated using an objective grading system devised by the research team. Results showed that all participants significantly improved in suturing performance over the eight days. They found that there was a significantly strong negative correlation between FMD and performance grade (on a scale of 1-5 with grade 1 being most optimal) only during the first four training sessions, but after about five days the effects dissipated.

Ambidexterity and hand-eye coordination are also considered important factors in surgical performance (Rui et al., 2018; Yokoyama, 2019). The following study was selected because it investigated in great detail how ambidexterity and hand-eye coordination affect motor skill acquisition in laparoscopic surgery and its results were consistent with the literature (Haslinger et al., 2004; Huang et al., 2016). Yang and colleagues (2015) conducted a study investigating ambidexterity in experienced laparoscopic surgical trainees on robotic surgery. Participants (n = 32; age: 31.5 years; 6 females) consisted of fellow surgeons (n = 15; 2 females), surgical residents (n = 13; 3 females) and medical students (n = 4; 1 females). All participants were right-handed as determined by the Edinburgh Handedness Inventory. They completed psychomotor testing measuring FMD (Grooved pegboard) as well as laparoscopic and robotic surgical testing. For laparoscopic skill evaluation, participants had three attempts to perform two simple sutures. For robotic surgical skill evaluation, participants were oriented to the DaVinci skills simulator before performing two VR suturing programs: easy (dots and needles) and difficult (suture sponge). Results showed that FMD significantly correlated with robotic suturing performance (with respect to ambidexterity, rather than speed), but did not correlate with the familiar laparoscopic performance for these participants. Interestingly, they found that the gap between low and high ambidexterity groups only decreased on the easier (dots and needles) task; the gap remained constant throughout all three sessions of the difficult task.

In contrast, Francis and colleagues (2001) compared hand-eye coordination, FMD and VS abilities in expert and novice surgeons. Participants (n = 40) consisted of expert endoscopic surgeons (n = 20; mean age: 47 years) with recommendations from their peers as excellent surgeons; and medical students (n = 20; mean age: 21 years) with no surgical experience. Both groups completed psychometric testing measuring hand-eye coordination (Gibson spiral maze test), FMD (Crawford small parts dexterity test) and VS abilities (Space relations test). There was no surgical evaluation in this study. Results showed that expert surgeons performed significantly better on hand-eye coordination ($p = .009$) but not FMD ($p = .06$) tests compared to medical students. This suggests that expert surgeons possess superior hand-eye coordination and FMD. Interestingly, medical students scored significantly higher on the VS ability test compared to expert surgeons. The authors suggested that the lower VS score in expert surgeons may be attributed to older age.

Visuospatial (VS) and perceptual abilities may be more important than pure motor ability in predicting surgical performance especially in the early learning stages (Hegarty & Waller, 2005; Steele et al., 1992). The following study was selected because it investigated in great detail how VS ability affects motor skill acquisition in laparoscopic surgery and its results were consistent with the literature (Steele et al., 1992; Keehner et al., 2004; Wanzel et al., 2002). Stefanidis and colleagues (2006) investigated cognitive and motor abilities in novice surgical trainees with minimal experience in laparoscopic surgery, but in a superbly extensive fashion. Participants (n = 20; mean age: 28 years; 6 females) consisted of 1st year surgical residents. They were required to complete a battery of twelve psychometric tests measuring FMD and VS ability as well as three validated simulators. The FMD psychomotor tests included Tremor, Purdue pegboard, Index finger tap (TAP), Reaction time and Grooved pegboard; the VS tests included Pictoral Surface Orientation, Matrix reasoning, Rey figure, Map planning, Cards rotation, Cube comparison, and Minnesota paper form board. They also completed a demographic questionnaire inquiring about prior experience with laparoscopy, simulators, video games and billiards. Next, participants were given three attempts to perform given tasks on each of the 3 following laparoscopic simulators: free-standing video trainer (VT), minimally invasive surgical trainer-virtual reality (MIST-VR) and laparoscopic camera navigation tasks (LCN). Following the initial baseline laparoscopic simulator testing, participants trained 1 hour per week until they were able to perform at expert level on two consecutive attempts. Results showed that a median of 12 hours were required to complete training (95% of participants completed training) and there was an overall 50% improvement in simulator score. Training duration and repetitions significantly correlated with prior video game and billiards exposure, as well as FMD tests (grooved pegboard and TAP) and VS tests (map planning and Rey figure immediate recall score) and baseline performance on VT and LCN. Interestingly, of all tests, the VS test (Map planning) was the most effective in predicting which surgeons were the slowest in motor skill acquisition. The authors concluded that psychometric testing may be useful in highlighting weak spots that need addressing during the process of motor skill acquisition.

Perceptual abilities also seem to play an important role in the initial stage of surgical skill acquisition (Gallagher et al., 2003; Arora et al., 2005). While similar to VS ability, perceptual abilities consist of purely depth perception of 3D objects by visual cues from a 2D line drawing. This unsurprisingly mimics a laparoscopic 2D monitor display, albeit with a simplified image (Bogdanova et al., 2016). All studies outlined below share similar methodology in utilizing the standardized and reliable Pictoral Surface Orientation (PicSOr) computer program to assess perceptual abilities (Henn et al., 2017). The following studies were selected because they investigated how perceptual ability affects motor skill acquisition in laparoscopic surgery and their results were consistent with the literature (Gallagher et al., 2003; Arora et al., 2005; Henn et al., 2017; Ritter et al., 2006).

Kolozsvari and colleagues (2011) looked at the relationship between cognitive abilities on surgical performance in novices on the Fundamentals of Laparoscopic Surgery (FLS) trainer box. Participants (n = 32; mean age: 23 years; 13 females) consisted of 1st year medical and dental students with no experience using a laparoscopic simulator. The majority of participants were right-handed (2 left-handed participants). All participants completed a demographic questionnaire inquiring about video game experience and interest in surgery. They were asked to perform tasks in the FLS trainer box, as well as complete psychometric tests measuring VS and perceptual abilities. There were five tasks to complete with FLS: peg transfer, circle cut, placement of a ligating loop and simple suture tied using extra- and intracorporeal techniques. The VS tests included card rotation, cube comparison and map planning; perceptual ability was assessed using PicSOr. Again, no psychomotor tests were employed. Results showed that PicSOr was the only psychometric test which was significantly correlated with initial laparoscopic performance. None of the other psychometric tests correlated with laparoscopic performance. They also found that interest in pursuing surgery significantly correlated with initial peg transfer score, while gender had no effect on initial performance.

In contrast, Westman and colleagues (2006) considered cognitive abilities of expert endoscopic surgeons. Participants (n = 11) consisted of expert surgeons with experience completing over 500 gastrointestinal colonoscopy procedures. All participants completed a demographic questionnaire inquiring about surgical and non-surgical experiences (e.g., computer gaming). They performed simulated endoscopies in GI Mentor II and completed psychometric testing measuring VS and perceptual abilities. The VS tests included card rotation and cube comparisons while perceptual testing included PicSOr. Results showed that out of all three psychometric tests, perceptual ability was the best at predicting colonoscopy performance. Interestingly, in the easier, less demanding simulated gastroscopy there were no correlations between cognitive abilities and performance. Further, surgeons who did not play video games performed better on PicSOr and cube comparison tests. The authors conclude that VS and perceptual ability correlate only with difficult, technically demanding simulated colonoscopy, not with the easier simulated gastroscopy.

In summary, both motor and non-motor skills had effects on the initial learning rate in surgical skill training. Most of the studies outlined in this section described novice surgical trainees, except Francis and colleagues (2001) and Westman and colleagues (2006) who investigated surgical experts. Interestingly, only difficult tasks correlated with VS and perceptual abilities in experts, comparably to simple tasks for novices. This agrees with motor skill acquisition theories showing that cognitive abilities are more important in the initial stage of motor skill learning (Fleishman & Rich, 1963), and that the importance of VS abilities diminished with increased surgical experience (Keehner et al., 2004). Motor abilities also seemed to provide significant advantage only during the early stages of surgical skill acquisition given the short-term benefits of FMD for example. Unfortunately, few studies collected background activity information such as whether medical students or junior surgical trainees engaged in activities like expert piano training, with the exception of a few studies showing conflicting evidence on the effects of videogame experience (Stefanidis et al., 2006; Kolozsvari et al., 2011; Westman et al., 2006). It is known, however that the benefits of videogames on surgical training are transient and do not last long-term (Tsai & Heinrichs, 1994; Rosenberg et al., 2005). The motor and non-motor skills previously discussed will function as building blocks to investigate whether piano training far transfers to the surgical domain. While motor experiences have been shown to enhance cognition (Moreau, 2015), excelling in psychometric tests alone does not prove transfer to a different domain. Thus, it is important to consider experiments that directly involve musicians performing tasks in the desired domain and to compare them with controls.

1.3 From music to surgery: tentative skill transfer

This section reviews the literature investigating whether piano trained skills far transfer to the surgical domain. Music and surgery are two domains requiring excellent fine motor skills and for this reason serve as a good opportunity to research far transfer of motor skills. Medical schools in the US and UK claim there is a decline in fine motor abilities among incoming medical students and residents (Murphy, 2019; Coughlan, 2018). At the same time, surgical residents have reduced training hours (McCaskie et al., 2011; Chikwe et al., 2004; Ahmed et al., 2014). This occurs despite the increased surgical complexity involved in the modern laparoscopic approaches compared to open surgery (Spruit et al., 2014; Subramonian et al., 2004). Some people believe that experience playing a musical instrument leads to advantages in medical school as well as in surgical training and performance (American Music Conference, 2007; Hond, 2015; Jackson, 2018). However, empirical research on this front is lacking. Thus, there is a need to measure these skills and differences in performance in order to later clarify whether they may be enhanced by piano training and possibly transfer to the surgical domain.

This section of the literature review concentrates on studies involving expert adult musicians in order to ensure musical expertise prior to examining far transfer to the surgical field. There exist studies which omit several details on musician characteristics based on neuroimaging studies previously described (Section 1.1) and suggest no far transfer of music performance to surgery (Madan et al., 2005; Sodergren et al., 2013; Zeng et al., 2010). However, without including all variables of music training, it is difficult to confirm whether music training transfers to surgery. As such, the following studies were selected to include most of the five musician characteristics discussed in Section 1.1. Further, their results were consistent with the literature (Rao et al., 2015; Glaser et al., 2005; Harper et al., 2007; Rui et al., 2018).

Moustaki and colleagues (2017) conducted a study investigating whether music performance transfers to microsurgery. Participants (n = 70) consisted of novice trainees with music experience (n = 26) and without music experience (n = 44). All participants completed a demographic questionnaire to assess experience playing a musical instrument and videogames. Music experience was defined as playing a musical instrument (violin, guitar, piano or other) at a grade 4 level or higher at least once every 6 months. Video game experience was defined as playing video games at least once every 6 months. First, participants attended a microsurgery training session and were then asked to perform a microsurgical anastomosis on the femoral artery of a chicken. Their performance was timed, and video recorded. The recordings were subsequently evaluated by two senior microsurgeons using the structured assessment of microsurgical skills (SAMS). No psychometric testing was performed. Results showed that those with music experience performed significantly better compared to those with no music experience; video game experience did not seem to have any effect. Furthermore, those who played specifically violin or piano tended to be the best out of those with music experience. The authors suggest that musical experience may be pertinent in future microsurgeon selection.

Harrington and colleagues (2018) assessed candidates for predictors of Fundamental Laparoscopic Surgery (FLS) performance. They enrolled medical students (n = 49; mean age: 19.3 years; 24 females) who had no prior experience with laparoscopic surgery. Participants completed a demographic questionnaire and five psychomotor tests (card rotations, cube comparisons, map planning, PicSOr and grooved pegboard). They then completed baseline FLS tasks (based on MISTELS) before undergoing a two-week-long training program with a laparoscopic training box. Laparoscopic tasks included: (1) peg transfer, (2) precision cutting, (3) ligating loop, (4) suture with extracorporeal knot, and (5) suture with intracorporeal knot. Next, they performed a post-training test during week 3. Finally, they were tested at four one-month interval times for retention. Results showed that all participants significantly improved with practice during the initial session and the first one-month interval. Of the psychometric tests, PicSOr and grooved pegboard performance were significantly associated with task 1 (and task 3 for grooved pegboard) performance during maintenance phase. Among the results, they found that experience playing a musical instrument was significantly associated with skill acquisition in tasks 1 and 5. They found that experience playing video games also significantly predicted performance in both tasks but during the maintenance phase only, while experience playing sports or having a competitive edge had no influence on scores. The authors suggest that fine motor skills developed during music and video game practice may promote neuroplasticity which allows for skill transfer to laparoscopy.

Similarly, Boyd and colleagues (2008) investigated whether experience in music influences laparoscopic performance. Participants (n = 30; 12 females) consisted of novice 1st and 2nd year medical students with no laparoscopic experience. They filled out a demographic questionnaire asking for their gender, handedness, prior experience in video games and music. Within the domains of video games and music, participants had to select one of three options: never, in the past, or currently which corresponded to labelling them as novice, intermediate and experienced, respectively. All participants were instructed on performing a laparoscopic intracorporeal suturing task using a teaching video and no feedback on performance. They were asked to perform three consecutive suturing trials while being timed, videotaped and subsequently evaluated using the objective structured assessment of technical skills (OSATS). Results showed that participants who currently played a musical instrument (and were adjusted for videogaming experience) were significantly faster compared to controls ($p < 0.001$). The authors suspect that the current musicians were actively enhancing their VS abilities which translated to improved laparoscopic performance.

The latest research conducted in the Piano Pedagogy Research Laboratory was interested in seeing whether musicians learned surgical skills with greater speed and quality (as measured by the OSATS) compared to controls (Comeau et al., 2020a). Participants were enrolled in two groups. First, pianists (n = 20; mean age: 23.5 years; 15 females) who were all at an advanced level of performance proficiency.

Second, controls (n = 20; mean age: 23.7 years; 13 females) with either no previous piano training (or < 2 years on another instrument) or no formal training. Participants were asked to attend two pairs of sessions held over two consecutive days. During the first pair, they performed a knot tying task. During the second pair, they performed a suturing task. In both cases, they learned by following an instructional video on screen with subsequent testing the next day. Results showed that musicians performed the suturing task with greater speed and quality as measured by OSATS, but this was only significant in knot-tying. In part II of this study, they also observed that females were significantly faster at Purdue Pegboard test compared to males; and that greater experience with chopsticks tended to result in faster knot tying and suturing, though non-significant (Comeau et al., 2020b). Overall, these results suggested that musicians do indeed have some advantage at learning certain surgical skills compared to controls.

In summary, piano training did seem to provide positive, short-term, far transfer to surgical training. However, a number of weaknesses exist in these studies on music training transfer which reduce their internal validity. First, they often failed to include crucial details regarding music training characteristics (such as frequency of training, age of onset, instrument type and total years' experience) which may obscure or confound results. Second, they often included short-term timelines, which can result in misleading conclusions of far transfer without measuring (a) the full performance curve until it plateaus to motor skill acquisition; and (b) measuring retention after a hiatus period following training. Third, not all studies took into account potentially confounding variables other than music training (frequently not specifying which musical instrument(s)) and surgical experience. Short-lived confounding effects are known to occur due to experience video gaming (Tsai & Heinrichs, 1994; Rosenberg et al., 2005) and chopstick proficiency (Comeau et al., 2020a). Thus, if not taken into account, these could give a false impression that piano training transferred to surgery, when in fact videogaming or chopstick proficiency (or other hobbies) were largely contributing to the initial stage of surgical skill acquisition. In other words, without documenting experience characteristics in order to strengthen the study's internal validity it is not possible to pin-point skill transfer. For these reasons, more thorough studies are required to contribute to this field of motor skill transfer research.

1.4 Research Questions

In view of the literature cited above, existing interpretations of piano training skill transfer to the surgical domain may be too generous due to lacking specifications of musical training, potentially confounding variables as well as lack of long-term timelines. The current study was an attempt to overcome these by collecting detailed participant information (both in regard to music training and other fine motor activities) and measuring performance at multiple time points to generate a performance curve of laparoscopic surgical training for both musician and control groups. This study collected information regarding experience playing musical instrument, video games, texting, etc., as well as a administered a battery of psychometric tests to measure VS ability, perception, FMD, ambidexterity, and hand-eye coordination. We measured performance over five consecutive days and measured retention one week later. There were two main aspects of laparoscopic skill acquisition considered: (a) rate of skill acquisition (i.e., how quickly a performance curve plateau was reached, if at all, within five training sessions), (b) skill retention one week later (i.e., how well these new surgical skills were remembered). A significant correlation between piano training and one or both of these aspects, would help confirm positive far transfer of motor skills developed in high levels of piano training to surgery (either rate of acquisition, effective retention or both). No correlation would still contribute to the field of motor skill learning and transfer suggesting that piano trained motor skills may be domain specific.

This study aimed to address the following research questions:

1. How do expert musicians compare to controls in novel laparoscopic motor skill training for each task as determined by speed (as measured by time of task completion) and accuracy (as measured by least number of dropped beads or pegs) considering the following aspects:
    a. Rate of skill acquisition (Days 1-5): represented by the steepest slope to plateau on the performance curve.
    b. Skill retention (Day 6 following one-week hiatus period): represented by an increase, decrease or consistency in performance.
2. Do musicians possess greater procedural abilities (non-motor and/or motor abilities) compared to controls as measured by a battery of psychometric assessments? Specifically, motor abilities which include FMD, ambidexterity and hand-eye coordination; as well as non-motor abilities including VS and perceptual abilities.
3. Are there any correlations between procedural abilities and laparoscopic performance at baseline (Day 1) and at plateau (Day 5)?

This study proposes the following research hypotheses:

1. We expect the musician group to perform better initially but that this effect is transient:
    a. Rate of skill acquisition (Days 1-5): We expect musicians to learn laparoscopic skills faster (Boyd et al., 2008) compared to controls as measured by speed (time of task completion) and accuracy (number of dropped beads or pegs) in all laparoscopic test sessions. However, this quick rate of skill acquisition is expected to be short-lived, likely lasting up to a few days into training (Masud et al., 2012) after which we expect the control group will catch up to the musician group by Day 5.
    b. Skill retention (Day 6): We expect both musicians and controls to retain the same performance plateau given transiency of non-surgical advantages (Harrington et al. 2018).

2. We expect musicians to possess greater procedural abilities since the literature suggests that musicians have greater FMD (Kimoto et al., 2019; Comeau et al., 2020b), ambidexterity (Jäncke et al., 1997; Christman, 1993), hand-eye coordination (Minetti et al., 2007), VS (Brochard et al., 2004) and perceptual abilities (Helmbold et al., 2005; Kolozsvari et al., 2011).
3. We expect increased procedural abilities to correlate with quicker and more accuracy laparoscopic performance (Stefanidis et al., 2006; Kolozsvari et al., 2011; Westman et al., 2006).

2. Methodology

2.1 Participants

This correlational study investigated young adult musicians who are currently studying piano performance at a university level or who have achieved minimum grade 8 Royal Conservatory of Music (RCM) level piano performance or equivalent. All pianists enrolled have studied piano performance in the past (100%, 19 of 19). The control group consisted of individuals who do not currently play a musical instrument nor have ever played one in the past. Previous experience playing a musical instrument was permissible only if experience was minimal (i.e., played in school band, but never had private lessons) and the instrument played was not piano. Exclusion criteria included having prior experience with laparoscopic surgery techniques.

2.1.1 Sample Size

Nineteen musicians and fourteen controls between the ages of 18 and 29 (inclusive) were enrolled in this study. Participants were recruited through convenience sampling by active email invitations, university lecture presentations, word of mouth and passive recruitment by wall-mounted posters throughout all University of Ottawa campuses. See Appendix A for recruitment materials. A power calculation was conducted based on a large effect size reported in laparoscopic studies by Glaser and colleagues (2005), Boyd and colleagues (2008) as well as Harrington and colleagues (2018). For a 2-sided test comparing musicians versus controls, with a power of 0.80 and alpha of 0.05, the minimum required number of participants per group was 16 for the musician group and 16 for the control group, for a total of 32 participants. A total of 33 participants were recruited for this study.

2.2 Study Design and Instrumentation

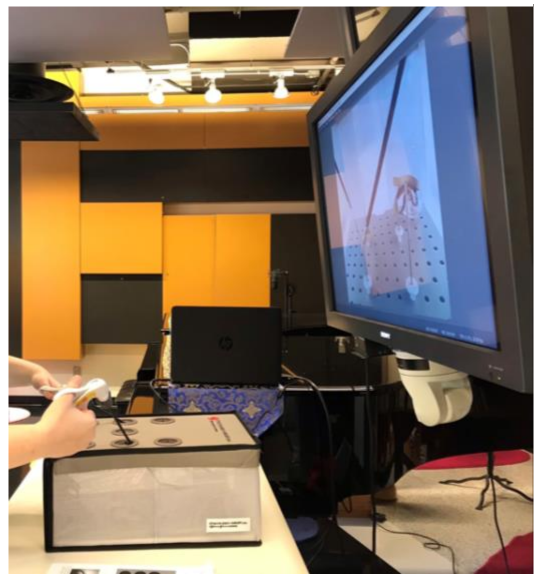
There were three main performance measurements in this study: rate of progress of laparoscopic training (as measured by speed and accuracy of performance), non-motor and motor ability tests and a piano test. The latter is required for musicians only. All sessions were audio and video recorded on an external Sony FDR-AX43 4K Handycam camcorder in case the researcher needs to review the data.

2.2.1 Laparoscopic Tasks

Speed and accuracy of performance were measured in a Train Anywhere Skill Kit (TASKit) laparoscopic training box (Ethicon Endo-Surgery Cincinnati, OH, USA) which connected to a large television monitor display in the laboratory (see Figure 3). Participants were provided with two laparoscopic graspers and instructions in written form with illustrations (see Appendix B) and in pre-recorded audio format for each task. An internal camera inside the laparoscopic training box provided the participant with a detailed view of their task performance displayed on the monitor display in front of them.

Figure 3

Laparoscopic training setup



After the training sessions, both internal and external camera recordings provided the researcher with a means of reviewing the data as needed. During each session, a Research Assistant (RA) completed one data sheet (paper and pencil) noting (a) time of task completion (using a timer), if the task was successfully completed within the time limit; (b) whether or not the participant used both graspers; and (c) the number of beads or pegs dropped. Cut-off times were based on previous studies (Fraser et al., 2003) and in consultation with a general surgeon.

2.2.1.1 Selection of Tasks

A total of six laparoscopic tasks were used in this study. Most of the tasks came from previous surgery training programs and a few of the other tasks were developed in consultation with a mechanical engineer and general surgeon. The rubber band transfer, bead transfer and bead to peg transfer tasks were selected since they required good hand-eye coordination. There were also tasks included in the laparoscopic training box instructions used in this experiment (Ethicon Endo-Surgery). The peg to grooved board transfer (peg transfer) was selected from the fundamentals of laparoscopic surgery program (Badalato et al., 2014) and slightly modified in consultation with a mechanical engineer and a general surgeon. This task design was also based on available equipment such that small pegs were transferred to a grooved pegboard (equipment already at our disposal in this study). The bead to peg task was selected given its use of fine motor dexterity, depth perception in a 2D field and hand-eye coordination (Fried et al., 2004). Similarly, the cup drop drill was selected given its prevalence in the literature and the use of fine motor dexterity, depth perception and hand-eye coordination (Rosser et al., 1997; Scott et al., 2000). The cylinder transfer task was developed based on the triangle transfer task given the additional use of ambidexterity and bimanual coordination and its frequent use in the literature (Rosser et al., 1997; Scott et al., 2000).

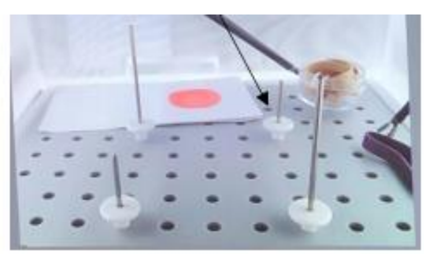
2.2.1.2 Description of Tasks

Each of the six laparoscopic tasks are summarized below. See Appendix B for the full participant instructions. The default descriptions are presented for right-handed participants since these were more common. For left-handed participants, all directions (left-right) were reversed.

Rubber band transfer (RB task): Materials inside the box included four rubber bands, one deep cup and four pegs (two short and two tall). Participants held both graspers, one in each hand, to make a square using four elastics by stretching each of them over two pegs at a time inside the box. Maximum allotted time for completion was three minutes for this task. See Figure 4.

Figure 4

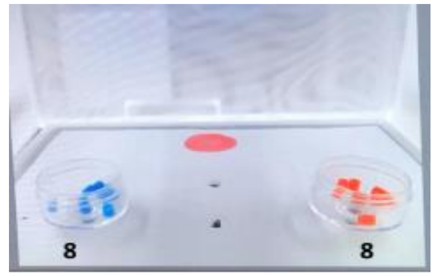
RB Task



Bead transfer (BT task): Materials inside the box included two deep cups, eight blue beads and eight orange beads. Participants held one grasper in their dominant hand and transferred five blue beads one at a time from one container on the left to another container on the right inside the box (sub-task 1). Then they transferred those same beads back to their original location (sub-task 2). This was repeated but holding the grasper in their non-dominant hand while transferring five orange beads from the right container to the left container (sub-task 3). Then they transferred those same beads back to their original location (sub-task 4). Maximum allotted time for completion was three minutes per sub-task. See Figure 5.

Figure 5

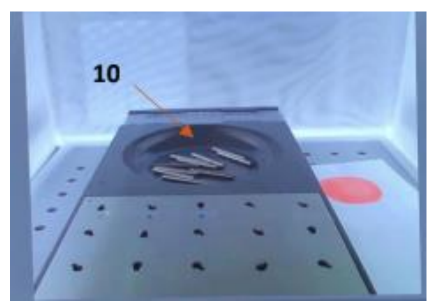
BT Task



Peg transfer (PT task): Materials inside the box included Grooved pegboard and ten pegs (from Purdue pegboard). Participants held both graspers, one in each hand, to place three small pegs into the first three holes of a Grooved Pegboard starting in the upper left corner and going right across the row (Note: pegs were groove-less and from Purdue pegboard). Maximum allotted time for completion was four minutes for this task. See Figure 6.

Figure 6

PT Task



Bead to peg transfer (BP task): Materials inside the box included one shallow cup, two short pegs and fifteen multicoloured beads. Participants held one grasper in their dominant hand and transferred three beads of any colour one at a time from the container in the center to the peg on the right (sub-task 1). Then they transferred three more beads to the peg on the left (sub-task 2). This was repeated but holding the grasper in their non-dominant hand while transferring three beads from the container in the center to the peg on the left (sub-task 3). Then they transferred three more beads to the peg on the right (sub-task 4). Maximum allotted time for completion was three minutes per sub-task. See Figure 7.

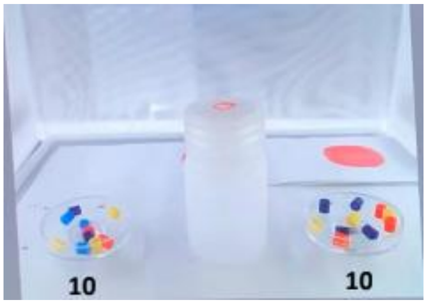
Figure 7

BP Task

Cup drop drill (CD task): Materials inside the box included two shallow cups, 20 multicoloured beads and one container with a small hole on the lid. Participants held one grasper in their dominant hand and transferred three beads of any colour one at a time from left container to bottle with small hole on top outlined in red (sub-task 1). Then they transferred three more beads from the right container to the bottle (sub-task 2). This was repeated but holding the grasper in their non-dominant hand while transferring three beads from the right container to bottle (sub-task 3). Then they transferred three more beads from the left container to the bottle

Figure 8

CD Task

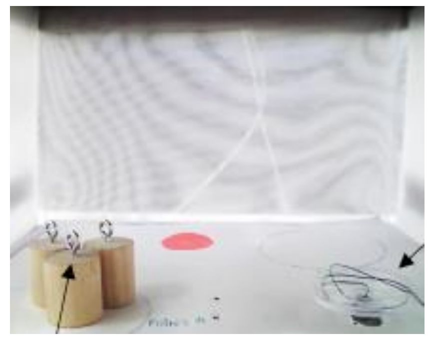


(sub-task 4). Maximum allotted time for completion was three minutes per sub-task. See Figure 8.

Cylinder transfer (CT task): Materials inside the box included one shallow cup, three cylinders and one suture. Participants used both graspers, one in each hand, to thread the suture through the loop of one of three cylinders located at point A and transferred it to point B located on the opposite side of the laparoscopic box. This was to be repeated twice more with the remaining cylinders. Maximum allotted time for completion was four minutes for this task. See Figure 9.

Figure 9

CT Task



2.2.2 Procedural Ability Tests

Participants' specific procedural abilities were tested using standardized equipment or paper and pencil tests. A laptop computer was used to run one program for the perceptual test. During this testing session, a single external camera was used to allow for revision of performance in case of any need to review. In general, the RA filled one data sheet (paper and pencil) for the entire session noting (a) time of task completion (using a timer), if the task was successfully completed within the time cap and (b) number of errors made (depending on the task at hand).

2.2.2.1 Selection of Tests

Two main types of standardized neuropsychological tests were used in this study to assess each participants' non-motor (cognitive and perceptual) and motor abilities since these are the two main faculties of procedural knowledge (Squire & Zola-Morgan, 1988; Green & Bavelier, 2008). A total battery of ten psychometric tests were selected based on frequency of use as well as their reliability. The following selection of psychometric tests is sub-divided into non-motor and motor abilities. See Figure 2 for summary taxonomy.

2.2.2.1.1 Non-motor abilities

With regard to non-motor abilities, we specifically measured VS, visual attention, fluid cognition and perceptual abilities because these were considered important in surgical performance (Wanzel et al., 2002, 2003; Cuschieri et al., 2001; Gallagher et al., 2003; Henn et al., 2017). VS ability has been frequently and reliably measured using the Mental Rotation Test (MRT) and paper folding tests (Peters et al., 1995; Ekstrom et al., 1976). Visual attention and fluid cognition have been reliably tested with the Trail Making Test (TMT) in several studies (Salthouse, 2011; Tombaugh, 2003). Finally, there have been strong justification for measuring depth perception in a two-dimensional field with the Pictorial Surface Orientation (PicSOr) (Gallagher et al., 2003; Henn et al., 2017).

2.2.2.1.2 Motor abilities

With regard to motor abilities, we measured FMD, ambidexterity and hand-eye coordination because these were considered important in surgical performance (Cuschieri et al. 2001; Francis et al. 2001; Hofstad et al. 2017; Rui et al., 2018; Francis et al., 2001; Yang et al., 2015). FMD has been previously measured in Comeau and colleagues (2020b) using the Purdue pegboard and fist-edge-palm (FEP) tests given their reliability. Additional tests include the Grooved Pegboard and Index Finger Tap (TAP) tests which were also recommended for measuring FMD (Causby et al., 2014). The Chopstick Test was also selected since it has been found to correlate with FMD and surgical performance (Madan et al., 2005; Comeau et al., 2020a). Ambidexterity and hand-eye coordination were reliably measured by the Dot Filling Test (DFT) and TAP tests (Tapley & Bryden, 1985; Yamashita, 2014). Finally, the FEP has also been shown to reliably measure unilateral coordination and is known as a “neurological soft sign” as it activates several cortical areas of the brain while the individual executes movements in sequence as quickly as possible (Chan et al., 2006, p. 189). For these tests, a laterality quotient (LQ) was calculated with the following formula: $\frac{(R-L)}{(R+L)}$ where 'R' is the right hand and 'L' is the left hand (Tapley & Bryden, 1985; Jäncke et al., 1997). The signs were reversed for the Grooved Pegboard and Chopstick rice subtasks given the target of obtaining a shorter time of completion (which represents faster speed and thus greater motor abilities) according to Yamashita and colleagues (2014).

2.2.2.2 Description of Tests

Each ability test is summarized below (see Appendix C for participant instructions). The tests were grouped into two types: cognitive and psychomotor tests.

2.2.2.2.1 Cognitive Tests

Mental Rotations Test (MRT): assessed visuospatial abilities by administering a multiple-choice paper test. The participant identified two of four rotated 3D blocks that matched target image.

Paper folding: assessed visuospatial abilities by administering a multiple-choice paper test. The participant identified one of five images that matched target image after imagining that a paper sheet was folded, hole-punched and completely unfolded.

Trail Making Test (TMT): assessed visual attention, speed and fluid cognition by administering a paper test where the participant quickly drew lines to connect numbers in order and alternating with letters (i.e., 1, A, 2, B).

Pictorial Surface Orientation (PicSOr): assessed depth perception (in 2D field) by administering a computer test. On screen, the participant maneuvered a spinning arrowhead (using up and down arrows on keyboard) until its shaft was perpendicular to surface of a cube on screen.

2.2.2.2.2 Psychomotor Tests

Grooved Pegboard: assessed fine motor dexterity (FMD) by administering grooved pins (pegs) that the participant quickly placed into grooved holes using right and left hands separately only.

Purdue Pegboard: assessed FMD and bimanual coordination by administering small pins (pegs) that the participant quickly placed in the board using right and left hands separately and hands together.

Index Finger Tapping (TAP): assessed FMD and ambidexterity by administering a space bar (keyboard) that the participant tapped as quickly as possible using only the index finger of their right and left hands separately.

Chopsticks: assessed FMD by administering small beads and raw rice that the participant transferred using chopsticks using right and left hands separately.

Dot Filling Test (DFT): assessed ambidexterity by administering a paper and pencil test. The participant quickly drew small dots in each circle in sequence using right and left hands separately.

Fist-Edge-Palm (FEP): assessed unilateral coordination and motor sequencing. Participants quickly repeated a sequence of three hand positions (fist, extended fingers with hand edge on table and palm resting flat) using right and left hands separately.

2.2.3 Piano Tests (musicians only)

Pianists had an additional requirement of performing scales in order to assess current level of piano performance. The piano test was done on a Yamaha grand piano equipped with MIDI recording in order to assess the number of note errors which requires good fine motor dexterity and bimanual coordination (Wilson, 1992; Slade et al. 2020). Pianists were instructed to play a C major scale (4 octaves, 16^{th} notes) hands together with a metronome at various increasing tempi (♩ = 88, 104 and 120 BPM). These were based on RCM grade 8 – 10 requirements.

2.3 Data Collection

2.3.1 Confidentiality and Informed Consent

This study has been approved by the University of Ottawa Research Ethics Board. Each participant read and signed an informed consent form prior to participating in this study. By signing the consent form participants indicated their understanding of the study procedures including no practice in between sessions. This was crucial so that all participants practiced the same amount in the lab during training sessions. All participant information and data collected are strictly anonymous and confidential and are used for research purposes only. Participants are identified only through alphanumerical codes instead of names during analysis and publication. Video recordings are only associated with the alphanumerical identification of the participant and are safely stored on secure computers with password protection inside the Piano Pedagogy Research Laboratory, which is locked and armed with security alarms when unoccupied.

2.3.2 Demographic Information

Participants completed a demographic questionnaire prior to laparoscopic training. Since this research was an extension of the previous studies by Comeau and colleagues (2020a and 2020b), and for later comparison purposes, we used a similar questionnaire (see Appendix D for questionnaires). The only difference was the addition of a question gauging interest in pursuing a surgical career due to a few studies illustrating motivation as a potential confounding factor on surgical performance (Kolozsvari et al., 2011; Hughes et al., 2014). The questionnaire included age, gender, ethnicity, handedness, experience playing a musical instrument, activities requiring fine motor skills (i.e., sewing, embroidery, scouts (knot-tying), knitting, etc.), experience playing video games, texting frequency, experience using chopsticks, and interest in pursuing surgery as a career. The rationale for demographic questions pertaining to fine motor activities was based on potentially confounding variables indicated in the literature (Badurdeen et al., 2010; Giannotti et al., 2013; Madan et al., 2005; Shin et al., 2009; Kolozsvari et al., 2011; Lee et al., 2012) and to maintain internal validity of this study. The questionnaire was expanded for the musician group to inquire about their musical training including highest level achieved, frequency of practice throughout lifetime, secondary musical instrument and occupation (i.e., professional performer, music student, music teacher or non-music related profession). All participants also completed the Annett Handedness Questionnaire prior to laparoscopic training in order to properly adjust the experiment for right- or left-handed participants (Annett, 1970).

2.3.3 Testing Sessions

2.3.3.1 Laparoscopic Training

Each participant attended six one-hour private laparoscopic training sessions in the following timeline: daily for first five consecutive days (typically Monday to Friday), followed a final session one week later (on Thursday or Friday) to measure retention. There was some flexibility to run sessions on weekends to best accommodate participants' schedules, but five consecutive days of training followed by a final session a week later was imperative. Participants stood in front of a laparoscopic trainer box with a monitor display in order to complete all six tasks (see Appendix B for participant instructions). Throughout all sessions a RA manually recorded the speed of task completion (using a timer) and the number of items dropped in error.

2.3.3.2 Ability Tests

Each participant attended a single one-hour private session to assess non-motor and motor abilities. Participants were seated at a table as a RA administered the battery of ten standardized psychometric tests (see Appendix C for participant instructions). These tests were given in a randomized order so as to eliminate potentially confounding effects due to order of administration.

2.3.3.3 Piano Performance Test

Only the musician group was required to perform the C major scale (4 octaves, 16th notes) hands together with a metronome. Participants were given five minutes to practice before recording.

2.4 Statistical Analysis

The collected data was entered into Microsoft Excel and statistical analysis was performed using SPSS Version 27 (SPSS, Inc., Chicago, Ill.). All tests were 2-sided and $p < .05$ were considered statistically significant. Different statistical tests were done for laparoscopic sessions, psychometric tests, piano scales and correlational analyses.

For the laparoscopic sessions, two types of performance curves were generated for each task across all six training sessions comparing both groups' speed and accuracy. Retention on day 6 was also compared between both groups. Using SPSS, a two-way mixed ANOVA was performed. Test of significant outliers was conducted using studentized residual values. Test of normality was conducted by visual inspection of Normal Q-Q plot. For non-normal data, the two-way mixed ANOVA was still run since ANOVAs are considered to be fairly robust to deviations from normality, although no specific research has been conducted into the two-way mixed ANOVA. Tests of homogeneity of variance, covariances and sphericity were conducted using Levene's test of homogeneity of variance; Box's test of equality of covariance matrices; and Mauchly's test of sphericity.

For the psychometrics tests, comparison of means between musician and controls groups was performed. Since the data did not meet the requirements for the independent-samples t-test (no significant outliers; normal distribution; and homogeneity of variances), the Mann-Whitney U test was used. Test of significant outliers was conducted by visual inspection of a boxplot. Normality was determined by the Shapiro-Wilk test. Homogeneity of variance was verified using Levene's test of homogeneity of variance.

The piano scales were assessed for number of note errors made at each of the three tempi to rank the pianists. Errors included substitutions, deletions, additions, hesitations (of 1 beat or more). Therefore, the lower the number of errors, the higher the ranking.

For correlational analyses, laparoscopic performance was compared against measured abilities and demographic characteristics of both groups. Spearman's rank-order correlations were run to assess the relationship between accuracy of performance on each task as well as to assess the relationship between accuracy of performance and average ranking amongst pianists. A Mann-Whitney U test was conducted for the confounding variables in comparison to laparoscopic performance.

3. Results

The results are presented in four parts: participant demographics, laparoscopic training, psychometric assessments and correlations. The first part reports on the baseline characteristics of participants. The second part reports on the performance curves between the musician and control groups. The third part reports on the psychometric test results between the musician and control groups. The fourth part reports on the correlations between demographic characteristics, specific non-motor and motor abilities and laparoscopic performance.

3.1 Baseline Characteristics of Participants

Demographics were similar between groups. There were nineteen musicians (mean age: 22.3 years, SD: 3.3, 12 females) and fourteen controls (mean age: 21.4 years, SD: 2.9, 9 females) in this study. See Table 1 for a detailed summary.

Table 1

Characteristics of Participants (N = 33)

		Number		*Percentage*	
	Response	MUS	CON	MUS	CON
Gender	Female	12	9	63%	64%
	Male	7	5	37%	36%
Handedness (Self-Reported)	RH	18	14	95%	100 %
	LH	1	0	5%	0%
Handedness M(SD) (Annett Questionnaire)	Scale (-2 to 2)	1.1 (1.2)	1.3 (1.0)	-	-
Knitting/sewing experience [a]	Yes	4	5	21%	36%
Play video games [a]	Yes	10	8	53%	57%
Texting frequency	More than 50 times per day	7	6	37%	43%
	20-50 times per day	8	5	42%	36%
	Less than 20 times per day	4	3	21%	21%
Chopstick ability	Use daily/weekly and/or fully proficient	10	6	53%	43%

Ethnicity	Caucasian	9	5	47%	36%
	Latino/Hispanic	0	1	-	7%
	Middle Eastern	1	3	5%	21%
	African	1	1	5%	7%
	South Asian	0	2	-	14%
	East Asian	2	0	11%	-
	Mixed	3	2	16%	14%
	No Response	3	0	16%	-
Interest in pursuing surgery as a career	Not interested at all	7	2	37%	14%
	Somewhat interested	4	4	21%	29%
	Very interested	4	7	21%	50%
	Don't know	1	1	5%	7%
	No Response	3	0	16%	-

Note. Mean (M); Standard Deviation (SD)

[a] - Categorized as "having experience" if participants regularly perform the activity for at least two years.

With respect to ethnicity, both groups had a large proportion of Caucasians with 47% and 36% for musicians and controls, respectively. There were, however, some differences between both groups, particularly regarding their activities. A larger proportion of controls than musicians had at least two years' experience knitting, sewing and/or playing video games. In contrast, the musician group seemed to use chopsticks more frequently and/or were more proficient. To that end, a larger proportion of the musician group were East Asian (11%) compared to the control group (0%). A large proportion of musicians were not at all interested in pursuing surgery as a career, whereas about half of the control group was very interested in pursuing surgery as a career.

Within the musician group, certain characteristics were assessed. The mean age of onset piano training was 6.3 years of age (SD: 1.8). The mean total years' experience was 15.7 years (SD: 3.1). See Table 2 for a detailed summary.

Table 2

Musician Characteristics (N = 19)

	Item	*Number*	*Percentage*
Level of piano performance	Grade 8	6	32%
	Grade 9	1	5%
	Grade 10	5	26%
	ARCT	3	16%
	CEGEP	1	5%
	ATCL	1	5%
	Bachelor of Music	2	11%
Frequency of training M(SD) (average hours per week)	As a child (12 years and under)	5.4 (3.3)	-
	As an adolescent (13-18 years)	8.3 (5.4)	-
	As a young adult (19-24 years)	7.7 (7.9)	-
	Currently	3.1 (3.9)	-
Age of onset training	3-4yo (1st Quartile)	3	16%
	5-6yo (2nd Quartile)	7	37%
	7-8yo (3rd Quartile)	7	37%
	9-10yo (4th Quartile)	2	10%
Main Instrument	Piano	19	100%
Secondary instrument(s)	Clarinet	4	21%
	Flute	3	16%
	Guitar	3	16%
	Violin	2	11%
	French Horn	1	5%
	Drums	1	5%
	Trumpet	1	5%
	Ukulele	1	5%
	Voice	1	5%
Total years' piano experience	11-13yrs (1st Quartile)	6	31%
	14-16yrs (2nd Quartile)	7	37%
	17-19yrs (3rd Quartile)	3	16%
	20-22yrs (4th Quartile)	3	16%

Note. Mean (M); Standard Deviation (SD)

Within the musician group, most pianists were RCM level 8 (32%) or level 10 (26%). The overall frequency of training seemed to be greatest during the adolescent years (8.3 hours per week) with the lowest frequency of training during their current university studies. The majority of musicians' age of onset of musical training started between 5 and 8 years of age. In addition to piano as their main instrument, many musicians also played a secondary instrument with clarinet, flute and guitar being most common. Total years of piano experience was predominantly in the second quartile ranging from 14-16 years' experience.

3.2 Research Question One: Laparoscopic Performance Curves

This section is divided into two parts: speed and accuracy of laparoscopic performance.

3.2.1 Speed

To investigate whether the participant groups and the number of training sessions interact or have any effect on the change in speed of laparoscopic performance, a two-way mixed ANOVA was used. The ANOVA was repeated for each of the six tasks. There were no statistically significant differences in speed between the musician and control groups, but there was a significant difference within both groups over the six days (except CT task). With respect to retention of speed, both the musician and control groups had well retained their trained skill following the one-week hiatus period between days 5 and 6 for all six tasks. The quality of the data is commented on extensively in this section and is summarized in Table 3. See Figure 10 for a summary and Tables 4-5 for statistical results of each task.

For the RB task, there were two outliers, which had studentized residual values of -3.65 and 3.13 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Time of completion was normally distributed, as assessed by Normal Q-Q Plot except for day 1. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .927$). Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction, $\chi^2(14) = 15.32$,

$p = .358$. For the RB task, speed became significantly faster by day 2 for both musician and control groups. The marginal means for time of completion were 176.33 (SE = 1.92) for session 1 and 140.39 (SE = 6.34) for session 2, a statistically significant mean difference of 35.94, 95% CI [16.71, 55.17], $p < .001$. Subsequent sessions (3-6) were also significantly greater in speed with respect to session 1. With regards to adjacent sessions, however, sessions 1-2 had the most significant change.

Table 3

Quality of results for speed (as determined by time of completion) of all laparoscopic performance data

Task	**No. of outliers**	**Studentized residual values**	**Normality (Q-Q plot)**	**Levene's test of homogeneity of variance (p > .05)**	**Box's test of equality of covariance matrices**	**Mauchly's test of sphericity**	**Adjustment**
RB	2	-3.65, 3.13	Yes, except day 1	Yes	Yes (p = .927)	Yes $\chi^2(14) = 15.32$, p = .358	-
BT (D)	2	3.16, 3.98	Yes	Yes	Yes (p = .615)	No $\chi^2(14) = 60.98$, p < .001	G ε = .521
BT (ND)	2	3.61, 3.46	Yes, except days 5 & 6	Yes	Yes (p = .167)	No $\chi^2(14) = 38.92$, p < .001	G ε = .623
PT	1	-3.02	Yes, except day 1 & 4	Yes, except day 3 (p = .035)	Yes (p = .480)	Yes $\chi^2(14) = 18.92$, p = .169	-
BP (D)	2	3.14, 3.04	Yes, except days 3-6	Yes, except day 4 (p = .050)	Yes (p = .731)	No $\chi^2(14) = 30.88$, p = .006	H ε = .889
BP (ND)	0	-	Yes	Yes	Yes (p = .833)	No $\chi^2(14) = 28.30$, p = .013	H ε = .894
CD (D)	1	3.15	Yes, except sessions 4-6	Yes	Yes (p = .580)	No $\chi^2(14) = 48.976$, p < .001	H ε = .775
CD (ND)	0	-	Yes	Yes, except day 3 (p = .002)	Yes (p = .192)	Yes $\chi^2(14) = 20.897$, p = .105	-
CT	5	-4.78, -3.71, -3.03, -3.43, -4.27	No	Yes, except for days 2 and 3	No (p < .001)	No $\chi^2(14) = 50.561$, p < .001	G ε = .634

Note. Dominant hand (D); Non-dominant hand (ND); Greenhouse-Geisser adjustment (G); Huynh-Feldt adjustment (H)

For the BT task (dominant hand), there were two outliers, which had studentized residual values of 3.16 and 3.98 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Time of completion was normally distributed, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .615$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 60.98$, $p < .001$. Thus, the Greenhouse-Geisser adjustment ($\varepsilon = .521$) was used.

For the BT task (dominant hand), speed became significantly faster by session 2 and 3 for both musician and control groups. The marginal means for time of completion were 96.55 (SE = 5.78) for session 1 and 61.32 (SE = 3.66) for session 2, a statistically significant mean difference of 35.23, 95% CI [15.81, 54.65], $p < .001$. Similarly, the marginal means for time of completion were 61.32 (SE = 3.66) for session 2 and 49.98 (SE = 2.28) for session 3, a statistically significant mean difference of 11.35, 95% CI [.221, 22.47], $p = .042$. Subsequent sessions (3-6) were also significantly greater in speed with respect to session 1. With regards to adjacent sessions, however, sessions 1-2 and 2-3 had the most significant change.

For the BT task (non-dominant hand), there were two outliers, which had studentized residual values of 3.61 and 3.46 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Time of completion was normally distributed, as assessed by Normal Q-Q Plot, except sessions 5 and 6. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .167$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 38.92$, $p < .001$. Thus, the Greenhouse-Geisser adjustment ($\varepsilon = .623$) was used.

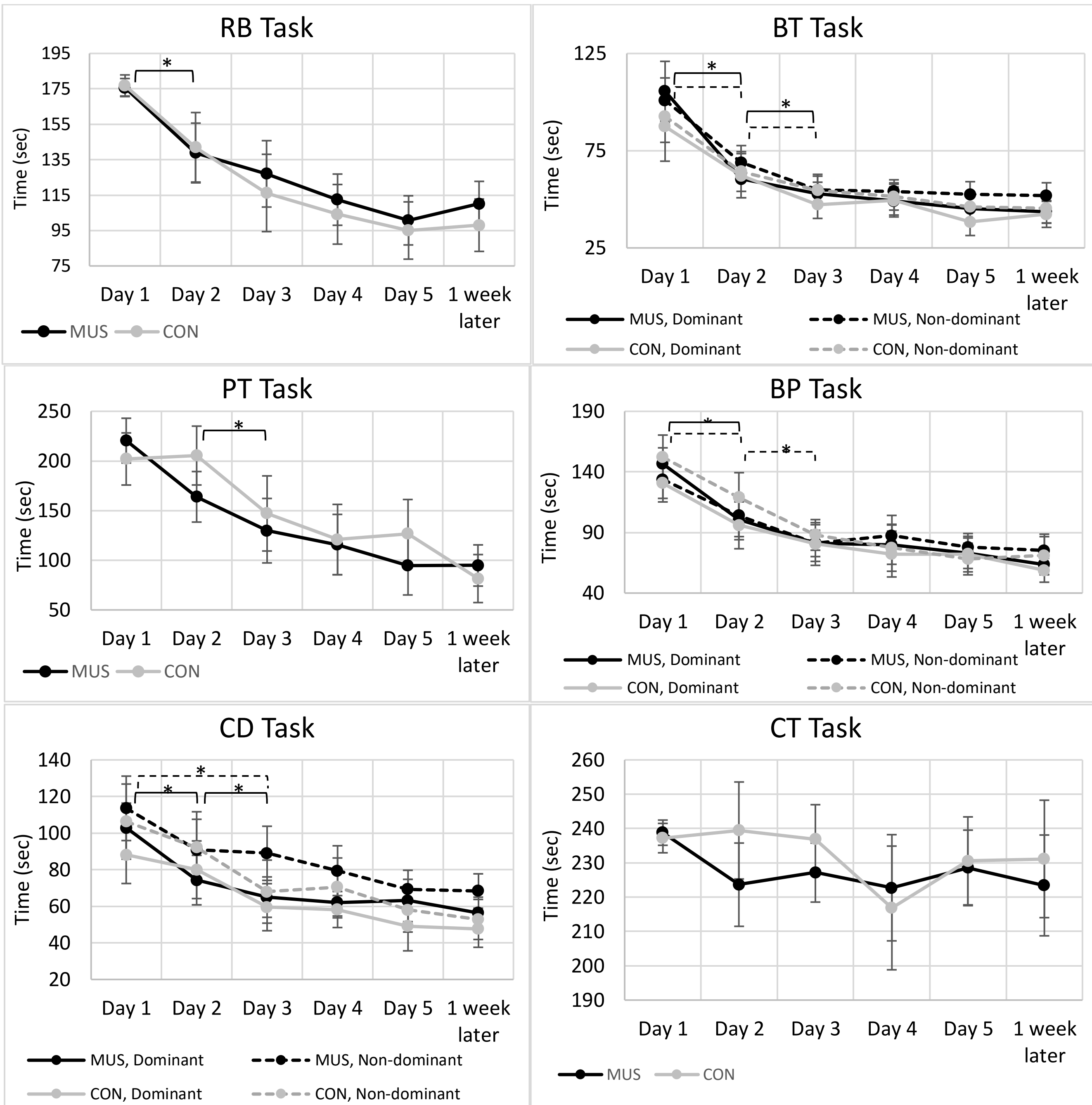
For the BT task (non-dominant hand), speed became significantly faster by session 2 and 3 for both musician and control groups. The marginal means for time of completion were 96.81 (SE = 4.31) for session 1 and 66.58 (SE = 3.30) for session 2, a statistically significant mean difference of 30.23, 95% CI [16.96, 43.50], $p < .001$. Similarly, the marginal means for time of completion were 66.58 (SE = 3.30) for session 2 and 54.72 (SE = 2.66) for session 3, a statistically significant mean difference of 11.85, 95% CI [3.76, 23.94], $p = .003$. Subsequent sessions (3-6) were also significantly greater in speed with respect to session 1. With regards to adjacent sessions, however, sessions 1-2 and 2-3 had the most significant change.

For the PT task, there was one outlier, which had a studentized residual value of -3.02. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without this outlier the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Time of completion was normally distributed, as assessed by Normal Q-Q Plot, except session 1 and 4. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$) except session 3, $p = .035$. There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .480$). Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction, $\chi^2(14) = 18.92$, $p = .169$.

For the PT task, speed became significantly faster at session 3 for both musician and control groups. The marginal means for time of completion were 184.66 (SE = 9.57) for session 2 and 138.47 (SE = 12.22) for session 3, a statistically significant mean difference of 46.19, 95% CI [10.67, 81.72], $p = .004$. Sessions

Figure 10

Marginal means of speed (as determined by time of completion) for laparoscopic performance on each task over the course of six training sessions



Note. Lower time indicates higher performance speed. Error bars represent the upper and lower 95% confidence intervals. Asterisk (*) denotes statistical significance (p < .05).

Table 4

Results of two-way mixed ANOVA comparing the change in speed of laparoscopic performance for each task

Task		*F*	*df*	*p*	*partial η2*
RB	Interaction (time point*participant group)	0.56	5	0.73	0.018
	Main effect of time point	48.86	5	<.001**	0.612
	Main effect of participant group	0.52	1	0.480	0.016
BT (D)	Interaction (time point*participant group)	1.58	2.61	0.205	0.049
	Main effect of time point (G)	51.40	2.61	<.001**	0.624
	Main effect of participant group	1.34	1	0.256	0.041
BT (ND)	Interaction (time point*participant group)	0.39	3.12	0.768	0.012
	Main effect of time point (G)	61.51	3.12	<.001**	0.665
	Main effect of participant group	1.29	1	0.264	0.040
PT	Interaction (time point*participant group)	1.82	5	0.111	0.056
	Main effect of time point	27.78	5	<.001**	0.473
	Main effect of participant group	0.75	1	0.393	0.024
BP (D)	Interaction (time point*participant group)	0.51	4.44	0.751	0.016
	Main effect of time point (H)	48.08	4.44	<.001**	0.608
	Main effect of participant group	0.58	1	0.454	0.018
BP (ND)	Interaction (time point*participant group)	2.31	4.47	0.054	0.069
	Main effect of time point (H)	44.76	4.47	<.001**	0.591
	Main effect of participant group	0.12	1	0.731	0.004
CD (D)	Interaction (time point*participant group)	1.30	3.88	0.275	0.040
	Main effect of time point (H)	24.27	3.88	<.001**	0.439
	Main effect of participant group	1.33	1	0.258	0.041
CD (ND)	Interaction (time point*participant group)	0.89	5	0.491	0.028
	Main effect of time point	20.88	5	<.001**	0.402
	Main effect of participant group	1.87	1	0.181	0.057
CT	Interaction (time point*participant group)	0.94	3.17	0.427	0.030
	Main effect of time point (G)	2.17	3.17	0.093	0.065
	Main effect of participant group	1.04	1	0.315	0.033

Note. Dominant hand (D); Non-dominant hand (ND); Greenhouse-Geisser adjustment (G); Huynh-Feldt adjustment (H)

* $p < .05$; ** $p < .001$

3-6 were also significantly greater in speed with respect to session 1. With regards to adjacent sessions, however, sessions 2-3 had the most significant change.

For the BP task (dominant hand), there were two outliers, which had studentized residual values of 3.14 and 3.04 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Time of completion was normally distributed, as assessed by Normal Q-Q Plot, except session 3-6. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$) except session 4, $p = .050$. There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .731$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 30.88$, $p = .006$. Thus, the Huynh-Feldt adjustment ($\varepsilon = .889$) was used.

For the BP task (dominant hand), speed became significantly faster by session 2 for both musician and control groups. The marginal means for time of completion were 138.65 (SE = 4.99) for session 1 and 98.29 (SE = 6.25) for session 2, a statistically significant mean difference of 40.36, 95% CI [17.17, 63.55], $p < .001$. Subsequent sessions (3-6) are also significantly greater in speed with respect to session 1. With regards to adjacent sessions, however, sessions 1-2 had the most significant change.

For the BP task (non-dominant hand), there were no outliers which supported the assumptions of the two-way mixed ANOVA. Time of completion was normally distributed, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .833$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 28.30$, $p = .013$. Thus, the Huynh-Feldt adjustment ($\varepsilon = .894$) was used.

For the BP task (non-dominant hand), speed became significantly faster by sessions 2 and 3 for both musician and control groups. The marginal means for time of completion were 143.00 (SE = 5.89) for session 1 and 111.55 (SE = 6.56) for session 2, a statistically significant mean difference of 31.45, 95% CI [15.61, 47.29], $p < .001$. Similarly, the marginal means for time of completion were 111.55 (SE = 6.56) for session 2 and 84.49 (SE = 4.09) for session 3, a statistically significant mean difference of 27.06, 95% CI [7.76, 46.36], $p = .002$. Subsequent sessions (3-6) were also significantly greater in speed with respect to session 1. With regards to adjacent sessions, however, sessions 1-2 and 2-3 had the most significant change.

For the CD task (dominant hand), there was one outlier, which had a studentized residual value of 3.15. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without this outlier the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Time of completion was normally distributed, as assessed by Normal Q-Q Plot except sessions 4-6. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .580$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 48.976$, $p < .001$. Thus, the Huynh-Feldt adjustment ($\varepsilon = .775$) was used.

For the CD task (dominant hand), speed became significantly faster by session 2 and 3 for both musician and control groups. The marginal means for time of completion were 95.52 (SE = 5.07) for session 1 and 77.14 (SE = 5.09) for session 2, a statistically significant mean difference of 18.38, 95% CI [1.42, 35.34], $p = .025$. Similarly, the marginal means for time of completion were 77.14 (SE = 5.09) for session 2 and 62.25 (SE = 4.15) for session 3, a statistically significant mean difference of 14.89, 95% CI [3.42, 26.36], $p = .004$. Subsequent sessions (3-6) were also significantly greater in speed with respect to session 1. With regards to adjacent sessions, however, sessions 1-2 and 2-3 had the most significant change.

For the CD task (non-dominant hand), there were no outliers which supported the assumptions of the two-way mixed ANOVA. Time of completion was normally distributed, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$) except session 3, $p = .002$. There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .192$). Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction, $\chi^2(14) = 20.897$, $p = .105$.

For the CD task (non-dominant hand), speed became significantly faster by session 3 with respect to session 1 for both musician and control groups. The marginal means for time of completion were 109.91 (SE = 6.63) for session 1 and 78.47 (SE = 5.57) for session 3, a statistically significant mean difference of 31.43, 95% CI [12.20, 50.67], $p < .001$. There was no significant difference between sessions 1-2 ($p = .106$). Subsequent sessions (4-6) were also significantly greater in speed with respect to session 1. With regards to adjacent sessions, however, none of the sessions changed significantly.

For the CT task, there were five outliers, which had studentized residual values of -4.78, -3.71, -3.03, -3.43 and -4.27 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. These results became statistically significant with outliers removed, $F(5, 135) = 2.915$, $p = .016$, partial $\eta^2 = .097$ with Greenhouse-Geisser adjustment ($p = .038$). Time of completion was not normally distributed, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$) except for sessions 2 and 3. The Box’s test of equality of covariance matrices indicated that the assumption of homogeneity of covariances was violated ($p < .001$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 50.561$, $p < .001$. Thus, the Greenhouse-Geisser adjustment ($\varepsilon = .634$) was used. For the CT task, speed never became significantly faster for either musician or control groups. Subsequent sessions (2-6) were also non-significant with respect to session 1.

Table 5

Mean difference of speed (as determined by time of completion) for all laparoscopic performance data

Task	Adjacent days with greatest improvement	Mean in seconds (SE)	Mean difference	95% Confidence Interval		*p* value
				Low	High	
RB	1-2	176.33 (1.92) 140.39 (6.34)	35.94	16.71	55.17	< .001
BT (D)	1-2	96.55 (5.78) 61.32 (3.66)	35.23	15.81	54.65	< .001
	2-3	61.32 (3.66) 49.98 (2.28)	11.35	.221	22.47	.042
BT (ND)	1-2	96.81 (4.31) 66.58 (3.30)	30.23	16.96	43.50	< .001
	2-3	66.58 (3.30) 54.72 (2.66)	11.85	3.76	23.94	.003
PT	2-3	184.66 (9.57) 138.47 (12.22)	46.19	10.67	81.72	.004
BP (D)	1-2	138.65 (4.99) 98.29 (6.25)	40.36	17.17	63.55	< .001
BP (ND)	1-2	143.00 (5.89) 111.55 (6.56)	31.45	15.61	47.29	< .001
	2-3	111.55 (6.56) 84.49 (4.09)	27.06	7.76	46.36	.002
CD (D)	1-2	95.52 (5.07) 77.14 (5.09)	18.38	1.42	35.34	.025
	2-3	77.14 (5.09) 62.25 (4.15)	14.89	3.42	26.36	.004
CD (ND)	1-3	109.91 (6.63) 78.47 (5.57)	31.43	12.20	50.67	< .001
CT	-	-	-	-	-	-

Note. Standard error (SE)

To summarize, the results pertaining to the speed of laparoscopic performance showed no significant difference between musician and control groups. This was true for all six tasks over the course of all six days of laparoscopic training. Both groups, however, significantly improved their speed for all tasks (except CT task) in parallel to one another over the course of the training sessions.

3.2.2 Accuracy

To investigate whether the participant groups and the number of training sessions interact or have any effect on the change in accuracy of laparoscopic performance, a two-way mixed ANOVA was used. There were no statistically significant differences in accuracy between the musician and control groups, except for BP task (non-dominant hand). A simple main effect was run using six separate one-way ANOVAs. There was also a significant difference within both groups over the six training sessions, except the BT task (both hands) and the CD task (non-dominant hand only). With respect to retention of accuracy, both the musician and control groups seemed to have well retained their trained skill following the one-week hiatus period between sessions 5 and 6 for all six tasks. The quality of the data is commented on extensively in this section and is summarized in Table 6. See Figure 11 for summary and Table 7-10 for statistical results of each task.

For the RB task, there were six outliers, which had studentized residual values of -3.34, -3.94, -3.83, -3.83, -5.57 and -4.99 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Number of bands transferred was not normally distributed, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$) except for sessions 4 and 5. Box's Test of Equality of Covariance Matrices was not computed because there are fewer than two non-singular cell covariance matrices. Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 70.04$, $p < .001$. Thus, the Greenhouse-Geisser adjustment ($\varepsilon = .490$) was used.

For the RB task, the number of bands transferred became significantly better by day 2 for both musician and control groups. The marginal means for number of bands transferred were 2.65 (SE = .182) for day 1 and 3.64 (SE = .137) for day 2, a statistically significant mean difference of -.991, 95% CI [-1.69, -.295], p = .001. Subsequent sessions (3-6) were also significantly greater in number of bands transferred with respect to session 1. With regards to adjacent sessions, however, sessions 1-2 had the most significant change.

Table 6

Quality of results for accuracy of all laparoscopic performance data

Task	No. of outliers	Studentized residual values	Normality (Q-Q plot)	Levene's test of homogeneity of variance (p > .05)	Box's test of equality of covariance matrices	Mauchly's test of sphericity	Adjustment
RB	6	-3.34, -3.94, -3.83, -3.83, -5.57, -4.99	No	Yes, except for sessions 4 and 5	N/A	No $\chi2(14) = 70.04$, $p < .001$	G $\varepsilon = .490$
BT (D)	5	3.34, 3.33, 3.22, 3.09, 3.09	No	Yes, except for sessions 1 and 4	Yes (p = .092)	Yes $\chi2(14) = 15.19$, $p = .367$	-
BT (ND)	4	3.86, 3.01, 3.55, 4.11	No	Yes	Yes (p = .982)	No $\chi2(14) = 32.38$, $p = .004$	H $\varepsilon = .826$
PT	3	3.27, 3.15, 3.56	No, except session 1	Yes, except session 2 (p = .049)	Yes (p = .412)	No $\chi2(14) = 33.30$, $p = .003$	H $\varepsilon = .839$
BP (D)	0	-	Yes	Yes	Yes (p = .614)	No $\chi2(14) = 30.65$, $p = .006$	H $\varepsilon = .879$
BP (ND)	3	3.22, 3.15, 3.03	No, except session 1 and 3	Yes, except sessions 2 and 6	Yes (p = .363)	No $\chi2(14) = 25.31$, $p = .032$	H $\varepsilon = .929$
CD (D)	4	4.46, 3.84, 3.04, 3.52	No, except session 1	Yes	Yes (p = .039)	No $\chi2(14) = 37.27$, $p < .001$	H $\varepsilon = .798$
CD (ND)	3	3.49, 3.07, 3.82	Yes, except session 2 and 4	Yes, except session 2	Yes (p = .065)	Yes $\chi2(14) = 21.34$, $p = .094$	-
CT	0	-	Yes	Yes	Yes (p = .928)	Yes $\chi2(14) = 25.77$, $p = .028$	-

Note. Dominant hand (D); Non-dominant hand (ND); Greenhouse-Geisser adjustment (G); Huynh-Feldt adjustment (H)

For the BT task (dominant hand), there were five outliers, which had studentized residual values of 3.34, 3.33, 3.22, 3.09 and 3.09 respectively. This violated one of the assumptions of the two-way mixed

ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Number of beads dropped was not normally distributed, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$) except for sessions 1 and 4. There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .092$). Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction, $\chi^2(14) = 15.19$, $p = .367$.

For the BT task (dominant hand), number of beads dropped never significantly improved for either musician or control groups. Subsequent sessions (2-6) were also non-significantly less in number of beads dropped with respect to session 1. For the BT task (non-dominant hand), there were four outliers, which had studentized residual values of 3.86, 3.01, 3.55 and 4.11 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Number of beads dropped was not normally distributed, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .982$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 32.38$, $p = .004$. Used Huynh-Feldt adjustment ($\varepsilon = .826$). Removing outliers improved sphericity ($p = .362$).

For the BT task (non-dominant hand), number of beads dropped never significantly improved for either musician or control groups. Subsequent sessions (2-6) are also non-significantly less in number of beads dropped with respect to session 1.

For the PT task, there were three outliers, which had studentized residual values of 3.27, 3.15 and 3.56 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Number of pegs dropped was normally distributed for session 1 only, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$) except session 2 ($p = .049$). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .412$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 33.30$, $p = .003$. Thus, the Huynh-Feldt adjustment ($\varepsilon = .839$) was used.

For the PT task, number of pegs dropped became significantly better by session 6 for both musician and control groups. The marginal means for number of pegs dropped were 2.98 (SE = .38) for session 1 and 1.35 (SE = .22) for session 6, a statistically significant mean difference of 1.63, 95% CI [.45, 2.81], $p = .002$. Other sessions (2-5) were not significantly less in number of pegs dropped with respect to session 1. With regards to adjacent sessions, however, none of the sessions were significantly different.

For the BP task (dominant hand), there were no outliers. Number of beads dropped was normally distributed, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .614$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 30.65$, $p = .006$. Thus, the Huynh-Feldt adjustment ($\varepsilon = .879$) was used.

For the BP task (dominant hand), number of beads dropped became significantly better by session 4 for both musician and control groups. The marginal means for number of beads dropped were 4.08 (SE = .37) for session 1 and 2.12 (SE = .31) for session 4, a statistically significant mean difference of 1.96, 95%

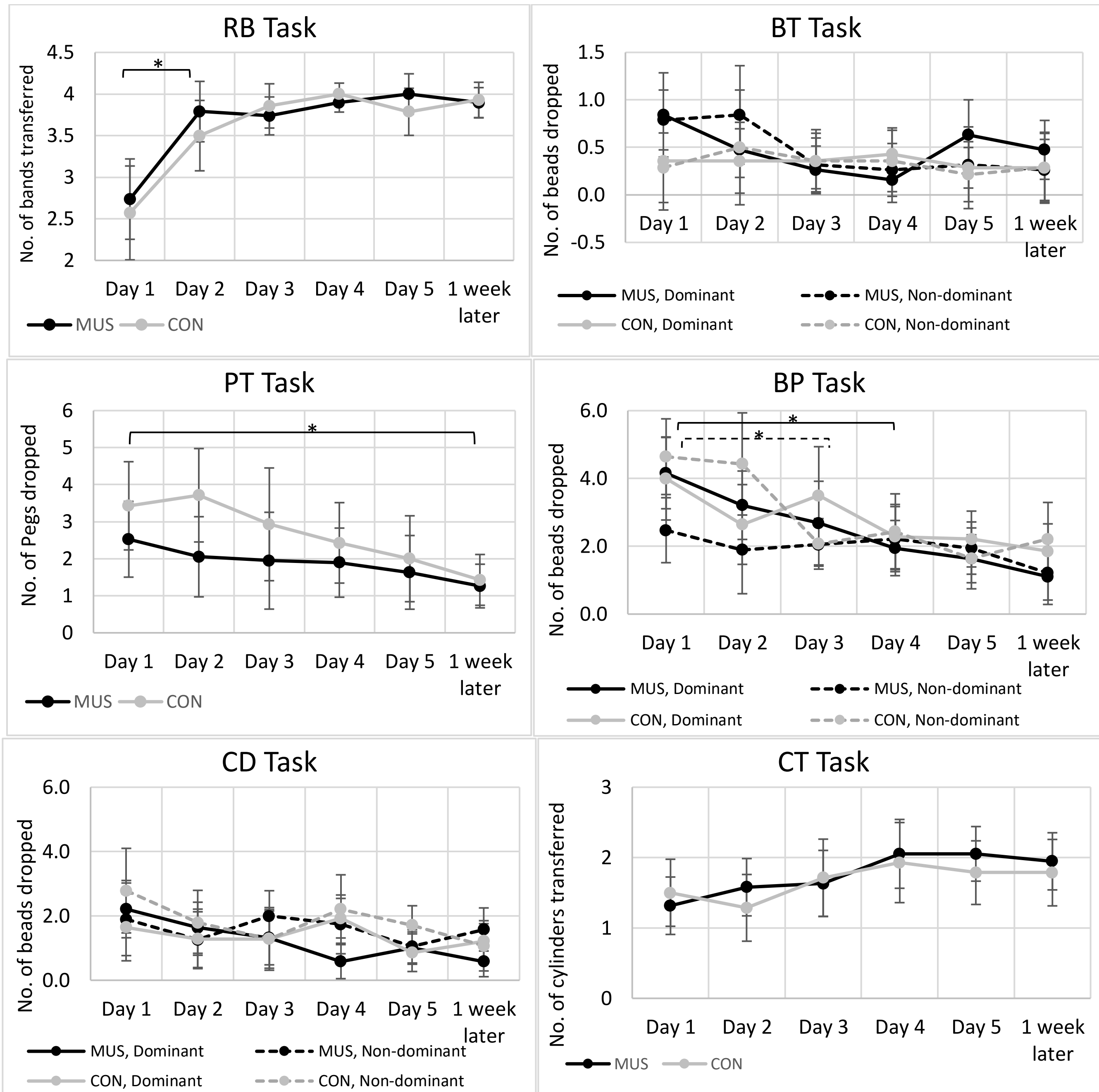
CI [.80, 3.13], $p < .001$. Subsequent sessions (5-6 only) were also significantly less in number of beads dropped with respect to session 1. With regards to adjacent sessions, however, there were no significant changes.

For the BP task (non-dominant hand), there were three outliers, which had studentized residual values of 3.22, 3.15 and 3.03 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Number of beads dropped was normally distributed, as assessed by Normal Q-Q Plot except session 2, 4-6. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$) except sessions 2 and 6. There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .363$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 25.31$, $p = .032$. Thus, the Huynh-Feldt adjustment ($\varepsilon = .929$) was used. Removing outliers improved sphericity ($p = .073$).

For the BP task (non-dominant hand), number of beads dropped became significantly better by session 3 for both musician and control groups. The marginal means for number of beads dropped were 3.56 (SE = .36) for session 1 and 2.06 (SE = .24) for session 3, a statistically significant mean difference of 1.50, 95% CI [.18, 2.81], $p = .015$. Subsequent sessions (5-6) are also significantly greater in number of beads dropped with respect to session 1. With regards to adjacent sessions, however, there were no significant changes. There was a statistically significant simple main effects difference in accuracy between musician and control groups at session 1 ($p = .005$) and session 2 ($p = .014$), but session 3 onwards it was no longer significant. See Table 8 for summary.

Figure 11

Marginal means of accuracy of laparoscopic performance on each task over the course of six training sessions.



Note. Higher number of items transferred (RB and CT tasks) or lower number of drops (BT, PT, BP and CD tasks) indicates higher accuracy of performance. Error bars represent the upper and lower 95% confidence intervals. Asterisk (*) denotes statistical significance ($p < .05$).

Table 7

Results of two-way mixed ANOVA comparing the change in accuracy of laparoscopic performance for each task

Task		*F*	*df*	*p*	*partial η2*
RB	Interaction (time point*participant group)	0.82	2.45	0.467	0.026
	Main effect of time point (G)	25.76	2.45	< .001**	0.454
	Main effect of participant group	0.27	1	0.610	0.008
BT (D)	Interaction (time point*participant group)	1.34	5	0.251	0.041
	Main effect of time point	0.87	5	0.502	0.027
	Main effect of participant group	1.44	1	0.240	0.044
BT (ND)	Interaction (time point*participant group)	0.94	4.13	0.444	0.03
	Main effect of time point (H)	1.81	4.13	0.114	0.055
	Main effect of participant group	1.24	1	0.273	0.039
PT	Interaction (time point*participant group)	0.60	4.2	0.669	0.019
	Main effect of time point (H)	3.31	4.2	0.007*	0.097
	Main effect of participant group	3.26	1	0.081	0.095
BP (D)	Interaction (time point*participant group)	0.78	4.39	0.552	0.024
	Main effect of time point (H)	9.21	4.39	< .001**	0.229
	Main effect of participant group	0.49	1	0.488	0.016
BP (ND)	Interaction (time point*participant group)	3.33	4.64	0.009*	0.097
	Main effect of time point (H)	5.49	4.64	< .001**	0.151
	Main effect of participant group	5.55	1	< .025*	0.152
CD (D)	Interaction (time point*participant group)	2.46	3.99	0.049*	0.074
	Main effect of time point (H)	2.78	3.99	0.020*	0.082
	Main effect of participant group	0.23	1	0.637	0.007
CD (ND)	Interaction (time point*participant group)	1.54	5	0.181	0.047
	Main effect of time point	2.12	5	0.066	0.064
	Main effect of participant group	0.32	1	0.579	0.010
CT	Interaction (time point*participant group)	0.48	5	0.788	0.015
	Main effect of time point	3.34	5	.007*	0.097
	Main effect of participant group	0.23	1	0.639	0.007

Note. Dominant hand (D); Non-dominant hand (ND); Greenhouse-Geisser adjustment (G); Huynh-Feldt adjustment (H)

* p < .05; ** p < .001

Table 8

Results of six separate one-way ANOVAs comparing participant groups' accuracy of laparoscopic performance for the BP task (non-dominant hand)

	Session Number	*F*	*df*	*p*	*partial η2*
Simple main effect of participant group	1	9.05	1	0.005*	0.226
	2	6.76	1	0.014*	0.179
	3	0.00	1	0.969	0.0005
	4	0.09	1	0.765	0.003
	5	0.28	1	0.604	0.009
	6	2.07	1	0.160	0.063

* p < .05

For the CD task (dominant hand), there were four outliers, which had studentized residual values of 4.46, 3.84, 3.04 and 3.52 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Number of beads dropped was normally distributed, as assessed by Normal Q-Q Plot except session 2-6. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance (p > .05). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices (p = .039). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(14) = 37.27$, $p < .001$. Thus, the Huynh-Feldt adjustment (ε = .798) was used.

For the CD (dominant hand), number of beads dropped was never significantly better for either musician or control groups. However, it reached close to significance at session 5 (p = .071) and session 6 (p = .090) with respect to session 1. There was a statistically significant difference in simple main effects for accuracy between musician and control groups at session 4 (p = .002) only, but all other sessions were non-significant. See Table 9 for summary.

Table 9

Results of six separate one-way ANOVAs comparing participant groups' accuracy of laparoscopic performance for CD task (dominant hand)

	Session Number	*F*	*df*	*p*	*partial η2*
Simple main effect of participant group	1	0.72	1	0.404	0.023
	2	0.34	1	0.567	0.011
	3	0.00	1	0.962	0.0005
	4	11.51	1	0.002*	0.271
	5	0.14	1	0.708	0.005
	6	3.26	1	0.081	0.095

* p < .05

For the CD task (non-dominant hand), there were three outliers, which had studentized residual values of 3.49, 3.07 and 3.82 respectively. This violated one of the assumptions of the two-way mixed ANOVA. However, in a comparison with and without these outliers the ANOVA results were similar in that there was no statistically significant difference between the musician and control groups. Number of beads dropped was normally distributed, as assessed by Normal Q-Q Plot except session 2 and 4. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance (p > .05), except session 2. There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices (p = .065). Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction, $\chi^2(14) = 21.34$, p = .094.

For the CD task (non-dominant hand), number of beads dropped never became significantly better for either musician or control groups.

For the CT task, there were no outliers. Number of cylinders transferred was normally distributed, as assessed by Normal Q-Q Plot. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance (p > .05). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices (p = .928). Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction, $\chi^2(14) = 25.77$, p = .028. For the CT task, the number of cylinders transferred never became significantly better for either musician or control groups. However, it reached close to significance at session 5 (p = .056) with respect to session 1.

Table 10

Mean difference of accuracy for all laparoscopic performance data

Task	Adjacent days with greatest improvement	Mean of items dropped/transferred (SE)	Mean difference	95% Confidence Interval		*p* value
				Low	High	
RB	1-2	2.65 (0.182) 3.64 (0.137)	-0.991	-1.69	-0.295	.001
BT (D)	-	-	-	-	-	-
BT (ND)	-	-	-	-	-	-
PT	1-6	2.98 (0.38) 1.35 (0.22)	1.63	0.45	2.81	.002
BP (D)	1-4	4.08 (0.37) 2.12 (0.31)	1.96	0.80	3.13	< .001
BP (ND)	1-3	3.56 (0.36) 2.06 (0.24)	1.50	0.18	2.81	.015
CD (D)	-	-	-	-	-	-
CD (ND)	-	-	-	-	-	-
CT	-	-	-	-	-	-

Note. Standard error (SE)

To summarize, the results pertaining to the accuracy of laparoscopic performance showed no significant difference between musician and control groups, except for two instances. The BP task (non-dominant hand only) from days 1-2 as well as the CD task (dominant hand) on day 4. Both groups significantly improved their accuracy for all tasks except the BT task (both hands) and the CD task (non-dominant hand only) over the course of the training sessions.

3.3 Research Question Two: Psychometric Assessments

This section is divided into three parts: cognitive tests, psychomotor tests and piano scales. The latter applies to the musician group only.

3.3.1 Cognitive tests

To compare the cognitive abilities between the musician and control groups, a comparison of means was conducted. Since the data did not meet the requirements for the independent-samples t-test (no significant outliers; normal distribution; and homogeneity of variances), the Mann-Whitney U test was used. There were no statistically significant differences in cognitive abilities between the musician and control groups, using an exact sampling distribution for U (Dinneen & Blakesley, 1973). The quality of the data will be commented on in this section. See Table 11 for statistical results.

Table 11

Results of Mann-Whitney U test comparing cognitive scores between musician and control groups

		Overall Score				
Test	*Item*	*MUS (N = 17)*	*CON (N = 13)*	*U*	*z*	*p*
MRT	Total score	9 (-15-18)	9 (-6-16)	114.0	0.147	0.902
Paper folding	Total	12 (2.0-18.5)	11 (5.0-18.5)	138.5	1.174	0.245
TMT	Test A Time (sec)	19 (12-53)	20 (12-26)	96.5	-0.587	0.563
	Test A Time (sec)	44 (26-84)	42.9 (34-61)	120.0	0.398	0.711
PicSOr	r value	0.389 (-.100-.932)	0.385 (.138-.954)	105.0	-0.230	0.837
	Time (min)	5.69 (2.59-11.17)	5.06 (2.20-9.45)	128.0	0.732	0.482

Note. Data are median (range) values.

For the MRT, there was one outlier in the MRT data, as assessed by inspection of a boxplot. Based on Shapiro-Wilk test, the MRT results were only normally distributed for the control group. The musician group was not normally distributed. Thus, a Mann-Whitney U test was run to determine if there were differences in MRT score between musicians and controls. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance (p = .874). The MRT score distribution for musicians and controls were similar, as assessed by visual inspection.

For the Paper Folding Test, there was one outlier in the paper folding test data, as assessed by inspection of a boxplot. Thus, a Mann-Whitney U test was used. Based on Shapiro-Wilk test, all of the Paper folding results were normally distributed. There was homogeneity of variances, as assessed by

Levene's test of homogeneity of variance (p = .646). The Paper Folding score distribution for musicians and controls were similar, as assessed by visual inspection.

For the TMT, there was one significant outlier in the TMT data, as assessed by inspection of a boxplot (Test A score). Based on Shapiro-Wilk test, all of the TMT results were normally distributed except for the musician group Test A score. Thus, a Mann-Whitney U test was used. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance (p > .05). Both TMT score distributions for musicians and controls were similar, as assessed by visual inspection.

For PicSOr, there were four outliers in the data, as assessed by inspection of a boxplot. Thus, a Mann-Whitney U test was used. Based on Shapiro-Wilk test, all of the PicSOr results were normally distributed. There was homogeneity of variances of the r value (p = .492) and time (p = .707), as assessed by Levene's test of homogeneity of variance. Both PicSOr score distributions for musicians and controls were similar, as assessed by visual inspection.

3.3.2 Psychomotor tests

To compare the psychomotor abilities between the musician and control groups, a comparison of means was conducted. Since the data did not meet the requirements for the independent-samples t-test (no significant outliers; normal distribution; and homogeneity of variances), the Mann-Whitney U test was used. There were no statistically significant differences in motor abilities between the musician and control groups, using an exact sampling distribution for U (Dinneen & Blakesley, 1973). The quality of the data will be commented on in this section. See Table 12 for statistical results.

For the Grooved Pegboard, there were outliers in the data, as assessed by inspection of a boxplot. For the dominant hand there were two outliers in insertion time and one outlier in removal time. For the non-dominant hand data, there was one significant outlier in insertion time and one significant outlier in removal time. In the LQ data, there were two and three outliers in the insertion and removal subtasks, respectively. Based on Shapiro-Wilk test, most of the grooved pegboard results were not normally distributed. Thus, Mann-Whitney U test was used. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance (p > .05). All grooved pegboard score distributions for musicians and controls were similar, as assessed by visual inspection.

Table 12

Results of Mann-Whitney U test comparing psychomotor scores between musician and control groups

			Overall Score				
Test		*Item*	*MUS (N = 17)*	*CON (N = 13)*	*U*	*z*	*p*
Grooved Pegboard	Insertion time (sec)	D	59.4 (50-83)	60 (53-94)	87.0	-0.985	0.341
		ND	62.7 (53-119)	68 (57-80)	77.5	-1.382	0.170
		LQ	0.03 (-0.10-0.18)	0.03 (-0.11-0.20)	117.0	0.272	0.805
	Removal time (sec)	D	21.7 (16-28)	21 (16-31)	106.0	-0.189	0.869
		ND	20.1 (16-27)	22 (19-33)	78.5	1.345	0.183
		LQ	0 (-0.13-0.11)	0.02 (-0.10-0.16)	96.0	-0.607	0.563
Purdue Pegboard	No. of pins inserted	D	15 (13-18)	14 (9-17)	133.5	0.977	0.341
		ND	14 (12-18)	13 (12-16)	156.5	1.967	0.053
		LQ	0.03 (-0.04-0.13)	0.06 (-0.14-0.10)	89.5	-0.888	0.385
		HT	13 (10-15)	11 (8-14)	146.0	1.511	0.145
TAP	No. of taps	D	116 (92-155)	113 (104-145)	110.5	0.000	1.000
		ND	108 (92-145)	105 (94-138)	134.0	0.985	0.341
		LQ	0.03 (-0.02-0.13)	0.06 (-0.03-0.10)	78.0	-1.360	0.183
Chopsticks	No. beads transferred	D	21 (7-28)	17 (10-23)	131.5	0.884	0.385
		ND	11 (2-18)	11 (3-16)	131.0	0.861	0.408
		LQ	0.14 (-0.35-0.71)	0.26 (-0.09-0.74)	88.5	-0.921	0.363
	Rice time (sec)	D	47 (13-150)	35 (16-170)	113.0	0.105	0.934
		ND	58.9 (24-150)	68 (26-170)	97.5	-0.548	0.592
		LQ	0.17 (-0.64-0.69)	0.12 (-0.43-0.76)	95.5	-0.628	0.536
DFT	No. of dots filled	D	60 (31-74)	62 (47-81)	88.5	-0.921	0.363
		ND	38 (24-61)	41 (32-155)	94.0	-0.692	0.509
		LQ	0.20 (-0.23-0.35)	0.20 (-0.16-0.32)	120.5	0.419	0.680
FEP	No. cycles	D	20 (10-27)	17 (11-26)	142.0	1.322	0.198
		ND	19 (11-31)	18 (15-24)	147.0	1.538	0.133
		LQ	-0.02 (-0.10-0.15)	-0.03 (-0.19-0.14)	137.5	1.132	0.263

Note. Dominant hand (D); Non-dominant hand (ND); Laterality Quotient (LQ); Hands together (HT).

Data are median (range) values.

For the Purdue Pegboard, there were outliers in the data, as assessed by inspection of a boxplot: one outlier for dominant hand number of pins inserted, no outliers for hands together; and two outliers for non-dominant hand. In the LQ data, there were three outliers. Based on Shapiro-Wilk test, all of Purdue pegboard results were normally distributed except for the pianist group for dominant hand number of pins inserted and the LQ data. Thus, a Mann-Whitney U test was used. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$), except for the LQ data ($p = .007$). All Purdue pegboard score distributions for musicians and controls were similar, as assessed by visual inspection.

For the TAP, there were outliers in the data, as assessed by inspection of a boxplot: one outlier for the dominant hand tapping score; two outliers for the non-dominant hand tapping score; and no outliers for the tapping difference or LQ data. Based on Shapiro-Wilk test, all of the TAP results were normally distributed except the control group non-dominant tapping score. Thus, a Mann-Whitney U test was used. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). All TAP score distributions for musicians and controls were similar, as assessed by visual inspection.

For the Chopsticks test, there were outliers in all dominant hand data, as assessed by inspection of a boxplot: one outlier in number of beads transferred and rice time. There were also outliers in some of the non-dominant hand data, as assessed by inspection of a boxplot: no outliers in number of beads transferred; and two outliers in rice time. In the LQ data, there were two outliers in the bead transfer subtask only. Based on Shapiro-Wilk test, all of the chopstick test results were not normally distributed, except the number of beads transferred subtask (both dominant and non-dominant hands). Thus, a Mann-Whitney U test was used. There was some homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$), except for number of beads transferred (dominant hand only), $p = .026$ and number of rice pieces transferred (non-dominant hand only), $p = .047$. All Chopstick score distributions for musicians and controls were similar, as assessed by visual inspection.

For the DFT, there were outliers in the data, as assessed by inspection of a boxplot: one outlier for non-dominant hand and two outliers (one of which was statistically significant) for the LQ data. Thus, a Mann-Whitney U test was used. Based on Shapiro-Wilk test, most of DFT results were normally distributed except the LQ data. All data was normally distributed except the pianist group for the LQ. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). All DFT distributions for musicians and controls were similar, as assessed by visual inspection.

There is one outlier in the FEP data and two outliers in the LQ data, as assessed by inspection of a boxplot (non-dominant cycles). Thus, a Mann-Whitney U test was used. Based on Shapiro-Wilk test, all of the FEP results were normally distributed for both the control and pianist groups. There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance ($p > .05$). All FEP score distributions for musicians and controls were similar, as assessed by visual inspection.

3.3.3 Piano scales (musicians only)

To determine which musicians performed best, piano scale errors were used as a parameter to rank pianists within the musician group. Errors included substitutions, deletions, additions, hesitations (of 1 beat or more). Therefore, the lower the number of errors, the higher the ranking. See Table 13 for results.

The average ranking for musicians with RCM level 10 to university level piano performance ($n = 10$) was 6.5 which was higher than musicians with RCM levels 8-9 ($n = 6$), who ranked 8.3 on average. A high number of errors were observed in certain pianists. Most notably MUS2101, MUS2107, MUS2108 and MUS2115 committed ten or more errors at certain tempi. For MUS2101, their highest level of piano performance was RCM level 10 though their current specialization was a non-music degree. They were currently still regularly playing piano, though at a low frequency of training of about one hour per week.

For MUS2107, their highest level of piano performance was RCM level 8 though their current specialization was a non-music degree. They were no longer regularly playing piano, practicing about half an hour per week. For MUS2108, their highest level of piano performance was RCM level 10 though their current specialization was in music pedagogy. They were no longer regularly playing piano. For MUS2115, their highest level of piano performance was RCM level 8 though their current specialization was a non-music degree. They were currently still regularly playing piano, though at a lower frequency of training at about 1.5 hours per week.

Table 13

Number of errors and ranking for each participant in the musician group playing a C major scale (four octaves, 16th notes) hands together at three different tempi (♩ = 88, 104 and 120 BPM)

Participant	Tempo 1		Tempo 2		Tempo 3		Average	
	No. of errors	Rank	No. of errors	Rank	No. of errors	Rank	No. of errors	Rank
MUS2101	4	12	5	12	17	15	8.7	13
MUS2102	5	14	0	1	0	1	1.7	5.3
MUS2103	0	1	0	1	0	1	0.0	1
MUS2104	0	1	1	6	0	1	0.3	2.7
MUS2105	0	1	2	8	2	8	1.3	5.7
MUS2106	5	14	3	9	5	10	4.3	11
MUS2107	2	11	10	15	9	13	7.0	13
MUS2108	0	1	17	16	7	12	8.0	9.7
MUS2110	1	8	0	1	1	7	0.7	5.3
MUS2113	0	1	0	1	0	1	0.0	1
MUS2115	8	16	9	14	12	14	9.7	14.7
MUS2116	4	12	4	10	4	9	4.0	10.3
MUS2117	1	8	4	10	6	11	3.7	9.7
MUS2118	0	1	0	1	0	1	0.0	1
MUS2119	1	8	1	6	0	1	0.7	5
MUS2120 [a]	0	1	5	12	-	-	2.5	6.5

[a] - Missing data for tempo 3 due to technical error

The top quartile of the musician group included four pianists: MUS2103 (1), MUS2104 (2.7), MUS2113 (1) and MUS2118 (1). Note that MUS2120 was excluded because of missing data for tempo 3 due to a technical error. For MUS2103, their highest level of piano performance was CEGEP level piano performance though their current specialization was a non-music degree. They were currently still regularly playing piano, though at a low frequency of training of about one hour per week. For MUS2104, their highest level of piano performance was ARCT level though their current specialization was a non-music degree. They were currently still regularly playing piano at about eleven hours per week. For MUS2113, their highest level of piano performance was RCM level 10 though their current specialization was music pedagogy. They were no longer regularly playing piano practicing about 1.5 hours per week. For MUS2118, their highest level of piano performance was RCM level 8 though their current specialization was a non-music degree. They were currently still regularly playing piano, though at a low frequency of training of about one hour per week.

3.4 Research Question Three: Correlations between abilities and laparoscopic performance

This section reports on correlations between non-motor and motor abilities and laparoscopic performance; pianist ranking and laparoscopic performance; and demographic characteristics and laparoscopic performance. Given few significant differences between musician and control groups, few comparisons were made between abilities and laparoscopic performance. There were no significant differences between musicians and controls in laparoscopic performance, except accuracy in the BP task (non-dominant hand). The musician group performed with significantly greater accuracy compared to the control group (up until session 3 only). The baseline score (day 1) and performance plateau (day 5) were key time points considered. This section is divided into three parts: non-motor and motor abilities, pianist ranking and potentially confounding variables. The latter of which considers comparison analyses between categories rather than continuous variables.

3.4.1 Procedural abilities

To investigate whether there were any associations between procedural abilities and laparoscopic performance (specifically on the BP task, non-dominant hand only), correlational analyses were conducted. Since the data did not meet the requirements for the Pearson's product-moment (linearity; no significant outliers; normal distribution), the Spearman's rank-order correlation was used. Most correlations between psychometric assessments and laparoscopic performance were non-significant. However, there were statistically significant correlations between baseline laparoscopic performance (BP task non-dominant hand) and musician LQ on grooved pegboard ($r = .56$, $p = .020$), control insertion time non-dominant hand ($r = .58$, $p = .036$), and control chopstick number of beads transferred with dominant hand ($r = -.64$, $p = .020$). Additionally, there were statistically significant correlations between plateau laparoscopic performance and musician DFT dominant hand ($r = .56$, $p = .021$) and control DFT LQ ($r = -.57$, $p = .043$). The quality of the data will be commented on in this section. See Table 14 for detailed summary.

The data for each correlation was assessed for linearity and outliers based on visual inspection of a scatter plot for each participant group at both the baseline and plateau timepoints. The data was also previously assessed for outliers and normality in Sections 3.3.1 and 3.3.2 for cognitive tests and psychomotor tests, respectively.

For the MRT, the musician and control data were monotonic (but non-linear) with a few outliers at both timepoints. The MRT variable was not normally distributed. For the Paper folding test and PicSOr, the musician and control data were monotonic (but non-linear) with a few outliers at both timepoints. Both the Paper folding test and PicSOr variables were normally distributed. For the TMT, the musician and control data were somewhat linear with one outlier at each timepoint. Not all TMT variables were normally distributed.

Table 14

Results of Spearman's Correlation between psychometric tests and accuracy of laparoscopic performance on the BP task (non-dominant hand)

Psychometric Tests		*Item*	*Baseline Score*				*Performance Plateau*			
			MUS (N=17)		*CON (N=13)*		*MUS (N=17)*		*CON (N=13)*	
			r value	*p value*	*r value*	*p value*	*r value*	*p value*	*r value*	*p value*
Non-motor Abilities										
MRT			0.072	0.783	0.046	0.880	0.064	0.807	-0.285	0.346
Paper folding			-0.274	0.288	-0.108	0.724	-0.005	0.984	-0.191	0.533
TMT		Test A	-0.228	0.378	-0.362	0.225	-0.389	0.123	0.539	0.058
		Test B	0.346	0.174	-0.389	0.189	0.199	0.445	0.507	0.077
PicSOr		r value	-0.072	0.783	0.236	0.438	-0.062	0.812	0.122	0.692
		Time (min)	0.145	0.578	-0.095	0.757	-0.021	0.937	-0.366	0.219
Motor Abilities										
Grooved Pegboard	Insertion time	D	-0.198	0.446	0.096	0.756	-0.196	0.452	0.233	0.443
		ND	0.232	0.369	**0.584**	**0.036***	-0.020	0.941	0.131	0.669
		LQ	0.423	0.091	0.255	0.400	0.256	0.321	-0.128	0.678
	Removal time	D	-0.116	0.658	0.211	0.489	-0.327	0.201	0.268	0.377
		ND	0.050	0.849	0.098	0.749	-0.132	0.614	0.017	0.955
		LQ	**0.558**	**0.020***	-0.006	0.985	-0.081	0.756	-0.173	0.572
Purdue Pegboard	No. pins inserted	D	-0.181	0.487	-0.547	0.053	0.078	0.766	-0.275	0.363
		ND	-0.097	0.712	-0.256	0.398	-0.038	0.885	-0.150	0.625
		LQ	-0.044	0.867	-0.138	0.653	-0.283	0.271	-0.470	0.105
		HT	0.051	0.847	-0.159	0.605	0.432	0.084	-0.314	0.295
TAP	No. of taps	D	0.114	0.663	-0.179	0.559	0.004	0.988	0.377	0.204
		ND	0.012	0.962	-0.215	0.481	-0.035	0.895	0.488	0.091
		LQ	0.066	0.802	0.006	0.985	0.027	0.917	0.187	0.541
Chopsticks	No. Beads transferred	D	0.162	0.534	**-0.635**	**0.020***	0.189	0.468	-0.229	0.452
		ND	0.213	0.411	0.290	0.337	0.421	0.093	-0.190	0.534
		LQ	-0.026	0.921	-0.438	0.134	0.165	0.526	0.088	0.775
	Rice time	D	0.062	0.812	-0.065	0.834	0.281	0.274	-0.238	0.433
		ND	0.071	0.786	-0.203	0.505	0.172	0.51	-0.134	0.663
		LQ	0.030	0.910	-0.281	0.352	-0.078	0.766	0.119	0.698
DFT	No. of dots filled	D	0.181	0.487	-0.027	0.931	**0.556**	**0.021***	0.132	0.667
		ND	0.137	0.599	0.231	0.448	0.174	0.505	-0.163	0.594
		LQ	-0.016	0.951	0.250	0.411	0.077	0.770	**-0.567**	**0.043***

		D	0.276	0.284	-0.126	0.681	0.272	0.291	0.033	0.916
FEP	No. cycles	ND	0.327	0.200	0.040	0.898	0.147	0.574	0.249	0.412
		LQ	0.187	0.471	-0.406	0.169	0.018	0.947	-0.145	0.637

Note. Dominant hand (D); Non-dominant hand (ND); Laterality Quotient (LQ); Hands together (HT)

$* p < .05$

For the Grooved Pegboard, Purdue Pegboard, TAP, DFT and FEP tests, the musician and control data were relatively linear with a few outliers at both timepoints, except the LQ data which was non-linear with a few outliers. Not all psychomotor test variables were normally distributed, except FEP. For the Chopstick test, the musician data was monotonic and had no outliers at both timepoints. The musician LQ data was non-linear and had no outliers. The Chopstick control data was non-linear at baseline but was monotonic at plateau and had no outliers. The control LQ data was non-linear and had no outliers. Not all variables were normally distributed.

3.4.2 Pianist ranking

A Spearman's correlation was run to assess the relationship between the average ranking amongst pianists (n = 16) and the accuracy of the BP (non-dominant hand) at the baseline performance (session 1) as well as the performance plateau (session 5). The accuracy of laparoscopic BP task (non-dominant hand) was selected for correlation because it was the only laparoscopic task with a statistically significant difference between the musician and control groups. See Table 15 for a summary.

For correlation with the baseline score, preliminary analyses showed the relationship to be linear. There was no statistically significant correlation between the average ranking amongst pianists and the accuracy of the BP task (non-dominant hand) at the baseline performance (session 1), $r(16) = .058$, $p = .832$.

Table 15

Results of Spearman's Correlation between pianist ranking and accuracy of laparoscopic performance on the BP task (non-dominant hand)

MUS (N=16)	*Baseline Score*		*Performance Plateau*	
	r value	*p value*	*r value*	*p value*
Pianist Ranking	0.058	0.832	-0.085	0.753

For correlation with the plateau, preliminary analyses showed the relationship to be somewhat linear. There was no statistically significant correlation between the average ranking amongst pianists and the accuracy of the BP task (non-dominant hand) at the performance plateau (session 5), r(16) = -0.085, p = .753.

3.4.3 Potentially confounding variables

A comparison analysis was conducted for several potentially confounding variables on laparoscopic performance such as gender, knitting/sewing, video games, texting, chopstick experience and interest in pursuing surgery as a career. Since the data did not meet the requirements for the independent-samples t-test (no significant outliers; normal distribution; and homogeneity of variances), the Mann-Whitney U test was used. Baseline score represents performance on day 1 while the plateau represents performance on day 5. The quality of the data will be commented on in this section. See Tables 16-21 for a detailed summary of the results for each potentially confounding variable.

Table 16

Results of Mann-Whitney U test comparing the effect of gender on accuracy of the BP task (non-dominant hand)

Test	*Female*		*Male*				
	MUS	*CON*	*MUS*	*CON*	*U*	*z*	*p*

Baseline Score	2.5 (0-6)	4 (1-8)	3 (0-4)	6 (3-8)	137.5	0.436	0.671
Plateau performance	1.8 (0-4.3)	2 (0.3-4.3)	1.6 (1-4.7)	2.3 (0.3-2.3)	108	-0.679	0.518

Note. Data are median (range) values.

Regarding gender, the data was normally distributed (Shapiro-Wilk's test p > .05) at baseline and at the performance plateau. There were five outliers at the performance plateau.

Table 17

Results of Mann-Whitney U test comparing the effect of knitting/sewing experience on accuracy of the BP task (non-dominant hand)

Test	*Experienced* [a]		*Little to no experience*				
	MUS	*CON*	*MUS*	*CON*	*U*	*z*	*p*
Baseline Score	2.5 (1-4)	5 (3-8)	3 (0-6)	4 (1-8)	105	0.716	0.501
Plateau performance	2 (1-3.3)	1.6 (0.3-4.3)	2.2 (0-4.7)	2.3 (0.3-4.3)	70	-0.949	0.365

Note. Data are median (range) values.

[a] - participants regularly performed the activity for at least two years.

Regarding knitting/sewing experience, the data was normally distributed (Shapiro-Wilk's test p > .05) at baseline and at the performance plateau. There were no outliers at baseline, however there were two outliers at the plateau.

Table 18

Results of Mann-Whitney U test comparing the effect of video game experience on accuracy of the BP task (non-dominant hand)

Test	*Experienced* [a]		*Little to no experience*				
	MUS	*CON*	*MUS*	*CON*	*U*	*z*	*p*
Baseline Score	3 (0-5)	5.5 (3-8)	2 (0-6)	3.5 (1-8)	162.5	1.007	0.325
Plateau performance	1.8 (1-4.7)	1.8 (0.3-2.3)	1.7 (0-4.33)	2.5 (0.3-4.3)	112.5	-0.820	0.421

Note. Data are median (range) values.

[a] - participants regularly performed the activity for at least two years.

Regarding video game experience, the data was normally distributed (Shapiro-Wilk's test p > .05) at baseline and at the performance plateau. There were no outliers at baseline, but there was one outlier at the plateau.

Table 19

Results of Mann-Whitney U test comparing the effect of texting on accuracy of the BP task (non-dominant hand)

Test	*Frequent [a] texting*		*Infrequent or no texting*				
	MUS	*CON*	*MUS*	*CON*	*U*	*z*	*p*
Baseline Score	1 (0-4)	5 (2-8)	3 (0-6)	3.5 (1-8)	126	-0.149	0.899
Plateau performance	1.7 (1-2.7)	2.5 (0.3-4.3)	1.8 (0-4.7)	1.7 (0.3-2.3)	146.5	0.613	0.548

Note. Data are median (range) values.

[a] - participants regularly texted at least 50 times per day.

Regarding texting frequency, the data was normally distributed (Shapiro-Wilk's test p > .05) at baseline and at the performance plateau. There were no outliers at baseline, but there were two outliers at the plateau.

Table 20

Results of Mann-Whitney U test comparing the effect of chopstick proficiency on accuracy of the BP task (non-dominant hand)

Test	*Fully proficient*		*Competent or have difficulty with chopsticks*				
	MUS	*CON*	*MUS*	*CON*	*U*	*z*	*p*
Baseline Score	2.5 (0-5)	3 (2-7)	2.5 (0-4)	5 (1-8)	94	-1.283	0.216
Plateau performance	1.7 (1-3.3)	2.3 (1.7-2.7)	2 (0-4.7)	1.7 (0.3-4.3)	139	0.438	0.682

Note. Data are median (range) values.

Regarding chopstick proficiency, the data was normally distributed (Shapiro-Wilk's test $p > .05$) at baseline and at the performance plateau. There were two outliers, one at baseline and one at the plateau, respectively.

Table 21

Results of Mann-Whitney U test comparing the effect of interest in pursuing surgery on accuracy of the BP task (non-dominant hand)

Test	*Very interested*		*Somewhat or not at all interested*				
	MUS	*CON*	*MUS*	*CON*	*U*	*z*	*p*
Baseline Score	4 (1-6)	5 (3-8)	2.5 (0-4)	3 (1-8)	152.5	2.097	0.037*
Plateau performance	3.8 (2.7-4.7)	2 (0.3-4.3)	1.7 (1-3.3)	2.3 (0.3-4.3)	142.5	1.651	0.103

Note. Data are median (range) values.

* $p < .05$

Regarding interest in pursuing surgery as a career, the data was normally distributed (Shapiro-Wilk's test $p > .05$) at the performance plateau. There was a non-normal distribution at baseline. There were two outliers at baseline and one outlier at the plateau.

4. Discussion

This study compared the laparoscopic performance curves and procedural abilities between musician and control groups while addressing many shortcomings of previous research, such as short-term timelines and specifying musician characteristics. An analysis of the relationship between the performance curves and participant group was conducted, as well as an analysis of the cognitive and psychomotor abilities of both participant groups. In addition, correlational analyses were performed. These results will be interpreted and compared to the literature.

4.1 Research Question One: Laparoscopic Motor Skill Training

The first research question asked how expert musicians compared to controls in novel laparoscopic motor skill training for each task as determined by speed (as measured by time of task completion) and accuracy (as measured by least number of dropped beads or pegs) considering the rate of skill acquisition (Days 1-5) and skill retention (Day 6). To answer this question, laparoscopic task speed and accuracy will be considered separately.

4.1.1 Speed

We expected the musician group to perform better than the control group initially but that this effect would be transient. However, our results showed no statistically significant differences in speed between participant groups. There was also no interaction between time point and participant group. This suggests that there was no transfer of skills between piano performance and laparoscopy. Our results are consistent with the few other studies investigating the effect of music experience on laparoscopic surgery performance. Madan and colleagues (2005) found no association between musical instruments and laparoscopic surgery score. They inquired about some musical characteristics including which type of instrument and number of years' experience. Sodergren and colleagues (2013), found that musical training experience did not give any advantage to learning single-incision laparoscopic surgery. They did not inquire about musical instrument type nor level of musical performance. Therefore, perhaps these motor skills are specific to piano and surgical performance domains, respectively.

Our findings are contrary to previous research conducted by Boyd and colleagues (2008) which found that surgical novices with previous musical experience performed a laparoscopic suturing task significantly faster ($p < .001$) compared to non-musicians. In their study, they categorized musicians as either novice, intermediate or experienced. It is worth mentioning that both novice and experienced musicians performed laparoscopic suturing significantly faster ($p = .002$ and $< .001$ respectively). Interestingly, intermediate musicians showed no significant difference compared to controls ($p = .289$). However, Boyd and colleagues admit to not asking participants what musical instrument they played nor assessing their musical abilities. Furthermore, they only assessed three consecutive laparoscopic suturing tasks in a one-day long session, whereas our study had a longer timeline over the course of six days. In regard to the musician characteristics, our study was more robust as we inquired not only about musical instrument, but also frequency of practice, age of onset musical training, etc. and we assessed and ranked pianists. Therefore, through our study's robust design, our findings may be more reliable at indicating no transfer of motor skill from music to surgery.

Some may contest that the level of piano performance of the musician group in our study was not high enough to see any visible difference compared to the control group. This study aimed to recruit high level pianists; however, it was challenging to recruit participants who were willing to dedicate several hours to laparoscopic training. Thus, to optimize the sample size, we had to lower our inclusion criteria to include RCM level 8 and 9 pianists. While the level of piano performance may not have been at the professional or elite level, it is likely that this would not have made any difference to the results. Zeng and colleagues (2010) found that elite level musicians had no significant correlation with laparoscopic task performance. They did not inquire about musical instrument type, but they did inquire about level of performance (recreational, high school, college, professional, elite). Furthermore, music training was routinely thought to enhance cognitive abilities (Graziano et al., 1999; Catterall & Rauscher, 2007), but recent and more thorough empirical research goes against this popular belief (Sala & Gobet, 2020). Similarly, motor abilities may not be significantly enhanced in musicians, as evidenced by our study.

It was also brought to the author’s attention that there may be a lack of diversity amongst the pianist group. This study required classically trained pianists with relatively high levels of performance. However, in doing so, we may inadvertently have excluded other musicians such as jazz pianists or self-taught pianists of equal or higher proficiency in piano performance. One might expect jazz pianists to perform better at improvising compared to classically trained pianists who tend to focus more on structured sight-reading and memorized performances. Nevertheless, we would not expect a difference in motor skills between these sub-genres, although no specific research has been conducted on this topic with regards to transfer of motor skills.

With respect to the overall performance curve, there was a significant difference within both groups over the six days of training for all tasks, except for the CT task (see Figure 10). This indicates that both groups learned and improved their performance for most tasks over the course of the six days of training, as expected. The lack of significant improvement on the CT task was probably because it was too difficult for both groups to complete. After all, this task involved threading a curved suture needle through a small loop before using only the suture itself to transfer the cylinder, and then repeating this procedure three times. The perceptual, ambidexterity and bimanual coordination required to complete this task may require more time and practice to significantly improve. Moreover, it was observed that some participants preferred to thread the suture itself instead of the curved needle as this allowed for easier perception. However, the thread was less solid than the needle which led to other challenges during this task. Cognitive and visuospatial abilities are particularly involved in the initial learning rate of learning new motor skills

(Fitts & Posner, 1967; Fleishman, 1972; Fleishman & Rich, 1963; Spruit et al., 2014). The final stage of motor skill acquisition is reached when little to no cognition is involvement (Fitts & Posner, 1967; Logan, 1988; Ackerman, 2007; Spruit et al., 2014; Halsband & Lange, 2006). Therefore, many participants were probably stuck in the perceptual stages over the six days of training which we observed as no significant improvement in their performance curve over time.

With regard to the rate of skill acquisition, in the RB, BP (dominant hand) and CD (dominant hand) tasks, speed significantly improved from baseline until day 2 (see Figure 10). This indicates that the performance plateau was reached around day 2 for both participant groups and was maintained throughout days 3-5 as well as retained at day 6. Since the performance plateau was reached relatively quickly for these tasks, this suggests that they were relatively easy to learn and improve. In contrast, the BT (both hands), PT, BP (non-dominant hand) and CD (non-dominant hand) tasks, speed improved from baseline until day 3 which indicates that the plateau was reached around day 3 for both groups and maintained throughout days 4-5 and retained at day 6. The longer time required to reach this plateau suggests that these tasks were slightly more challenging. Particularly given the use of the non-dominant hand in the BP and CD tasks. The slower rate of skill acquisition regarding speed of the non-dominant hand compared to the dominant hand suggests that both groups had similar low ambidexterity ability. This was also confirmed by the Annett Questionnaire and psychomotor assessments. These results also support the notion that skills are non-transferable and specific to domains of expertise.

This section reports no evidence of musicians performing faster than controls in laparoscopic tasks over the course of six days of training, which suggests no far transfer from music to surgery.

4.1.2 Accuracy

We expected musicians to learn laparoscopic skills faster compared to controls as measured by accuracy (number of dropped beads or pegs) in all laparoscopic test sessions. However, similar to the previous section on speed of laparoscopic performance, the majority of laparoscopic tasks had no statistically significant differences in accuracy between the musician and control groups with the exception of a few tasks. There was no interaction between time point and participant group except for the BP task (non-dominant hand) and CD task (dominant hand), respectively. These results indicate that musicians performed better at a few time points during the training timeline of these two tasks, but that for the majority of tasks, there was no transfer of motor skills from piano performance to laparoscopic surgery.

For the BP task (non-dominant hand) the musician group was significantly more accurate only up until day 3 (See Table 8). This is somewhat consistent with the literature given that this quick rate of skill acquisition was expected to be short-lived, likely lasting up to a few days into training. In a study by Masud and colleagues (2012) the control group caught up to the musician group by day 5. Therefore, in our study this window of time was much shorter by three days. This could be due to the difference in surgery type since Masud and colleagues investigated suturing whereas our study concentrated on laparoscopy. Additionally, it could be due to the level of difficulty of the task itself where an increase in task difficulty results in more training time required to reach the performance plateau.

For the CD task (dominant hand), musicians performed with significantly greater accuracy only on day 4 (See Table 9). This may have been an anomaly seeing as it does not correspond with any of the literature (Harrington et al., 2018). The CD task does involve more perceptual abilities in order to visualize the small hole in the cup, compared to the other tasks, which may explain this discrepancy. This suggests that musicians transiently had better perceptual abilities which allowed them to increase their rate of skill acquisition as measured by a significantly lower number of beads dropped on day 4. It is worth noting however that all other time points showed no significant differences in performance between participant groups. A more likely explanation for this discrepancy is that with a p value of .05 some positive results will appear by random variation of the data. Given that we conducted many comparisons with the data in this study, we would expect to get some significance (about once every twenty comparisons). Therefore, these results ultimately suggest that there is little to no transfer of motor skills from piano to laparoscopic performance.

It is possible that perhaps the laparoscopic tests administered were not specific or sensitive enough to measure a difference. In particular optimization of cut off times, level of difficulty (CT task for example), more explicit instruction for participants and consideration of more spaced-out training sessions (on the scale of months or years). There was no difference in the instructions provided between the musician and control groups since we wanted to see if there was a difference in their performance based on their previous musical training experience. Nevertheless, the instructions could have been more explicit in explaining the evaluation criteria. There are several studies which include some form of training, whether by watching an instructional video or offered by a trained surgeon in-person (Moustaki et al., 2017; Harrington et al. 2018; Boyd et al., 2008; Comeau et al., 2020a). Though it is not clear as to whether these studies explicitly informed participants about what they are being evaluated on specifically. Our study introduced and oriented participants to the different features of the laparoscopic grasper and the TASKit training box as well as provided written and audio instructions for each task (see Appendix B for participant instructions). Given the relatively simple nature of the objective for each laparoscopic task, no video or instructor training was offered. Furthermore, it was observed that at later sessions around day 3 onwards, some participants requested that the instructions not be repeated to them given their understanding of the task.

Within both participant groups, there was a significant improvement in performance over the six training sessions, except the BT (both hands) and CD (non-dominant hand only) tasks (see Figure 11). This indicates that these tasks were particularly challenging in avoiding dropping beads. In the BT task this could be due to the perceptual challenge of the thick plastic walls of the containers which distorted visibility of the beads within. In the CD task this challenge could be in visualizing the small hole at the top of the cup and orienting the bead in the proper orientation to get it in. The perceptual challenges of the BT and CD (non-dominant hand) tasks may have caused participants to spend more time in the initial learning stages with few participants ever reaching the final stage of motor skill acquisition. Since cognitive and visuospatial abilities are particularly involved in the initial learning rate of learning new motor skills (Fitts & Posner, 1967; Fleishman, 1972; Fleishman & Rich, 1963; Spruit et al., 2014). Therefore, we observed no significant improvement in their performance curve over the six training sessions.

With regards to the rate of skill acquisition, in the RB task, accuracy significantly improved only between days 1-2 (see Figure 11). This indicates that the performance plateau was reached around day 2 for both participant groups and was maintained throughout days 3-5 as well as retained at day 6. The BP task (dominant hand), accuracy significantly improved from baseline by day 4. The non-dominant hand on the same take significantly improved by day 3. Initially this may seem counterintuitive, however it is likely that given the order of performance of the dominant hand performing the task first before switching to the non-dominant hand gives a slight advantage to the non-dominant hand. Partial near transfer of learning across unimanual movements have been previously reported (Nozaki et al., 2006). In the PT task, accuracy significantly improved from baseline only by day 6. This is the longest rate of learning which indicates that this task may have been challenging given the FMD, ambidexterity and bimanual coordination involved. In the BT (both hands), CD (both hands) and CT tasks, accuracy never improved significantly from baseline. This is consistent with these tasks being more challenging than the other laparoscopic tasks.

This section reports little to no evidence of musicians performing with more accuracy than controls in laparoscopic tasks over the course of six days of training, which suggests that these skills are specific to each respective domain of expertise. Speed and accuracy between days 5 and 6 was also well retained in both participant groups. This is supported by the literature given transiency of non-surgical advantages (Harrington et al. 2018). Overall, our results are important in showing no transfer of skills given our robust study design.

4.2 Research Question Two: Procedural Abilities

The second research question asked whether musicians possess greater procedural abilities (non-motor and motor abilities) compared to controls as measured by a battery of psychometric assessments. Specifically, motor abilities which include FMD, ambidexterity and hand-eye coordination; as well as non-motor abilities including VS and perceptual abilities. To answer this question, we will consider non-motor and motor abilities separately.

4.2.1 Non-motor abilities

We expected musicians to possess greater non-motor abilities compared to controls. However, there was no statistically significant difference on any of the cognitive tests. Similar to our first research question, this demonstrates that there is little to no transfer of non-motor skills. The musician group's pianistic skills did not show on the ability tests. Our results agree with some of the limited literature available on this topic. Pietsch & Jansen (2012) found that there was no significant difference in MRT scores in musicians compared to controls ($p = .062$). Similarly, Helmbold and colleagues (2005) found that there was no significant difference in MRT. This indicates no difference in VS ability. However, musicians in the Helmbold study demonstrated better flexibility of closure and perceptual speed compared to controls.

Our findings are contrary to some of the literature which suggests that musicians have greater VS and perceptual abilities. Brochard and colleagues (2004) tested VS abilities using a perceptual and mental imagery task and found that musicians had a significantly shorter reaction time compared to controls (p <

.01). However, their experiment utilizes a different psychometric test compared to those used in our study, thus direct comparisons are difficult to make.

Our study reports no significant differences in cognitive abilities in musicians compared to controls which suggests that pianist skills are specific to piano performance and do not result in increased procedural abilities.

4.2.2 Motor abilities

We expected musicians to possess greater motor abilities compared to controls. However, there was no statistically significant difference on any of the motor tests. This demonstrates that there is little to no transfer of skills. The pianist group's pianistic skills did not show on the ability tests. Our results agree with some of the limited literature available on this topic. McCoy (1970) found that there were no statistically significant differences between musicians and controls on the Purdue pegboard, among other psychometric tasks. This study had an impressive sample size of 100 musicians (wind, percussion, string or keyboard instrumentalists) and 100 controls for a total of 200 participants, though within the musician group there were only 17 pianists. Therefore, a larger musician sample size is probably needed to properly investigate motor abilities. Kopiez and colleagues (2010) found that there was no significant correlation between years of musical training experience on the TAP test score. Similarly, they found no correlation between age of onset music training and TAP test score.

Previous research in our lab by Comeau and colleagues (2020b) also found that there was no significant difference between musician and control group in their Grooved or Purdue pegboard performance. However, they did find that musicians performed the FEP test significantly better with the dominant ($p = .002$) and non-dominant ($p = .03$) hands, whereas we did not find any significant difference in our study. This discrepancy could be due to small sample size ($n = 30$) in our study compared to Comeau and colleagues (2020b) ($n = 40$); or that the FEP test was not sensitive enough to detect differences between musician and non-musician individuals. In their study they had similar ratios of self-reported right:left handedness between musician (19:1) and control (19:1) groups. Though a handedness questionnaire rather than self-reported handedness would ensure more accurate baseline participant characteristics.

Our findings are contrary to some of the literature which suggests that musicians have greater FMD (Kimoto et al., 2019), ambidexterity (Jäncke et al., 1997; Christman, 1993), and hand-eye coordination (Minetti et al., 2007). Kimoto and colleagues (2019) studied the neuromuscular and biomechanical functions in FMD. They found that pianists' fingers moved faster and more independently compared to controls. While this study did not utilize any of the same psychometric tests used in our study, they did administer a maximum finger tapping rate test which was similar to TAP except that they examined each of the finger in different directions. They found that pianists were significantly faster at flexion-extension tapping ($p < .001$). Jäncke and colleagues (1997) found that musicians were more ambidextrous than controls based on the TAP test. Christman (1993) found similar results through administering a handedness questionnaire and classifying musicians based on their major instrument. They found that musicians who played instruments requiring the use of both hands simultaneously (e.g., piano) had increased ambidexterity. However, these results have been contested by Kopiez and colleagues (2010) due to the higher number of left-handed musicians compared to controls in their sample.

Our results suggest that perhaps previous psychometric studies showing significant differences between musician and control groups were unreliable. Particularly regarding the TAP test, results in the literature have been mixed. It does seem that having a higher proportion of left-handed participants within the musician group may be skewing previous results, as highlighted by Kopiez and colleagues (2010). But this is not always the case, as seen in research by Comeau and colleagues (2020a and 2020b), though they never administered a handedness questionnaire. In recent years, more studies are scrutinizing previous research and showing that in some cases, previous research was not reliable. Since there are so few psychometric studies investigating musicians' abilities and characteristics in particular, few comparisons can be made. Nevertheless, our study contributes to the literature supporting no significant differences in abilities between musicians and controls. Furthermore, this confirms the laparoscopic results which showed that there was no transfer of motor skills from music to laparoscopic surgery.

4.3 Research Question Three: Correlations between abilities and laparoscopic performance

The third research question asked whether there were any correlations between procedural abilities and laparoscopic performance on days 1 and 5 respectively. Given few significant differences between musician and control groups, few comparisons were made between abilities and laparoscopic performance. There were no significant differences between musicians and controls in laparoscopic performance, except accuracy in the BP task (non-dominant hand). The musician group performed with significantly greater accuracy compared to the control group until day 3. Therefore, for the correlational analyses, only the BP task (non-dominant hand) was considered because it was the only instance of significant difference in baseline laparoscopic performance between participant groups. To answer this question, we will consider three separate parts: procedural abilities, pianist ranking and potentially confounding variables.

4.3.1 Procedural abilities

We expected increased procedural abilities to correlate with greater laparoscopic performance (Stefanidis et al., 2006; Kolozsvari et al., 2011; Westman et al., 2006). However, there was no significant difference between participant groups as measured by a battery of ten psychometric assessments (refer to research question two). There were no significant correlations between laparoscopic performance and the majority of the cognitive and motor abilities. Similar to accuracy of laparoscopic performance (research question one) from a statistical point of view, with a p value of .05 some significant results will appear by random variation of the data. Given that we conducted many comparisons with the data for correlational analyses, we would expect to get some significance (about once every twenty comparisons). Overall, our results demonstrate that there was no transfer of motor skills from piano performance to laparoscopic surgery.

Correlation analysis between the baseline laparoscopic performance and psychometric assessments revealed three instances of significance (see Table 14). There was a statistically significant large positive correlation between Grooved pegboard insertion time (non-dominant hand) and baseline laparoscopic performance (BP task non-dominant hand) in the control group, $r = 0.58$, $p = .036$. This indicates that Grooved pegboard insertion time (non-dominant hand) predicted accuracy of laparoscopic performance on the BP task (non-dominant hand). According to Table 12, the median grooved pegboard insertion times were 62.7 sec and 68 sec for musician and control groups, respectively. A lower insertion time indicates better FMD and ambidexterity given the isolated use of the non-dominant hand only. Similarly, there was a statistically significant large positive correlation between Grooved pegboard LQ removal time and baseline laparoscopic performance (BP task non-dominant hand) in the musician group, $r = 0.56$, $p = .020$. This indicates that ambidexterity may have also given musicians an advantage on their baseline laparoscopic performance. According to Table 12, the median grooved pegboard LQ removal times were 0 and 0.02 for musician and control groups, respectively. A lower LQ represents similar performance between left and right hand and thus greater ambidexterity. In parallel, the marginal means of number of beads dropped were significantly different with the musician group dropping fewer beads than the control group. Although there was no significant difference between participant groups in the grooved pegboard scores, there was a significant difference in baseline accuracy of laparoscopic performance which utilizes similar skills. Stefanidis and colleagues (2006) also found that the grooved pegboard score correlated with better FMD and laparoscopic training. However, their study did not specify which exact element of the Grooved pegboard scoring was utilized (i.e., insertion time, removal time or laterality quotient).

The third and final significant correlation between baseline laparoscopic performance and psychometric assessments involved the chopstick test. There was a statistically significant large negative correlation between the number of beads transferred using chopsticks (dominant hand only) and baseline laparoscopic performance (BP task non-dominant hand) in the control group, $r = -0.64$, $p = .020$. This indicates that the Chopstick test (bead transfer subtask) predicted accuracy of laparoscopic performance on BP task (non-dominant hand). According to Table 12, the median number of beads transferred using chopsticks were 21 and 17 for musician and control groups, respectively. A higher number of beads transferred indicates greater FMD. In parallel, the marginal means of number of beads dropped were significantly different with the musician group dropping fewer beads than the control group. Although there was no significant difference between participant groups on the chopstick test (both bead and rice subtasks), there was a significant difference in baseline accuracy of laparoscopic performance which utilizes similar skills. These results are consistent with the literature that chopstick proficiency leads to improved laparoscopic performance. Madan and colleagues (2005) found that chopstick proficiency correlated with significantly greater speed in laparoscopic placement of a piece of bowel in a retrieval bag and measuring a piece of bowel ($p < .04$). While their study suggests increased speed in laparoscopic performance, this was not observed in our study. Comeau and colleagues (2020a) also found that chopstick proficiency had a positive effect on speed and accuracy in a suturing setting. However, their results do not necessarily translate to laparoscopy. Interestingly, chopstick proficiency appears to be short-lived, similar to other studies (Glaser et al., 2005; Comeau et al., 2020a).

With regards to the laparoscopic performance plateau, correlational analysis with psychometric assessments revealed two instances of significance (see Table 14). There was a statistically significant large positive correlation between DFT (dominant hand) and the laparoscopic performance plateau (BP task non-dominant hand) in the musician group, r = 0.56, p = .021. This indicates that as the number of dots filled with their dominant hand decreased, there was a decrease in the number of beads dropped in laparoscopic performance on the BP task (non-dominant hand). Thus, greater accuracy of laparoscopic performance. This is counterintuitive, since the DFT assesses ambidexterity and hand-eye coordination where one would expect an increase in number of dots filled should correlate with an increase in accuracy. A similar discrepancy was noted by the statistically significant large negative correlation between DFT LQ and the laparoscopic performance plateau (BP task non-dominant hand) in the control group, r = -0.57, p = .043. This indicates that as the LQ decreased, there was an increase in the number of beads dropped in laparoscopic performance on BP task (non-dominant hand). This means that greater ambidexterity leads to lower accuracy on laparoscopic performance. Again, this is counterintuitive, since the LQ assesses ambidexterity where one would expect a decrease in LQ should correlate with an increase in accuracy. While these results at the performance plateau may seem surprising at first, they are likely due to our small sample size – it was smallest for the control group (n = 13) – for psychometric assessments. This serves as an example as to why sample sizes are important to discern the proper results with more statistical power. Additionally, with a *p* value of .05 some significant results will appear by random variation of the data, especially with many comparisons conducted with the correlational data. Furthermore, there was no significant difference in accuracy between musicians and controls at day 3 onwards, which indicates any advantage the musician group had on their particular task was short-lived. This evidence also suggests that psychomotor tests may only be effective at baseline laparoscopic performance (if at all). Once a new skill is learned and rehearsed, perhaps abilities do not have much of an effect on performance. Glaser and colleagues (2005) found that previous experience (i.e., music or video games) was short-lived when learning and acquiring skills on a simulator for sinus surgery. For this reason, our study is important because it had a longer timeline spanning two weeks to assess the effects of baseline procedural abilities.

Overall, our findings agree with the literature in some areas but disagree in others. Hughes and colleagues (2014) similarly found no correlation between musicians' suturing score and FMD score as assessed by Purdue Pegboard. They did find, however, that the FMD had a positive moderate correlation with suturing score $r = .34$, $p = .007$. This could be due to a different type of surgical technique (suturing as opposed to laparoscopy). A research study conducted in Toronto by Garbens and colleagues (2019) found no differences in PicSOr performance between high performing and low performing medical students. Similarly, in Louridas' thesis (2016), she found that there was no significance with PicSOr. The lack of any correlation between PicSOr and initial laparoscopic performance also disagrees with previous studies highlighting the predictive capacity of perceptual abilities as measured by PicSOr (Kolozsvari et al., 2011; Westman et al., 2006). However, in Kolozsvari and colleagues' (2011) study, PicSOr correlated with the baseline laparoscopic performance score, though the majority of the cognitive tests they administered did not correlate with baseline performance score. Also, they admitted failing to address participants' experience playing a musical instrument in their study. Similarly, Westman and colleagues (2006) found that there were strong positive correlations between PicSOr score and performance on difficult endoscopic surgery tasks (colonoscopy), $r = .60$, $p = .05$. However, their participant group consisted of a small group of expert endoscopic surgeons ($n = 11$), thus their perceptual abilities have likely been well trained on specific endoscopic surgery tasks.

Our study results are important because they show little to no correlations between procedural abilities and baseline laparoscopic performance in both musician and control groups with no prior experience performing laparoscopic techniques. Of course, correlation alone does not equate to causation.

Nevertheless, our results are significant because they indicate that there is no transfer between domains of expertise and that piano and surgical skills are predominantly specific to their own respective domains.

4.3.2 Pianist ranking

We expected pianists who ranked higher, as determined by committing fewer errors on the scales test, would perform with greater accuracy in the laparoscopic tasks. However, there was no significant correlation between pianist rank and accuracy of laparoscopic performance. Few laparoscopic studies ask musicians to perform a test such as the scales test included in our study. The majority of previous studies only inquired about participants' level of piano performance without ever directly assessing it through piano tests. For example, Boyd and colleagues (2008) categorized musicians as either novice, intermediate or experienced through a survey response alone. Similarly, Harrington and colleagues (2018) categorized musicians as either currently playing or performing with distinction on a musical instrument based on an electronic questionnaire. Sodergren and colleagues (2013) merely labelled certain participants as musicians without documenting their major instrument or level of musical performance. Therefore, our study is more robust and reliable in comparison because we evaluated the musicians' abilities through the piano test. This helps confirm that there is likely no transfer of motor skills from piano performance and laparoscopic surgery.

4.3.3 Potentially confounding variables

The demographics were largely similar between both participant groups which was ideal for comparison between groups. But we also wanted to consider the effect of several potentially confounding variables. This included gender, knitting/sewing, video games, texting, chopstick proficiency and interest in pursuing surgery. Overall, there were no significant effects of any of the potentially confounding variables listed, except for one. There was a significant effect of interest in surgery on the baseline laparoscopic performance accuracy. However, contrary to popular belief, interest in surgery seemed to decrease accuracy in laparoscopic performance. This may suggest that interest in surgery is not predictive factor in surgical performance. A large proportion of musicians were not interested at all in pursuing a career in surgery (37%) and fewer musicians were very interested in surgery (21%). Whereas a large proportion of the control group was very interested in surgery (50%) and few were not interested at all (14%). This was likely related to the way we advertised for our study, since recruitment posters offered interested participants an opportunity to learn laparoscopic surgery. Our results then suggest that many of the controls were interested in learning surgical skills and therefore participated in this study. Perhaps the control groups' strong interest in surgery contributed to anxiety to perform well in the laparoscopic tasks. General performance anxiety may temporarily interfere with the motor skill acquisition process, thus resulting in decreased baseline performance. Heart rate data was collected but not included in this manuscript. Additionally, given the long-term timeline of this study and the university student population, which was the main demographic of our participants, fatigue was a potential limitation due to long sessions and at times sleep deprived, over-caffeinated and stressed students.

The significant negative effect of interest in surgery and baseline laparoscopic performance contrary to the literature. A previous study by Kolozsvari and colleagues (2011) found that there was a significant positive relationship ($p = .02$) between high interest in a surgical career and starting score as well as learning rate. However, they found that there was no significant relationship between interest in surgery and plateau, which agrees with our results. In contrast, Hughes and colleagues (2014) found no significant correlation between interest in surgery and suture skill score ($p = .427$). They also found no significant correlation between interest in surgery and manual dexterity ($p = .096$). This could be due to Hughes and colleagues investigating a different form of surgical skills (i.e., suturing as opposed to laparoscopy).

The results pertaining to the other confounding variables agree with the literature in some areas but disagree in others. No significant effects of knitting/sewing, video games and texting agree with previous research by Comeau and colleagues (2020a). For knitting/sewing experience, note there was a small number of musicians (n = 4) and controls (n = 5) that actually had experience knitting/sewing for at least 2 years. This may have an effect on the results being insignificant. However, the lack of significant effects of gender or chopstick experience on laparoscopic performance are contrary to Comeau and colleagues (2020a) as well. Albeit their study investigated knot-tying and suturing and compared musician and control groups.

This section reports no effect of potentially confounding variables except for interest in surgery which had a negative effect on baseline laparoscopic performance. These results support previous findings that there is no transfer of motor skills from one domain of expertise to the surgical domain.

4.4 Limitations

The main limitation of our research was that we had a small sample size. In the context of investigating our first main research question, n = 33 was appropriate based on our previous power calculation (Section 2.1.1). However, regarding psychometric assessments in our second research question, few studies explicitly reported on the effect size. Of the few that reported it the effect size seemed to be small to moderate (Helmbold et al., 2005). Despite this small effect size, many studies continue to include small sample sizes ranging from 20-70 participants in total, whereas a more appropriate sample size would be on the level of hundreds of participants. Further recruitment on this front is recommended and would help improve the quality of the psychometric results.

This study was also done under the limitations of the COVID-19 pandemic. The lockdown measures in Ottawa, Canada took effect March 2020 – seven months into the recruitment process of this two-year master’s thesis. A safe research plan for in-person data collection during COVID was later developed in accordance with Ottawa Public Health measures and the University of Ottawa Research Ethics Board. However, participants were not interested in attending laparoscopic training during the pandemic, especially given the many consecutive in-person sessions. Despite our best efforts, the coronavirus pandemic severely limited our ability to recruit more participants.

4.5 Conclusion

This study aimed to address many shortcomings of previous research, such as short-term timelines and specifying musician characteristics. We compared the laparoscopic performance curves and procedural abilities between musician and control groups over a few weeks, and results showed that overall, there was no transfer of motor skills from piano performance to laparoscopic surgery. In many instances, these findings were contrary to several previous studies as well as popular belief that musical training provided an advantage in learning surgical skills. This may surprise readers who defer to previous studies without thinking critically about how the research was conducted. To make better informed decisions, more robust empirical research investigating musicians' motor skills should be conducted. As we saw in the review of literature, the existing body of research is limited. Longer term timelines in motor skill research should be considered, since there is growing evidence suggesting that any effects are short-lived. Finally, musicians' characteristics should be thoroughly documented otherwise it is difficult to make meaningful comparisons. Our study's robust design addressed these shortcomings and contributed to empirical research investigating musicians' motor skills.

The interdisciplinary context of piano performance and surgical domains allowed for investigation of the transfer of motor skills since both domains have well-established levels of performance and require complex fine motor skills. While quantifying musical and surgical skills are conceptually appealing, in practice they were very difficult to measure given the combination of various abilities required in each domain of expertise in addition to each participants' various experiences (i.e., music or other). The surgical community might be better off developing more portable ways to simulate surgical training to allow their trainees to practice specific surgical skills outside of the operating room such as virtual reality simulators.

Of course, playing a musical instrument or any other hobbies that involve fine motor skills would likely not do any harm. However, to expect a musician to perform surgery better than a non-musician may be asking too much. Future research could expand to other surgical tasks or techniques such as robotic surgery or remote surgery; as well as other musicians such as violinists or oboists. Further research is required to confirm our finding that there is no transfer of motor skills from one domain of expertise to another. More concrete next steps include: (a) addressing specifically how individuals are being trained in surgery, since this study featured audio recording and written instructions with no feedback; (b) comparing unvaried versus varied tasks, since this study featured identical tasks at each session thus perhaps changing the skills everyday (i.e., cups are in a different places) might show if musicians are better able to adapt; (c) measuring and comparing the magnitude of change in speed of laparoscopic performance as an absolute or as a percentage improvement since participants inherently start at different levels of performance when acquiring a new motor skill.

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Appendix A: Recruitment Materials

uOttawa

Labo PIANO

From Music to Medicine

Calling pianists, violinists and non-musicians to come partake in an exciting new study! Test your fine motor skills through the use of laparoscopic surgery equipment and other medical training tools. Participation involves learning performing motor skill tasks over six research sessions.

Location: Room 204, Perez Hall

Contact us at for more information

This project has been reviewed and has received ethics clearance by the University of Ottawa. If you have any questions regarding the ethical conduct of this study contact the Protocol Officer for Ethics in Research. University of Ottawa, Tabaret Hall, 550 Cumberland St, Room 154, Ottawa, ON K1N 6N5. Tel: 613-562-5318. email: ethics@uottawa.ca

From Music to Medicine

Pianists, Violinists & Non-musician Participants Wanted

Participate in a fascinating investigation into transfer of motor skills from music to medicine!

Participation involves learning and performing some motor skill tasks over six research sessions

Location: Room 204, Perez Hall

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LETTER OF INFORMATION and CONSENT FORM

Title of the study: Transfer of skills: from music medicine

Principal Investigator: Professor Gilles Comeau
Director of the Piano Pedagogy Research Laboratory
School of Music
University of Ottawa

Co-Investigators:

Dr. Kuan-chin Jean Chen
Faculty of Medicine
University of Ottawa

Dr. Fady Balaa
Faculty of Medicine
University of Ottawa

Invitation to Participate: You are invited to participate in the abovementioned research study conducted by Drs. Gilles Comeau, Jean Chen, and Fady Balaa. We are conducting research to further our understanding of transferable motor skills from one activity to another. In particular, we will explore if pianists and violinists have any advantage in developing surgical skills. We are recruiting participants to learn how to do laparoscopic and other tasks, practice the tasks over a 5 day period and finally perform them again one week later.

Purpose of the Study: The objective of this study is to determine if participants with proficiency in piano/violin playing show any advantage in the rapidity of acquiring suturing skills and the quality of performing the skills.

Participation: Participants must:

- Be of age 18 to 28.
- Be fluent in English (the training is only available in English).

Pianist/violinist participants must:

- Have achieved grade 9 RCM (or equivalent) or are studying piano or violin performance at a University level.

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Participation (continued):

Non-musician participants must:

- Not currently play a musical instrument.
- Either have never played a musical instrument in the past, or if they have:
    - past experience is minimal (i.e., participant could have played in a school band, but never had private music lessons).
    - The instrument played must not be violin or piano.

Participants will be required to attend five sessions on consecutive days, followed by one more session the following week. The sessions will include the following:

- Cognitive tests (paper and pencil)
- Fine motor skill tests (peg boards)
- Laparoscopic training box tests
- Piano or violin playing task (musician group only, no preparation necessary)

The tests will be video recorded for post-test evaluation.

Benefits:

This study will contribute to the understanding of fine motor skill acquisition and the transfer of those skills from one domain to another. Understanding if specificity of training environment can be substituted with practice of unrelated fine motor skills would have beneficial applications to resource allocation and teaching approaches.

Risks:

There is minimal risk for participants in the research. They may feel mild discomfort in the form of slight anxiety and/or nauseousness due to performing suturing on synthetic skin tissues. If so, participants are free to take a break or cease the activity if necessary.

Confidentiality and anonymity:

All participant information and data collected in this study will remain strictly anonymous and confidential and are used for research purposes only. Only the primary researcher, Dr. Gilles Comeau and authorized research members at the Piano Pedagogy Research Laboratory will have access to this data. Participants will only be identified through alphanumerical codes that will be used in place of names during analysis and publication. Video recordings will only be associated with the alphanumerical identification of the participant and will be securely stored. Videos will be watched by the researchers for the purposes of

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	evaluating the suturing skill level. All collected data will be kept on secure computers under password protection inside the Piano Pedagogy Research Laboratory, which is locked and armed with security alarms when unoccupied. Access to all computers is strictly monitored by lab administration.
Conservation of data:	All audio and video data will be destroyed five years after the completion of this study.
Compensation:	Participation in this study is strictly on a voluntary basis. Participants will not receive any form of compensation for participating in this study.
Voluntary participation:	Participation in this study is strictly voluntary and p*articipants have the right to refuse to answer any questions or continue the sessions without fear of reprisal or ill treatment*. Participants can choose to withdraw from the study at any time while the experimental sessions are being conducted. After the testing session, participants will not be able to withdraw from the study since it will not be possible to identify the data associated with them. Participants do not have to provide any reason or justification to withdraw.
Information about study results:	We would be pleased to share the results of this project with you. In order to receive a summary of the results, please contact the primary investigator, Gilles Comeau.
Funding:	This research project is possible thanks to a $5000 grant from the Faculty of Arts Support for Interdisciplinary Research Groups.

If you have any questions with regards to the ethical conduct of this study, you may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON, K1B 6N5. tel: 613-562-5387 or ethics@uottawa.ca.

If you have any questions or require more information about the study itself, you may contact the researcher or her supervisor. Please keep this form for your records.

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I, ____, confirm that I have read and understood the information presented in the consent form above, and acknowledge the risks of participation as they have been described. I understand that I am under no obligation to participate, and that I have the right to withdraw from the study at any point, for any reason. By signing this form I confirm that I meet the criteria for participation as described and that I participate at my own risk.

______________________________________ ________________________________
Signature of participant Date

______________________________________ ________________________________
Signature of researcher Date

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Between-session instructions agreement

For the entire duration of my participation:

1. I will not not watch any other instructional videos on the study tasks outside of the research sessions.
2. I will not practice the tasks that I have learned outside of these sessions (this includes mental practice as well as actual physical practice).

____________________________________ ______________________________

Signature of participant Date

Email transcripts

Hi **____**,

Thank you for your interest in our research! We are conducting a study examining motor skill acquisition, and the transfer of motor skill from one domain to another (in this case from music to medicine). The primary tasks in this study will be tests within a laparoscopic training box.

We are looking for participants from two groups: ***musicians (violinists and pianists)***, and ***controls (non-musicians)***. For the pianist/violinist group, participants must have minimum grade 9 RCM or are studying piano or violin performance at a University level. For the control group, participants must not currently play a musical instrument; if they've played in the past: not piano/violin, no private lessons (i.e., school band is ok). The age range we are accepting is 18 to 28 inclusive.

Participants will be asked to:

- Fill out a short questionnaire
- Perform (fun) tasks within a laparoscopic training box
- Some additional (fun) cognitive tasks (either paper-pencil, or on a computer)
- A short music-playing task on your instrument (*a scale at different tempi*)

Participants will attend sessions on **five consecutive days (Monday to Friday) followed by one follow-up session one week later (Thursday or Friday).** Each session will take approximately 45 minutes, with the exception of one of the sessions in which the additional cognitive tasks and musical tasks will be administered. Location is at the Piano Lab (Perez, room 204) at the University of Ottawa.

For more information, I've attached the letter of information.

If you're interested in participating, please send an e-mail to   to coordinate days/times. Or, you could register for all 6 sessions using the following link:
https://doodle.com/poll/hs2d9ph2md9qmt7g#calendar

- Enter your name
- Click the time slots that work for you (only one per day please. Only sessions starting on the hour are shown, if you prefer another time, please let me know via email).
- Submit
- **Please also email me to let me know you've completed the submission**

If you prefer, we could do the scheduling in person; just come to the piano lab to discuss.
The doodle calendar shows availability for the next month. If you're interested in participating, but at a later date, please let me know and I'll get back to you later about scheduling.

Registration will be for a one-hour timeframe although it may be shorter. We will coordinate additional time for cognitive tests for one of these sessions separately (not in the doodle) at a later date.

Your participation is most appreciated! Please also feel free to share this information with friends you think might be interested and/or eligible to participate!

Kind regards,
Valeria

Hi _____,

I am emailing you to schedule the remaining portions of this study which are the cognitive testing and the piano test. The cognitive testing lasts about an hour and will be done onsite at the piano lab. The piano test lasts about 5-10min.

<u>Requirements for piano</u>:
C major scale (4 octaves), hands together with a metronome at various increasing tempos (scales played in 16th notes):
Tempo 1: ♩ = 88 BPM
Tempo 2: ♩ = 104 BPM
Tempo 3: ♩ = 120 BPM

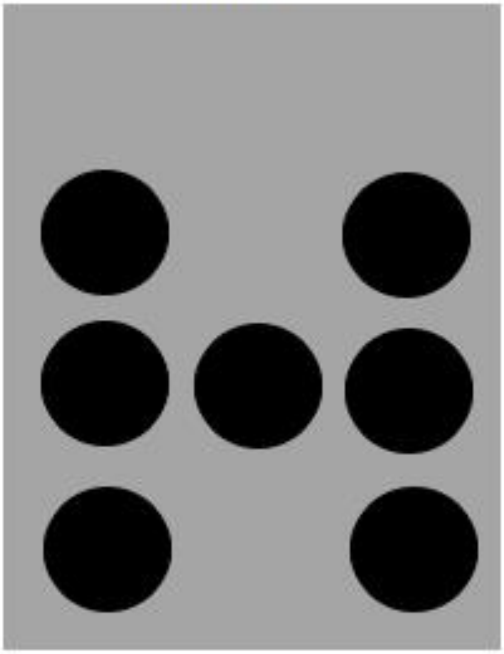
Please let me know when you might be available to come in to do these two remaining tests.

Many thanks,
Valeria

Appendix B: Participant Instructions for Laparoscopic Tasks

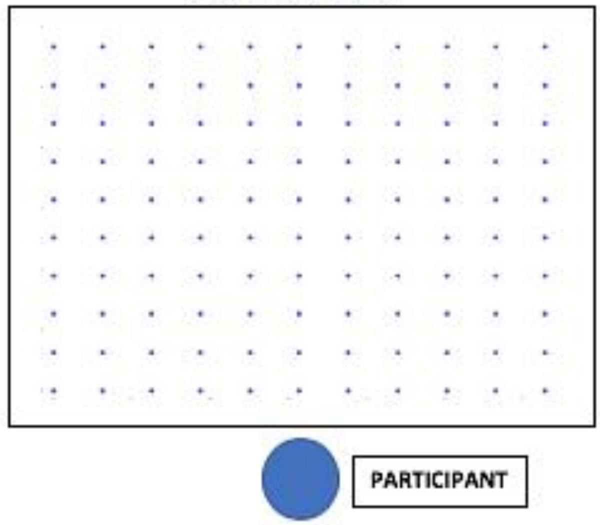
Basic Layout of Surgery Box

TOP VIEW

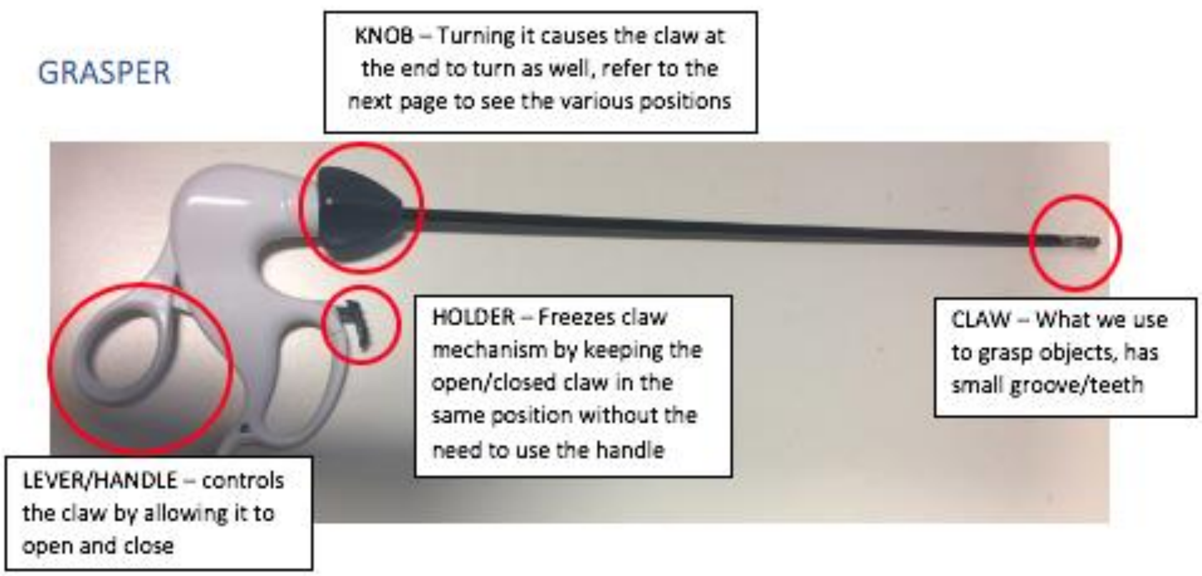


INSIDE BOX (CAMERA VIEW)

10 HOLES X 11 HOLES

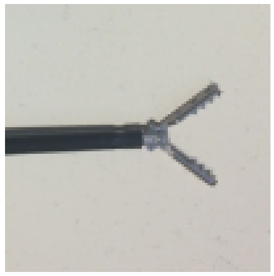


GRASPER



GRASPER POSITIONS

CLOSED – FLAT

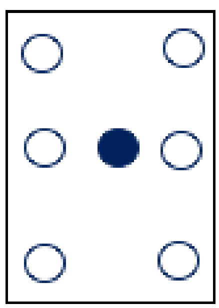


OPEN – FLAT

OPEN – ROTATED 90 degrees

A few things before we start:

1. All procedure steps will be read to you by the research assistant present as you follow along on your package.
2. The image present at the top right corner of every activity indicates which hole you must insert the grasper in.
    a. Example:

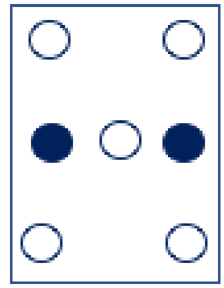


Here the hole colored in black indicates the hole you must use to complete the task

    b. Please be aware that the hole is chosen for you at the start of each task and you are not allowed to change this. The entire task must be complete from the hole that you started with initially.

3. Please be aware that to start and stop the time for each of the task you must wait for the researcher's signal and your grasper must be touching the red dot.
4. The tasks will specify whether both hands will be used (bi-manual task) or if only one hand will be used at a time. IF ONLY ONE HAND is used, please remember to place the idle hand behind you back.

ACTIVITY 1: RUBBER BAND TRANSFER



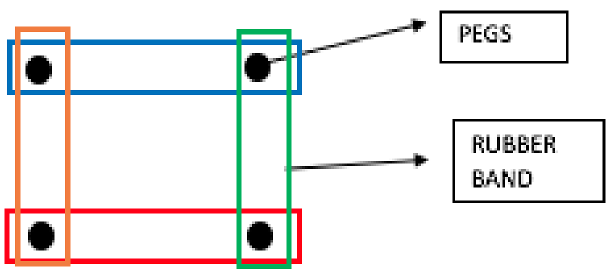
The objective of this task is to create a SQUARE with the provided rubber bands by pulling it over the pegs in the box. This task requires the use of **BOTH DOMINANT AND NON DOMINAT HAND TOGETHER.**

Be sure to await the researcher's signal regarding when you can start and stop.

The following steps is a breakdown of the activity you must carry out, in detail.

NOTE 1: If a rubber band snaps, move the band to the side and take another from the container.

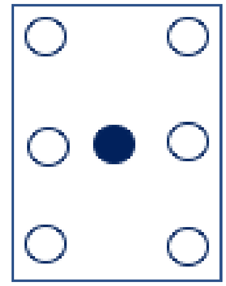
1. Take one grasper in each hand.
2. Insert the graspers, each into a separate hole, present on the box, as shown in the image on the top right corner.
3. Touch the red dot with one of the graspers. When the research signals you to start, you may remove your grasper from the dot and the time will start.
4. Pick up **ONE** rubber band within the container placed to the right.
5. With the use of both graspers move the rubber band over each peg to create a "side" of the desired square shape as shown below.
    a. A "side" is created when you place the rubber band over TWO pegs.
6. Repeat step 5, **Three** more times to complete the square shape. The order in which you place the rubber bands does not matter.



7. When the task is complete touch the red dot on the placemat inside the box to stop the time and remove the graspers from the box.

YOU HAVE COMPLETED THE TASK.

ACTIVITY 2: BEAD TRANSFER



The objective of this task is to move 5 beads to and from the containers in the box using your dominant and non-dominant hand. Both hands will be tested but **ONLY ONE** hand can be used at a time. The idle hand must be placed behind your back. Be sure to await the researcher's signal regarding when you can start and stop.

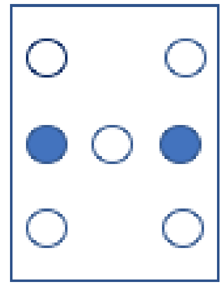
The following steps is a breakdown of the activity you must carry out, in detail. We will read through these steps carefully BEFORE YOU START THE TASK.

NOTE: If you drop any beads during the transfer and it is within camera view, you are allowed to pick it up and proceed with your task. If a bead rolls out of frame, go back to the starting container and pick up another bead of the same color. In conclusion you MUST transfer 5 beads to and from the containers.

1. Place grasper in **DOMINANT HAND.**
2. Insert the grasper into middle hole on the second row. Refer to image on the top right corner of the page.
3. Touch the red dot with one of the graspers. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
4. With your **DOMINANT** hand move **5 BLUE** beads, **ONE AT A TIME,** from the **LEFT** container to the **RIGHT** container.
5. When the task is complete touch the red dot on the placemat to stop the time.
6. Once the time is recorded by the researcher, touch the red dot with one of the graspers. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
7. With the **DOMINANT HAND** move the **5 BLUE** beads back from the **RIGHT** container to the **LEFT** container, **ONE AT A TIME.**
    a. IF you drop a blue bead which rolls out of camera view and you have no other blue beads left, you may use an orange bead in replacement. In the end, 5 beads MUST be moved.
8. When the task is complete touch the red dot on the placemat inside the box to stop the time and remove the grasper from the box.

9. Once time is recorded by the researcher you may switch graspers to your **NON-DOMINANT HAND.**
10. Insert grasper into the same hole mentioned in step 2. Refer to image on the top right corner.
11. Touch the red dot with one of the graspers. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
12. With your **NON-DOMINANT** hand move **5 ORANGE** beads **ONE AT A TIME** from the **RIGHT** container to the **LEFT** container.
13. When the task is complete touch the red dot again on the placemat inside the box to stop the time.
14. Once the time is recorded by the researcher, touch the red dot with one of the graspers. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
15. With the **NON-DOMINANT HAND** move the **5 ORANGE** beads back from the **LEFT** container to the **RIGHT** container, **ONE AT A TIME.**
    a. IF you drop an orange bead which rolls out of camera view and you have no other blue beads left, you may use an orange bead in replacement. In the end, 5 beads MUST be moved.
16. When the task is complete touch the red dot on the placemat inside the box to stop the time.

YOU HAVE COMPLETED THE TASK.



ACTIVITY 3: PEG GROOVE BOARD

The objective of this task is to place 3 metal pegs into the holes on the board in the box. This task requires the use of **BOTH DOMINANT AND NON DOMINAT HAND TOGETHER.**

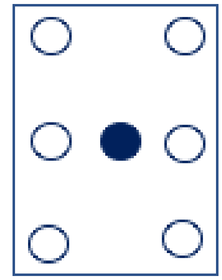
Be sure to await the researcher's signal regarding when you can start and stop.

The following steps is a breakdown of the activity you must carry out, in detail.

1. Take one grasper in each hand.
2. Insert the graspers, each into a separate hole, present on the box, as shown in the image on the top right corner of the page.
3. Touch the red dot with one of the graspers. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
4. Pick up one peg and place it in the groove on the board marked as 1. (First hole being the hole on the left corner of the board).
5. Repeat step 4 with two more pegs, placing each peg in the consecutive hole. This means that the second peg will go into the hole marked 2 and the third will go into the hole marked 3.
6. Once the task is complete, touch the red dot again to stop the timer and remove the graspers.

YOU HAVE COMPLETED THE TASK.

ACTIVITY 4: BEAD TO PEG TRANSFER



The objective of this task is to move 3 beads from the container to the pegs on either side, using your dominant and non-dominant hand. Both hands will be tested and **ONLY ONE** hand can be used at a time. The idle hand must be placed behind your back.

Be sure to await the researcher's signal regarding when you can start and stop.

The following steps is a breakdown of the activity you must carry out, in detail.

NOTE 1: If you drop any beads during the transfer and it is within camera view, you are allowed to pick it up and proceed with your task. If a bead rolls out of frame, go back to the starting container and pick up another bead. In conclusion you MUST transfer 3 beads to each peg.

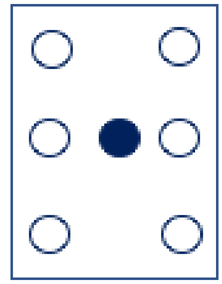
NOTE 2: You will **NOT** be required to remove any of the beads once they have been placed on the peg.

1. Place grasper in **DOMINANT HAND.**
2. Insert the grasper into middle hole on the second row. Refer to image on the top right corner.
3. Touch the red dot with the grasper. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
4. With your **DOMINANT** hand move **3 beads, ONE AT A TIME,** of any color, from the container to the **RIGHT** peg.
5. When the task is complete touch the red dot again on the placemat inside the box to stop the time.
6. Once the time is recorded by the researcher, touch the red dot on the placemat inside the box to start time again.
7. With the **DOMINANT HAND** move another set of **3 beads, ONE AT A TIME,** of any color, from the container to the **LEFT** peg.
8. When the task is complete touch the red dot on the placemat inside the box to stop the time and remove the grasper from the box.

9. Once time is recorded by the researcher you may switch graspers to your **NON-DOMINANT HAND.**
10. Insert grasper into the hole mentioned in step 2. Refer to the image on the top right corner.
11. Touch the red dot with the grasper. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
12. With your **NON-DOMINANT** hand move **3 beads, ONE AT A TIME,** of any color, from the container to the **RIGHT** peg.
13. When the task is complete touch the red dot again on the placemat inside the box to stop the time.
14. Once the time is recorded by the researcher, touch the red dot with one of the graspers. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
15. With the **NON-DOMINANT HAND** move another set of **3 beads, ONE AT A TIME,** of any color, from the container to the **LEFT** peg.
16. When the task is complete touch the red dot on the placemat inside the box to stop the time.

YOU HAVE COMPLETED THE TASK.

ACTIVITY 5: CUP DROP DRILL



The objective of this task is to move 6 beads from the containers to the bottle with a hole in it, using your dominant and non-dominant hand. Both hands will be tested but **ONLY ONE** hand can be used at a time. The idle hand must be placed behind your back.

Be sure to await the researcher's signal regarding when you can start and stop.

The following steps is a breakdown of the activity you must carry out, in detail.

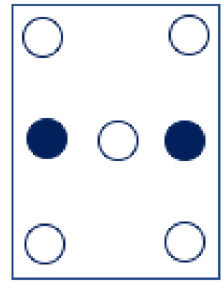
NOTE 1: If you drop any beads during the transfer and it is within camera view, you are allowed to pick it up and proceed with your task. If a bead rolls out of frame, go back to the starting container and pick up another bead of any color. In conclusion you MUST transfer 6 beads to the bottle.

1. Place grasper in **DOMINANT HAND.**
2. Insert the grasper into middle hole on the second row. Refer to image on the top right corner of this page.
3. Touch the red dot with the grasper. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
4. With your **DOMINANT** hand move **3 beads, ONE AT A TIME,** of any color, from the **LEFT** container to the **bottle**.
5. Once the task is done touch the red dot to stop the time.
6. Repeat step 4 except this time, move the beads from the **RIGHT** container.
7. When the task is completed touch the red dot on the placemat inside the box to stop the time and remove the grasper from the box.

8. Once time is recorded by the researcher you may switch graspers to your **NON-DOMINANT HAND**.
9. Insert the grasper into middle hole on the second row. Refer to image on the top right corner.
10. Touch the red dot with one of the graspers. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
11. With your **NON-DOMINANT** hand move **3 beads, ONE AT A TIME,** of any color, from the **LEFT** container to the **bottle**.
12. Once the task is done touch the red dot to stop the time.
13. Repeat step 10 except, this time, move the beads from the **RIGHT** container.
14. When the task is complete touch the red dot on the placemat inside the box to stop the time.

YOU HAVE COMPLETED THE TASK.

ACTIVITY 6: CYLINDER TRANSFER



The objective of this task is to move 3 cylinders using both hands from point A to B. This task requires the use of **BOTH DOMINANT AND NON DOMINAT HAND TOGETHER.**

Be sure to await the researcher's signal regarding when you can start and stop. The following steps is a breakdown of the activity you must carry out, in detail.

NOTE 1: You may only move ONE cylinder at a time from Point A to Point B.

NOTE 2: IF the cylinder drops, continue the task from where it fell. If the cylinder has fallen where the visibility of the loop is hidden you may use the grasper to nudge the cylinder around so that the loop is in view.

NOTE 3: The only way to move the cylinder from point A to point B is by threading the suture and needle through the metal loop and then picking up the suture and needle with either graspers.

NOTE 4: The suture in this case refers to the **purple string** attached to the needle. Be aware that one end of the material is a needle while the other end is the suture.

1. Take one grasper in each hand.
2. Insert the graspers, each into a separate hole, present on the box, as shown in the image on the top right corner of the page.
3. Touch the red dot with one of the graspers. When the researcher signals you to start, you may remove your grasper from the dot and the time will start.
4. Pick up the suture and needle.
5. Move **1 CYLINDER from** point A, into the **CIRCLE** (Point B) located on the top right corner. Move the cylinder by lifting it up with the suture, once you have threaded the needle and suture through the loop.
6. Repeat step 4 with the other 2 cylinders from Point A.
7. Once step 6 is done, you should have all 3 cylinders from Point A moved to Point B
8. Once the task is done, touch the red circle to stop the time and remove the grasper from the box.

YOU HAVE COMPLETED THE TASK

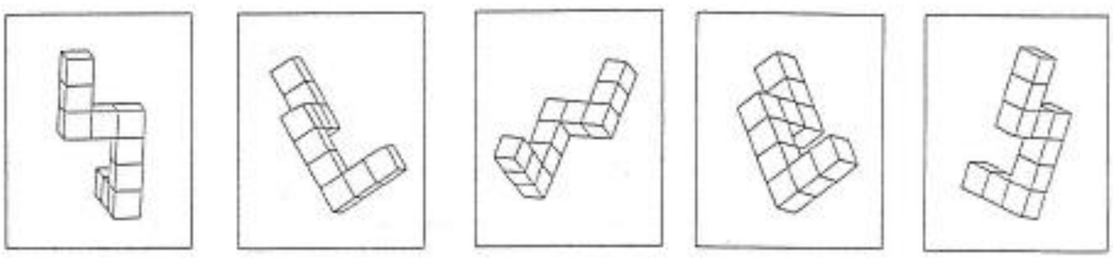
Appendix C: Participant Instructions for Ability Tests

1. Mental Rotation Test (MRT)

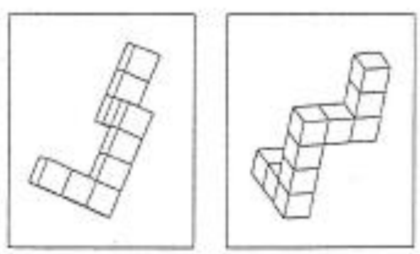
MENTAL ROTATIONS TEST 1

AUTOCAD drawings of Vandenberg & Kuse (1978)* items. Michael Peters, PhD, Dept. Psychology, University of Guelph, Guelph, ON, Canada N1G 2W1

Look at these five figures.



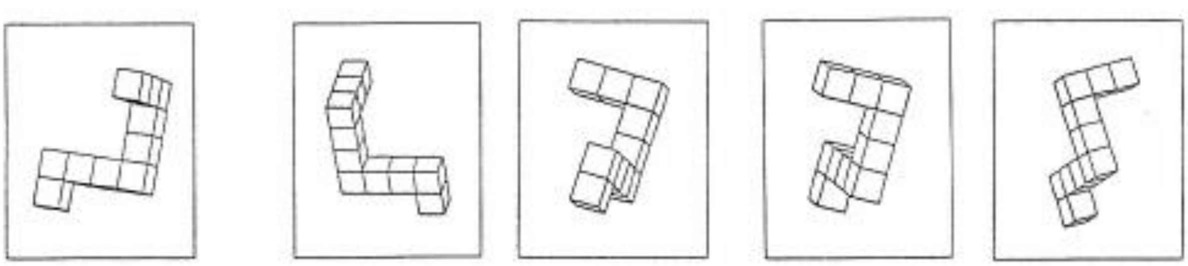
Note that these are all pictures of the same object which is shown from different angles. Try to imagine moving the object (or yourself with respect to the object), as you look from one drawing to the next.



Here are two drawings of a new figure that is different from the one shown in the first 5 drawings. Satisfy yourself that these two drawings show an object that is different and cannot be "rotated" to be identical with the object shown in the first five drawings.

Now look at this object:

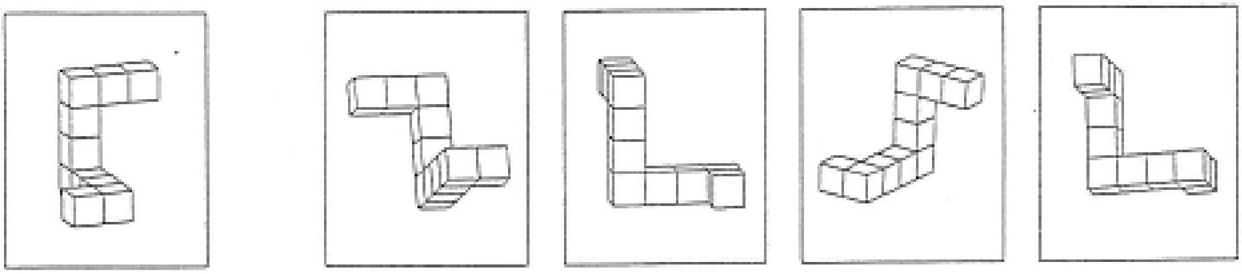
Two of these four drawings show the same object. Can you find those two ? Put X's in the lower right corner.

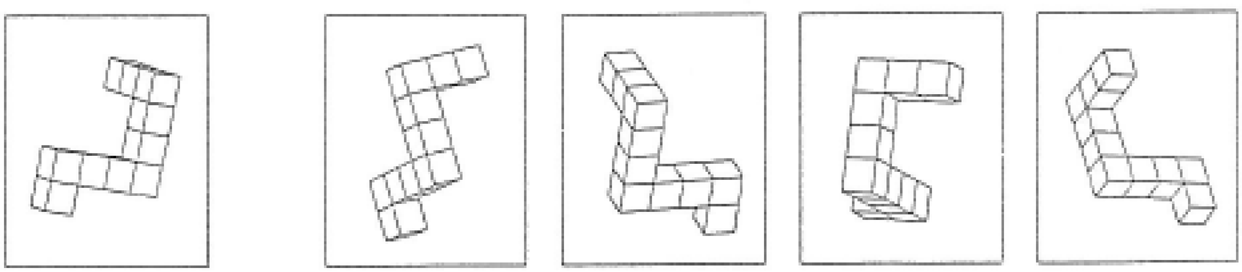


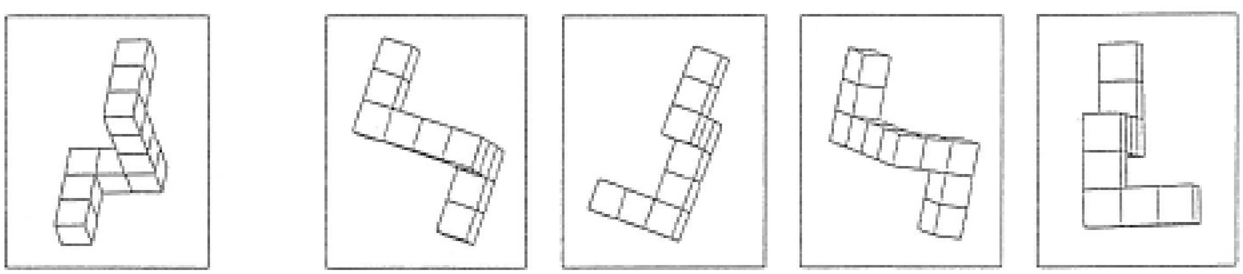
If you marked the first and the third drawings, you made the correct choice.

2

Here are three more problems. Again, the target object is shown twice in each set of four alternatives from which you choose the correct ones.







Correct choice for 1: second and third, for 2: first and fourth
3: first and third

When you do the test, please remember that for each problem set there are two and only two figures that match the target figure. What is your best strategy in doing the problems ? Because an incorrect choice is subtracted from a correct one, you are better off to check only one of the figures if you can be only sure of one. Of course, you will always try to get both of the figures that match.

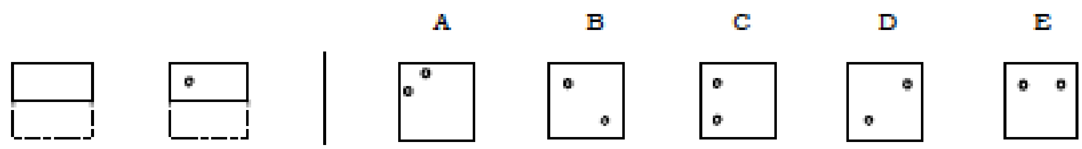
* S.G. Vandenberg of the University of Colorado selected this subset of figures from a larger set devised by Shepard and Metzler. Two versions of the mental rotations test exist: one with 20 problems and one with 24 problems; this is the latter one. Because the quality of available reproductions has deteriorated over the course of making copies of copies, we have redrawn the set of figures with help of the AUTOCAD drawing program (the AUTOCAD drawings were done by Diane Duncan, School of Engineering, U of Guelph). It was decided not to use the natural perspective option provided by the program because the perspective shown here seems to give the clearest representation of the problems.

2. Paper Folding

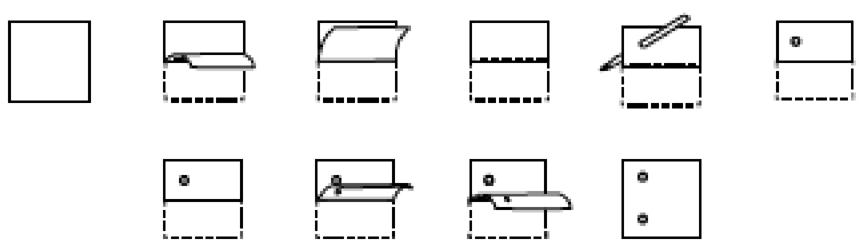
Paper Folding Test—Vz-2-BRACE

In this test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others drawn at the right of the line. The figures at the left represent a square piece of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures on the right of the vertical line shows where the holes will be when the paper is completely unfolded. You are to decide which one of these figures is correct and draw an X through that figure.

Now try the sample problem below. (In this problem only one hole was punched in the folded paper).



The correct answer to the sample problem above is C and so it should have been marked with an X. The figures below show how the paper was folded and why C is the correct answer.



In these problems all of the folds that are made are shown in the figures at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. Remember, the answer is the figure that shows the positions of the holes when the paper is completely unfolded.

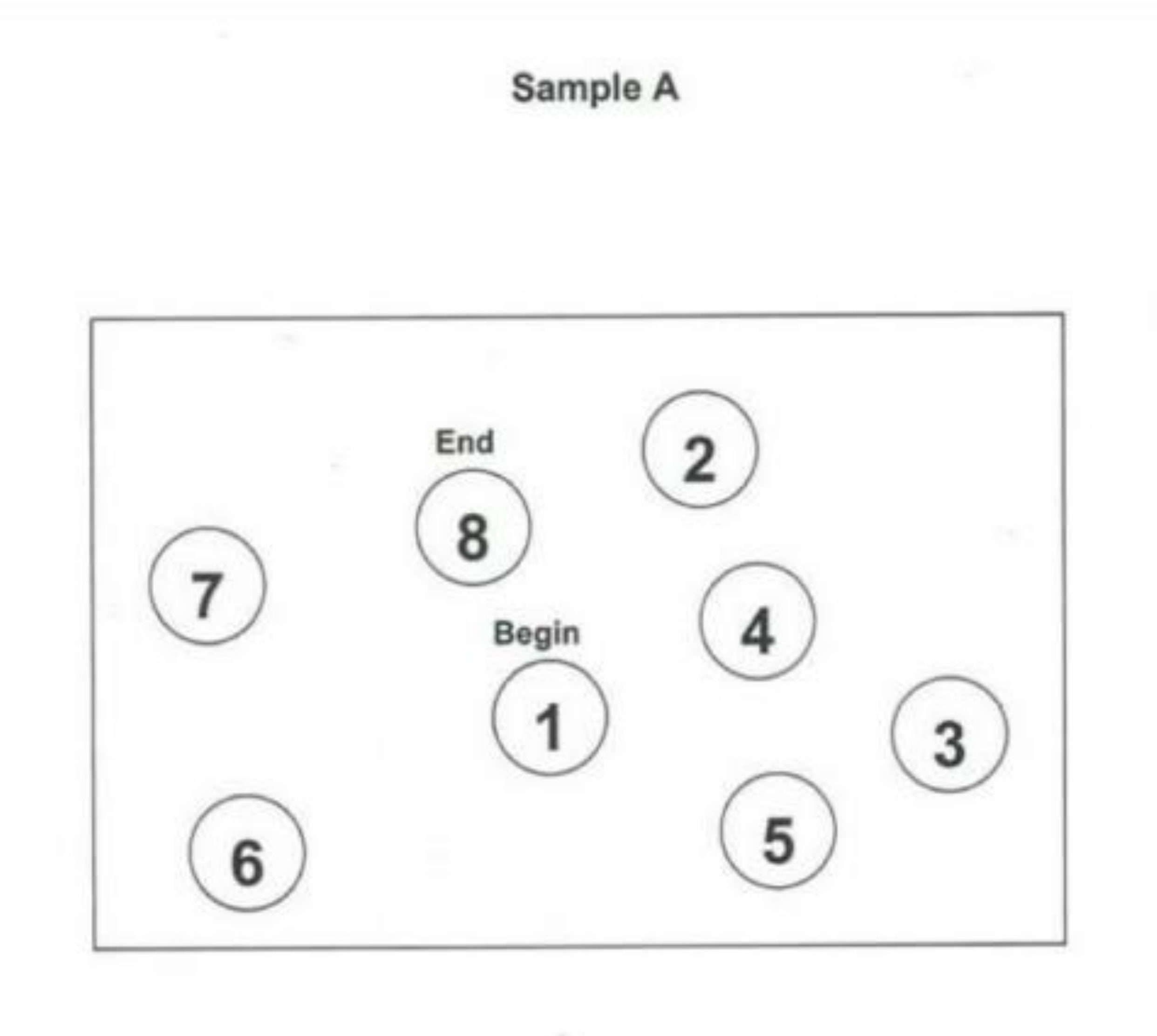
Some of the problems on this sheet are more difficult than others. If you are unable to do one of the problems, simply skip over it and go on to the next one.

You will have three minutes for each of the two parts of this test. Each part has one page. When you have finished Part One, STOP. Please do not go on to Part Two until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

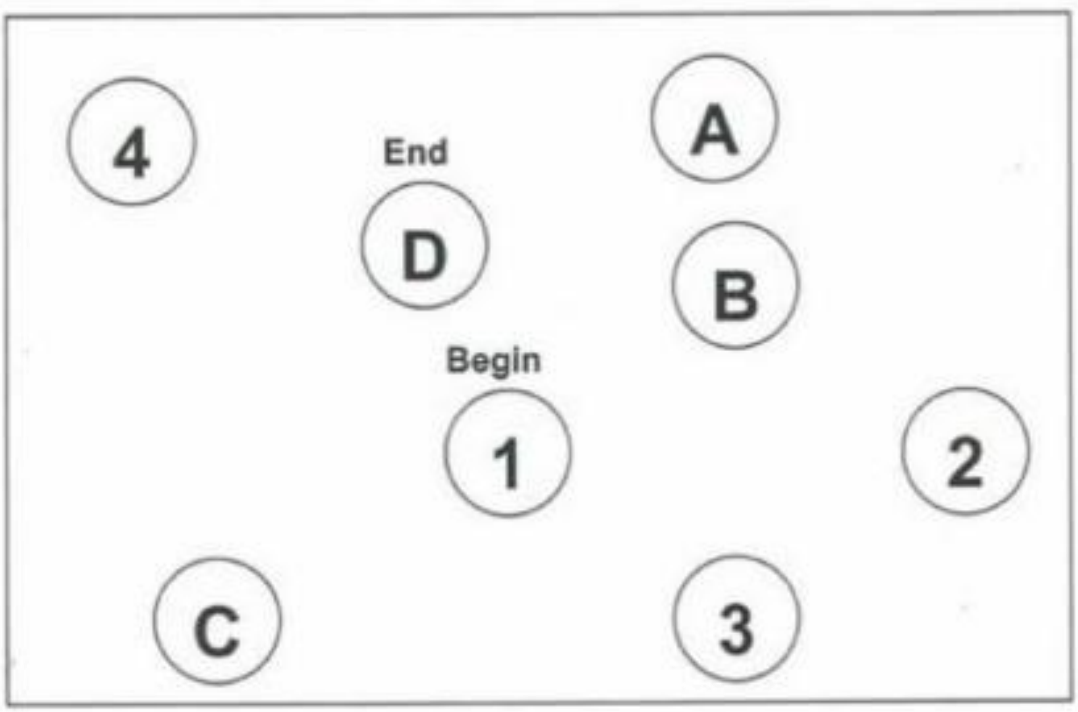
3. Trail Making Test (TMT)

On this page are some numbers in circles. Begin at number one, and draw a line from 1 to 2, 2 to 3, and so on, in order, until you reach the end. Please try not to lift the pen as you move from one number to the next. Work as quickly and accurately as you can. Try this:



Now we'll try another one. On this page are both numbers and letters in circles. Begin at 1, and draw a line from 1 to A, A to 2, 2 to B, B to 3, 3 to C, and so on, in order, until you reach the end. Remember, first you have a number, then a letter, then a number, then a letter, and so on. Draw the lines as fast as you can. Do you have any questions?

Sample B



4. Pictorial Surface Orientation (PicSOr)

This test is a series of 35 different images that is a cube and a rotating arrow on the cube. Your task will be to use the up and down keys on the keyboard to navigate the arrow until the arrow's shaft is perpendicular to the surface of the cube while being timed. Once the arrow shaft is perpendicular, click the "enter" key on the keyboard. The goal is to be timely but accurate. There will be no set time, however time will be important. You will be allowed one practice trial that will give you feedback on your angle. After wards you will click "Quit" and begin the experiment run. We will not answer any questions during the test.

5. Grooved Pegboard

In front of you, you have a pegboard. The pegs are sitting right above the board. All the pegs are the same. They have a groove, that is, a round side and a square side and so do the holes in the boards. What you must do is match the groove of the peg with the groove of the board and put these pegs into the holes.

Dominant hand

We will start with your dominant hand (e.g. right hand). When I say go, start placing the pegs from the left side of the board to the right side. Fill the row in order. Do not skip any holes. When you finish the row, do the same thing again on the row beneath. Remember, you will start on the LEFT side again. You can ONLY use your right hand.

Watch me do it. Now, you can try one row.

When I say go, you will start, and complete this activity as fast as you can. When you are done, I will stop the timer. Then, you will remove the pegs in the exact same order you put them in. So that is from left to right, starting at the top of the board and going down, as fast as you can. If you drop a peg onto the board, pick it up and continue. If you drop it on the floor or table, leave it there and get a new peg. Any questions?

Non-dominant hand

Now we will do the same thing with your non-dominant hand (e.g. left hand). One thing changes however – you will put in the pegs starting on the RIGHT side of the board, towards the LEFT. Fill the row in order. Do not skip any holes. When you finish the row, do the same thing again in the row beneath. Remember, you will start on the RIGHT side again. You can use ONLY your left hand. When I say go, you will start, and complete this activity as fast as you can. When you are done, I will stop the timer. Then, you will remove the pegs in the exact same order that you put them in. So that is from right to left, starting at the top of the board and going down. Any questions?

6. **Purdue Pegboard**

This is a test to see how quickly and accurately you can work with your hands. Before you begin each battery of the test, you will be told what to do and then you will have an opportunity to practice. Be sure you understand exactly what to do.

Dominant hand

First, we will start with your dominant hand (e.g., right hand). Pick up one pin at a time with your right hand from the right sided cup. Starting with the top hole, place each pin in the right-handed row. Watch me do it. Now you try. I will take out the pins when you're done.

If during the testing time you drop a pin, do not pick it up. Simply continue by picking another pin out of the cup. Now you may insert a few pins for practice. I will take out the pins when you're done.

When I say 'Begin,' place as many pins as possible in the right-handed row, starting with the top hole. Work as quickly as you can until I say 'Stop.' Questions?

Non-dominant hand

Now we will do the same thing, but with your non-dominant hand (e.g., left hand). Pick up one pin as a time with your left hand from the left-handed cup. Place each pin in the left-handed row, starting with the top hole. You may insert a few pins for practice. I will take out the pins when you're done.

When I say ‘Begin,’ place as many pins as possible in the left-handed row, starting with the top hole. Work as quickly as you can until I say ‘Stop.’ Questions?

Hands together

For this part of the test, you will use both hands at the same time. Pick up a pin from the right-handed cup with your right hand, and at the same time pick up a pin from the left-handed cup with your left-hand. Then place the pins down the rows. Begin with the top hole of both rows. Watch me do it. Now you try. I will take the pins out when you’re done.

When I say ‘Begin,’ place as many pins as possible with both hands, starting with the top hole of both rows. Work as rapidly as you can, until I say ‘Stop.’ Question?

7. **Index Finger Tapping (TAP)**

In this test, you will be using your index finger to tap the spacebar of the keyboard. Put your arm resting comfortably, with your palm down. Watch me do it. Now you try.

When I say go, you will tap as many times as you can until I say stop. Remember, you can only use the index finger of your dominant hand. Make sure to keep your arm rested. Questions?

Now we will do the same thing with your non-dominant hand. When I say go, you will tap as many times as you can until I say stop. Remember, you can only use the index finger of your non-dominant hand. Make sure to keep your arm rested. Questions?

8. **Chopsticks**

In this test we will be using chopsticks. Please leave the chopsticks on the table until I tell you to pick them up. In the board in front of you, there are two bowls. Using only your dominant hand to move the chopsticks, you will transfer as many beads as you can into the other bowl as fast as you can, until I say stop. You may only move one bead at a time. If you drop a bead, do not pick it up. Grab another one from the bowl. Do you have any questions? You may now pick up the chopsticks. Go.

Now we will do the same thing with your non-dominant hand. Do you have any questions?

Now we will do a similar test with rice. Using only your dominant hand to move the chopsticks, you will transfer 5 grains of rice into the other bowl as fast as you can. You may only move one grain at a time. If you drop a grain, do not pick it up. Grab another one from the bowl. Do you have any questions?

Now we will do the same thing with your non-dominant hand. Do you have any questions?

9. Dot Filling Test (DFT)

In this test, you will be putting dots in circles. When I say go, draw a dot in each circle following the pattern as quickly as you can until I say stop. Make sure the dot is IN the circle, and not on the edge or outside of it. In the first and last boxes, you will use your dominant hand. In the middle two boxes, you will use your non-dominant hand. Do you have any questions?

10. Fist-Edge-Palm (FEP)

In this test, you will be repeating a hand sequence with 3 distinct movements. I will show you three times. Do not move your hand while I am showing you, just watch.

- Here is one
- Here is two
- Here is three

Try it with me. Show me on your own.

We will start with your dominant hand. When I say go, repeat the sequence as many times as you can, as fast as you can. Make sure each position is clear. If you make a mistake, just keep going. Continue until I say stop. Do you have any questions?

Appendix D: Questionnaires

MUS
Participant Intake Questionnaire

Identifiers	
Name	
1. Email address	
2. Phone number	
3. Current City/town	
4. Alpha-Numeric Codes (for office use only)	
Physical characteristics	
5. Date of birth	
6. Gender	
7. Ethnicity (circle your response)	a) Caucasian b) Latino/Hispanic c) Middle Eastern d) African e) Caribbean f) South Asian g) East Asian h) Mixed: ___________________________________ i) Other: ____________________________________
8. Left or right handedness	
Musical Background	
9. Number of years playing your instrument:	
10. At what age did you commence studying your instrument?	
11. Are you currently maintaining practice on your instrument?	Yes ___ No ___
12. What is the highest RCM grade level you have attained (if applicable)?	
13. What is the highest level of post-secondary education you have attained (if applicable)?	
a) Institution/University:	
b) Program:	

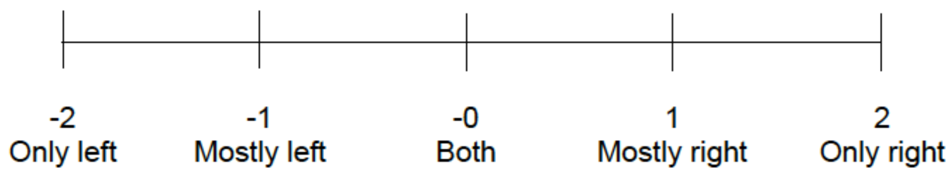
c) Current year of program or year of graduation:		
d) Specialization (performance, musicology/theory, education, pedagogy, etc.):		
14. Approximately how many hours per week did you spend practicing/playing piano within the following age ranges: a) Child (12 years and under) b) Adolescent (13 to 18 years) c) Young Adult (19 to 24 years) d) Currently		
15. On average how long is your typical practice session?		
16. On average, how many practice sessions do you have per day?		
17. How many **<u>days</u>** per week do you typically play your instrument (practice/rehearsal/ performance)?		
18. How many **<u>hours</u>** per week do you typically play your instrument (practice/rehearsal/ performance)?		
Secondary Instrument		
19. Do you play a second instrument? If yes, which instrument?		
20. Number of years playing this instrument:		
21. At what age did you start?		
22. How many hours (or minutes) do you play this instrument every week?		
Occupation		
23. Which of the following best describes your occupation? Check all that apply.	Full Time	Part time
a) Professional Performer	_____	_____
b) Music Student	_____	_____
c) Music Teacher	_____	_____
d) Non-music related profession	_____	_____
Activities		

24. List any task or activity that you currently do or have done in the past that requires fine motor skills (i.e. sewing, embroidery, scouts (knot-tying), knitting, etc.). For each item please answer the following: a) Which activity? b) At what age did you start? c) For how long did you do this activity (years)? d) Do you currently do this activity?	
25. If you play, or have played video games regularly, please answer the following: a) On which platform (PC, Playstation, Xbox, Phone, iPad, handheld game console, other (please specify))? b) At what age did you start playing video games? c) For how long did you regularly play (years)? d) How much did/do you typically play (hours per week)?	
26. How often do you use a mobile phone to text message (not using voice command)? (circle your response)	a) More than 50 times a day b) 20-50 times a day c) 10-20 times a day d) 1-10 times a day e) rarely f) never
27. Which of the following do you use to input text on a handheld device? (circle your response)	a) keyboard b) touch screen c) combination of both d) I don’t use a handheld device

28. Which hand do you input text with (circle your response)	a) Left b) Right c) Both
29. How often do you use chopsticks? (select one answer, and enter number for frequency of use)	a) Daily basis (___ times per day) b) Weekly basis (___ times per week) c) Monthly basis (___ times per month) d) Rarely (___ times per year) e) Almost never or never
30. If you use chopsticks, how would you rate your ability using chopsticks? (circle your response)	a) I have difficulty using chopsticks b) I am competent, but not fully proficient c) Fully proficient
31. Do you have any issues with your vision? If yes, please describe.	a) Yes ______ No _____ If yes, please describe________________
Interest in Surgery	
How interested are you pursuing a career in surgery?	a) Not interested at all in surgery b) Somewhat interested c) Very interested d) Don’t know
Future research	
Would you be interested in being contacted to participate in other studies happening at the Piano Lab?	a) Yes ______ No _____

Annett Handedness Questionnaire

This test is to see how much you use each of your hands. I will ask a series of tasks. I want you to pretend to do that tack. I will then ask you to rate how often you use each hand for that task on a scale of -2 to +2. -2 means you always use your left hand. +2 means you always use your right hand. Zero means you use both hands equally. A one, for example, would mean you usually use your right hand, but sometimes your left. Here is a scale:



Do you have any questions?

What score do you give?

Writing

Throwing

Using a racket

Striking a match

Cutting with scissors

Threading a needle (hand that is guiding)

Sweeping with a broom

Shoveling with a long-handled shovel, the hand guiding at the bottom

Dealing playing cards

Hammering a nail into wood

Using a toothbrush

Unscrewing a jar