2019

Role of Spatial Ability in Musical Instrument Choice: Implications for Music Education

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ROLE OF SPATIAL ABILITY IN MUSICAL INSTRUMENT CHOICE: IMPLICATIONS FOR MUSIC EDUCATION

by

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A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Psychology
in the College of Sciences
and in the Burnett Honors College
at the University of Central Florida
Orlando, Florida

Spring Term
2019

Thesis Chair: Valerie K. Sims, PhD

ABSTRACT

The intent of this thesis is to explore the relationship between spatial ability and the wide range of musical instruments musicians play. Existing literature has established a link between musicianship and improved spatial ability, but researchers have yet to look at how the spatial makeup of different musical instruments may, in turn, reveal unique levels of spatial proficiency from one instrumentalist to the next. This study was formatted as an online survey that included a music experience scale, a demographics scale, and two measures of spatial ability: the Card Rotations Test (CRT) and the Paper Folding Test (PFT). Participants who played larger instruments were hypothesized to score higher on the spatial ability tests. Results show that specific musical instruments score differently on spatial ability measures, and large instruments like the piano and marimba consistently outperform smaller instruments. This largely exploratory study attempts to show that the psychological discipline as a whole should reevaluate how it categorizes and studies musicians. Furthermore, these preliminary findings will encourage better practice for how music educators handle the musical instrument selection process, hopefully leading to a more long-term, student-centered approach.

ACKNOWLEDGMENTS

I would like to thank Dr. Valerie Sims for her unwavering support and infectious passion throughout my undergraduate career. Without her guidance, my journey to graduate school would not be possible. I would also like to thank Dr. Matthew Chin and Dr. Scott Lubaroff for their help and belief in my work. This study would not be the same without your expertise and shared passion for a better future for music education.

I would like to thank Ms. Karen Cox for helping me find my way at UCF. I spent the majority of my first two years on campus lost, but I will never forget stepping into your office for the first time. Thank you for everything.

I would like to thank my grandparents, Nana and Poppy, for making my opportunities at UCF a possibility. From growing up idolizing the Knights, to getting to walk across the stage as a graduate, it is all only possible with your love and support. Thank you.

I would like to thank my parents, Tim and Donna, for raising me with an unparalleled amount of love and support. Everything you did for me helped me get to this point, and I am forever grateful for that. Never forget that. Thank you, from the bottom of my heart. To Trey and Cosmo, I love you more than you will ever know.

I would like to thank my best friend, Matt, for being a rock for me these past nine years. Our long talks, and infinite amount of shared experiences, always reminded me of who I was, what I loved, and eventually, what I wanted to do with my life. I owe you everything.

I would lastly like to thank my girlfriend, Kait, for the endless amount of support she has given me during this past year. Thank you for always being there and for always being the amazing person you are. You inspire me every single day. Thank you for being you.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Overview

Music has been shown to have very strong relationships with a plethora of cognitive processes. One of these processes is spatial ability (e.g., Lee, 2012; Perham, Lewis, Turner, & Hodgetts, 2014; Pietsch & Jansen, 2012; Sluming, Brooks, Howard, Downes, & Roberts, 2007). Currently, researchers have yet to look at how specific musical instrumentation may play a role in a musician's proficiency at spatial ability. Furthermore, research assumes that this relationship between music and spatial ability only goes one way (music strengthening spatial skills). This study aims to shed light on these gaps in the literature and will examine how these findings could impact the current state of music education.

Music and the Brain

Psychologists have seemingly always had a fascination with music's role in the human experience. In recent years, the study of music has shifted mostly into the realm of cognitive neuroscience, where cutting-edge brain scanning is used to give us a glimpse into the wonders of music. While each study has its own unique contribution to the literature, the field as a whole is largely looking at how music enriches other aspects of human cognition.

Music is well known for strengthening the brain, mentally and physically. For example, keyboard players have been shown to have a higher volume of gray matter in many areas of the brain, but most notably the cerebellum (Gaser & Schlaug, 2003; Hutchinson, Lee, Gaab, & Schlaug, 2003; Pascual-Leone, 2001). This can be attributed to the immense motor skills required when playing a keyboard instrument. Beyond physically restructuring the brain, formal music training is positively associated with "sustained attention, visual-motor coordination, visual scanning ability, visual processing speed, spatial memory, and information manipulation skills," which all involve some aspect of working memory (Suárez, Elangovan, & Au, 2016).

Schellenberg (2006) showed a long-term causality between individuals who take music lessons and their increased performance on IQ tests. These findings have been backed up for verbal and non-verbal intelligence over the years. Musicians exhibit higher verbal reasoning and verbal working memory (Brandler & Rammsayer, 2003; Hansen, Wallentin, & Vuust, 2013); and for non-verbal reasoning, we also see substantial improvements (see *Spatial Ability* to read more).

Researchers have also aimed to distinguish between learned and born traits of musicianship. Trehub (2001) has shown that infants possess the fundamentals needed for melodic and rhythmic recognition, as displayed in their ability to distinguish between the pitch and cadence of each parent's voice. This study shows that all infants start with an innate understanding for the frameworks of music, but these findings are rarely supported when extended beyond listening, or beyond infancy. When looking at pre-existing neural, cognitive, and motor functions in 5 to 7-year old's, children who participate in music show no differences in brain function from their peers (Norton et al., 2005).

These studies suggest that while basic musical traits are innate, there is no clear genetic advantage that breeds musicians. Trainor (2005) states there are "multiple pathways" to gaining sufficient levels of musical experience, regardless of age. Again, while the majority of the literature insists that music increases cognitive functions, more recent findings suggest that cognitive functions can help a student's experience with music. Tezer, Cumhur, & Hürsen's 2016 study on spatial-temporal reasoning illustrates this concept beautifully by stating: "children with advanced cognitive skills are better at perceiving music and improving it."

Spatial Ability

According to Linn & Petersen (1985), spatial ability can be vaguely defined as the "skill in representing, transforming, generating, and recalling symbolic, nonlinguistic information." Spatial ability is generally split into three categories: spatial perception, mental rotation, and spatial visualization. These definitions and categorizations are still used throughout the field today and are included many current meta-analyses (e.g., Voyer & Jansen, 2017).

For context, one of the most notable and controversial links between spatial ability and music, simply known as the "Mozart effect," claimed that by listening to Mozart, scores on spatial ability tasks could be improved (e.g., Rauscher et al., 1993). It did not take much time before the mainstream media took these findings and began falsely claiming that listening to classical music boosts IQ scores. While the Mozart effect has since failed to be replicated, has been criticized for its flawed research design, and has been grossly over-generalized, this study did pave the way for many researchers to investigate the true relationship that exists between spatial ability and music (Chablis, 1999).

While the Mozart craze focused on listening to music, recent findings are uncovering that playing music is where the real magic happens. Sluming et al. (2007) showed orchestral musicians performed significantly better on mental rotation tasks than a non-musician control group. Additionally, these findings were supported when comparing musicians to purely academic students and student-athletes (Pietsch & Jansen, 2012). Lee (2012) continued this research by theorizing that the spatial nature of reading musical notation may be an underlying factor for why musicians seem to outperform their peers. This stems from the idea that musical notation has many spatial properties (e.g., notes higher on the staff being higher in pitch). Lee

(2012) supported his hypothesis by finding that the high note-reading group made fewer errors on spatial tasks than their low-note reading counterparts.

Before going deeper into this area of research, it is important to note that sex differences in mental rotation tasks have been documented early on in spatial ability meta-analyses (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995). Males slightly outperform females on most measures of spatial ability. Recent research, like Uttal et al. (2013), has shown that spatial skills are malleable and can be improved regardless of sex or age. These recent findings suggest that sex differences in the field of spatial ability are not as permanent or prominent as they were once believed to be.

In music, we also see sex differences in terms of musical instrument choice (Harrison, 2007). Smaller, higher-pitched, instruments (e.g., the flute and clarinet) are strongly preferred by girls, while larger, lower-pitched, instruments (e.g., the drums and trombone) are strongly preferred by boys (Hallam, Rogers, & Creech, 2008). A literature review on these sex-based instrument selections states that many factors go into these stereotypes, like gender norms, self-identity, peer pressure, pop culture influences, classroom demonstrations, and more (Eros, 2008). Unfortunately, unlike recent changes in the field of spatial ability, we do not see signs of improvement within these trends in the near future (Abeles, 2009).

Music Education Today

According to Eros (2008), musical instrument choice is one of the most important factors in a student's music education experience. This statement seems obvious but is often overlooked in reality. This phase is commonly a child's first experience in a formal music environment and has important implications on how the student will continue with music (McPherson & Davidson, 2006). But because of our mishandling of this process, we have extremely low retention rates with students continuing music throughout their schooling (Chen & Howard, 2004).

When 23 middle school students are asked why their peers do not continue band in high school, they state that the students are making a conscious effort to avoid music, rather than choosing to pursue other options (Gouzouasis, Henrey, & Belliveau, 2008). When 50 band directors are asked the same question, “lack of commitment to work” was the most common reason listed (Boyle, DeCarbo, & Jordan, 1995). Regardless of the perspective, it is clear that music inadvertently turns away more people, than it retains.

The middle school instrument selection process has always been messy. When surveying 322 beginning band directors, Bayley (2004) looked into the specifics. Band directors often intentionally exclude certain instruments from student selection because of availability or popularity, already limiting potential “best matches” with these instruments for certain students. 95.2% of directors admit to guiding their students through the selection process, but mostly for the purposes of balanced instrumentation. Students then commonly try playing instruments to see which ones they sound best at (before any instruction has started). Finally, students often write a top 3 list of instruments, and then the band director sorts through these until the ensemble is filled (Bayley, 2004).

Already, we can see potential problems with these methods. For starters, other than the illusion of free choice, these tactics are more “band-centered” than “student-centered.” Of course, there is a good reason why these practices are a necessary evil for music education; a middle school band composed of all trumpet players is not much of a band in the conventional sense. Additionally, most factors used in selection only concern the short-term success of the student and the band. Poor instrument pairings and high dropout rates are far from a long-term sustainability plan. Furthermore, a student's initial sound it attempts to make on the instrument should not hold the weight that it does in the audition process. Music educators are more than equipped to teach their students, but by trying to place students on instruments that they, by chance, make decent sounds on is just a shortcut down a path with no destination.

Ideally, matching students to instruments their brain is more adept at mastering, therefore making the student more likely to stick with it and enjoy it, may offer a refreshing change of pace to the music education community. The current study will aim to provide evidence that the instrument a musician plays is directly related to their performance on spatial ability tasks. The better we understand the differences that exist between different types of musicians, the better we will be able to identify which musician is best suited for each instrument. Beyond that, the more we uncover about how the brain conceptualizes the vastly different spatial layouts of each instrument, the more the music education community can begin to move towards a different, more student-centered long-term philosophy to the instrument selection process.

Current Research and Hypothesis

Reforming the musical instrument selection process is the goal, but there is a long road ahead. The current theory this study is putting forward is: given the unique range of spatial properties in each musical instrument, pre-existing spatial ability levels in an aspiring musician may be a strong predictor of long-term musical success on that specific instrumentation.

A huge flaw in previous research is that all instruments are viewed the same. While implicitly, researchers know instrumentation is important enough to list within a methods section, explicitly, these unique instruments are rarely analyzed separately in data analysis. Currently, it is unclear the differences in cognitive processing between a trombonist and a flutist, a drummer and a saxophonist, and so on.

Each instrument has an entirely different structural makeup, and there is good reason to believe that certain instruments are better suited for some individuals' brains over others. To best answer this question, classifying instrument groups becomes an important procedural decision before moving to the data analysis phase. There are many different ways to separate instrument groups, but the Hornbostel-Sachs (H-S) Instrument Classification System has become a very streamlined and effective way to do so. Essentially the system (created in 1914) categorizes instruments based on how the instrument fundamentally makes its sound (what way the instrument interacts with the air molecules around them).

The main instrument families are idiophone (sound comes from the instrument itself vibrating), membranophone (sound comes from an attached membrane vibrating), chordophone (sound comes from strings vibrating), and aerophone (sound comes from a column of air vibrating). Specific differences in instruments are then classified further (within these families) like the Dewey Decimal System, giving every instrument a unique string of numbers. This current study will look at the Basic H-S Level (the first digit of the instrument identifier; e.g., the instrument "family") and a Specified H-S Level (which will be defined as the first three digits of the instrument identifier). For example, an oboe's classification would have a Basic H-S Level of 4 for being an aerophone (wind instrument) and a Specified H-S Level of 422 for being a reed instrument. Its full H-S classification is 422.112 (double-reeded aerophone with keys).

Instrument classification aside, the working hypothesis for this exploratory study is that musicians that play bigger instruments will score higher on the spatial ability measures. This, along with many other questions, will be looked into further throughout the course of this study.

METHOD

Participants

Young adults (*N* = 288; 54% female) between the ages of 18-30 (*M* = 20.90, *SD* = 2.58) were asked to complete a short online survey. Participants were recruited locally at the University of Central Florida (UCF) through emails sent through the music department. Any student enrolled in at least one music class (regardless of major) during the Spring 2019 semester was sent the email with information on the survey. Additional participants were recruited beyond UCF's campus through two means: 1) all members of the College Band Director's National Association (CBDNA) were sent an email from UCF's Director of Bands asking the directors to share the study with their students, and 2) the survey was shared via social media to reach other populations of musicians.

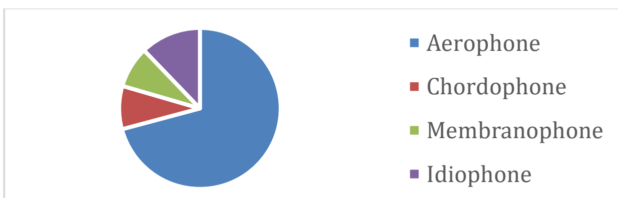

Figure 1: Basic Hornbostel-Sachs Breakdown

This study was interested in looking at formally trained musicians (see instrument breakdowns in Figure 1 above, Figure 2 below, and Figure 3 on the next page).

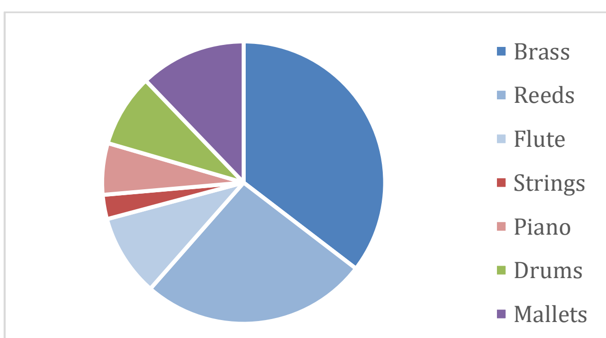

Figure 2: Specified Hornbostel-Sachs Breakdown

“Formally trained musician” was operationally defined as participants needing to self-report at least four years of instrumental music experience to be included in the final data analysis. Participants were also eligible to be removed from the final data set for not following directions, scoring above or below three standard deviations from the mean on the spatial ability measures, and taking too much or too little time to finish.

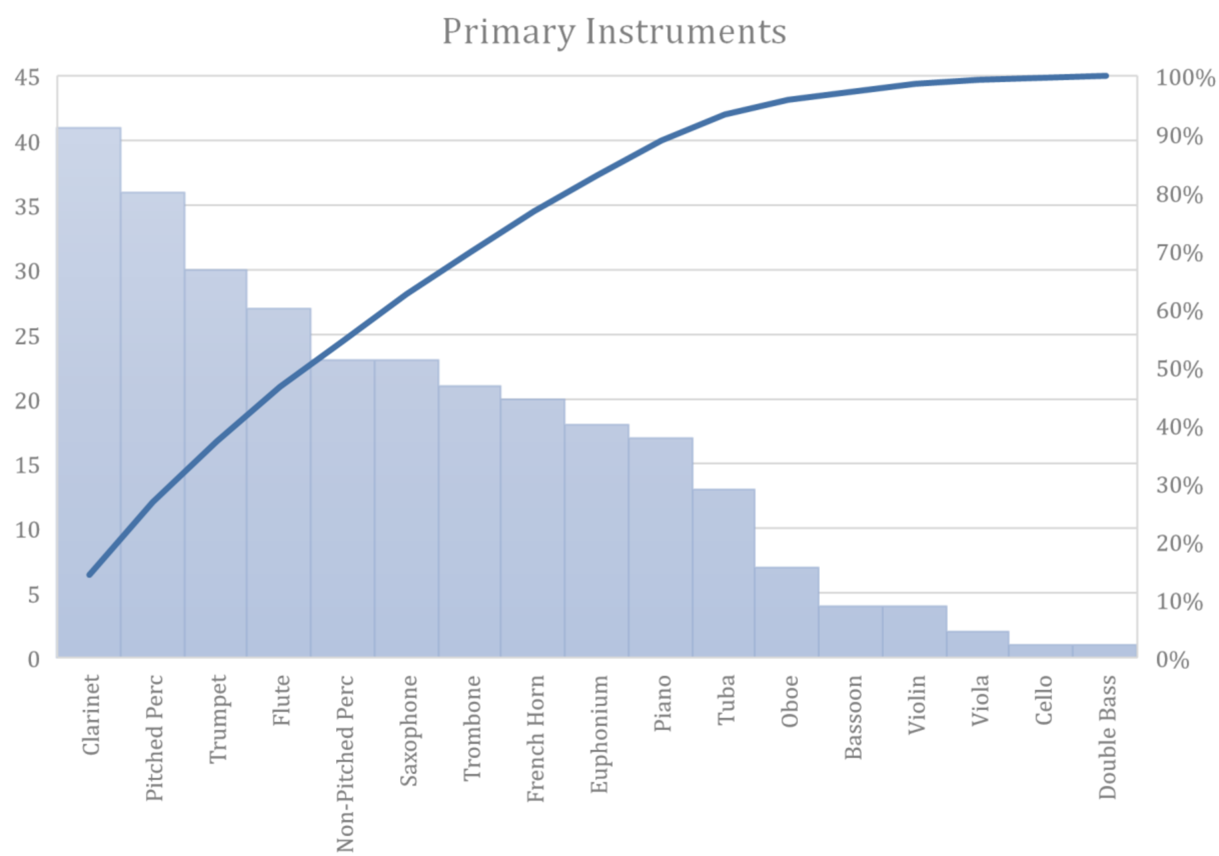

Figure 3: Primary Instrument Frequencies Breakdown

Procedure

Participants completed an online survey questionnaire of approximately 20 minutes in length. Each participant was first presented with questions on their musical experience, then they were presented two different types of spatial ability tests adapted from the French Kit (French, Ekstrom, & Price, 1969): the Card Rotations Test and the Paper Folding Test. These two spatial tests appeared in random order from participant to participant to eliminate any possible ordering effects. The two spatial tests were separated by a short demographics section to reduce the chance of cognitive fatigue.

Materials

The online survey was created through Qualtrics. The data from the surveys were entered into Microsoft Excel and then further analyzed with Statistical Package for the Social Sciences (SPSS). Specific measures included in the survey can be seen below.

Demographics Scale

This section was five questions long. Basic background questions involving age, sex, college major, high school, and hometown zip code was asked to the participants. None of this information was used to identify participants, but rather to combine the data into separate groups when entering the data analysis phase. To see the full scale, please see *Appendix A*.

Music Experience Scale

This section was 13 questions long. Questions included what their primary instrument was, number of instruments they could play, how many years they have been playing, etc. These questions aimed to categorize participants into varying levels of musical experience, skill, and instrumentation. Participant responses helped create different sub-groups for data analysis. To see the full scale, please see *Appendix B*.

Card Rotations Test (CRT)

The CRT (see example question below) contains ten questions to be completed over the span of three minutes. The objective of the task is to determine if the one card (shape) on the left matches any of the eight cards (shapes) on the right. The cards on the right can be rotated between 0 and 360 degrees, but not flipped, to be considered the same as the card on the left.

Participants mark if each of the cards on the right is the same (S) or different (D) from the card on the left. Multiple answers can be correct for each question. This is a measure of spatial orientation, one of the most fundamental levels of spatial ability. Spatial orientation primarily looks at the process of mentally rotating a configuration in space.

Figure 4: Card Rotations Test Example Question

Paper Folding Test (PFT)

The PFT (see example question below) contains ten questions to be completed over the span of three minutes. A question on the PFT consists of images on the left-hand side depicting the steps involved in folding a piece of paper and then punching a hole completely through a portion of that folded paper. On the right-hand side, there will be images of potential “unfolds” that the steps on the left-hand side would create. These “unfolds” on the right cannot be flipped or rotated to better match the images on the left. Participants match the “unfold” they believe was created through the steps on the left. Only one answer is correct for each question. This is a measure of spatial visualization (which takes the fundamental skills found in spatial orientation and adds an additional working memory component to manipulate the mental images in space).

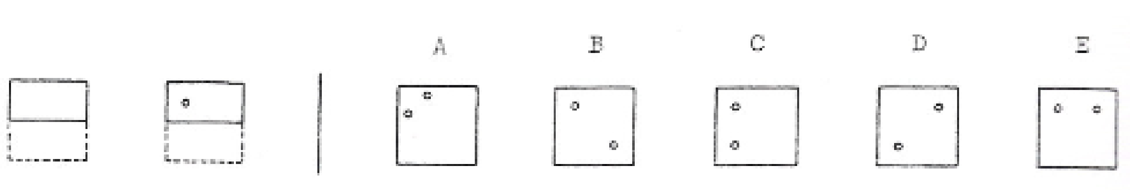

Figure 5: Paper Folding Test Example Question

RESULTS

Card Rotations Test (CRT)

A series of one-way ANOVAs were conducted on various grouping variables to see how each musical instrument differed from one another on their performance of the CRT. For all of these analyses, it will be assumed that the dependent variable is always score on the CRT. For the sake of brevity, it will be assumed that group names of instruments refer to the group of musicians that play them (e.g., aerophones refer to aerophone players, pianos refer to pianists).

The first ANOVA compared the effect of Hornbostel-Sachs (H-S) instrument family (one digit of specification) on CRT score. The results were not significant [$F(3,284) = .82$, $p = .483$]. But, when breaking the groups into more specified H-S classifications (three digits of specification), significant results are found [$F(3,284) = 2.43$, $p = .026$]. Post-hocs reveal that strings score significantly lower than all other groups except membranophones (LSD *ps* for mean differences < .05) and pianos score significantly higher than membranophones and reeds (LSD *ps* for mean differences < .05).

To further explore the instrument size hypothesis, motor skill type and clef type were used to explore how instrument size may impact performance on spatial tasks. For motor skill type, instruments were separated into two groups: fine motor only or fine/gross motor combination. When running an ANOVA comparing the effect of motor skill type on CRT score, no significant results were found [$F(1,286) = .242$, $p = .623$]. For clef type, instruments were separated into four groups: bass clef, treble clef, alto clef, or multiple clefs. An ANOVA comparing clef type on CRT score yielded significant results [$F(3,284) = 2.95$, $p = .033$], and post-hocs displayed that multiple clef group scored significantly higher than the treble and alto clef groups (LSD *ps* for mean differences < .05).

Paper Folding Test (PFT)

A series of one-way ANOVAs were conducted on various grouping variables to see how each musical instrument differed from one another on their performance of the PFT. For all of these analyses, it will be assumed that the dependent variable is always score on the PFT. For the sake of brevity, it will be assumed that group names of instruments refer to the group of musicians that play them (e.g., aerophones refer to aerophone players, pianos refer to pianists).

The first ANOVA compared H-S instrument family (one digit of specification) to PFT score. Significant results were found [$F(3,284) = 2.93$, $p = .034$] and post-hocs showed that chordophones significantly outscored aerophones (LSD *p* for mean difference = .011). Furthermore, breaking the groups into smaller H-S classifications (three digits of specification) to compare their effect on PFT score yielded significant results as well [$F(3,284) = 2.29$, $p = .036$]. Post-hocs show that idiophones score higher than reeds (LSD *p* for mean difference = .012) and pianos score higher than reeds and brass (LSD *ps* for mean differences > .05).

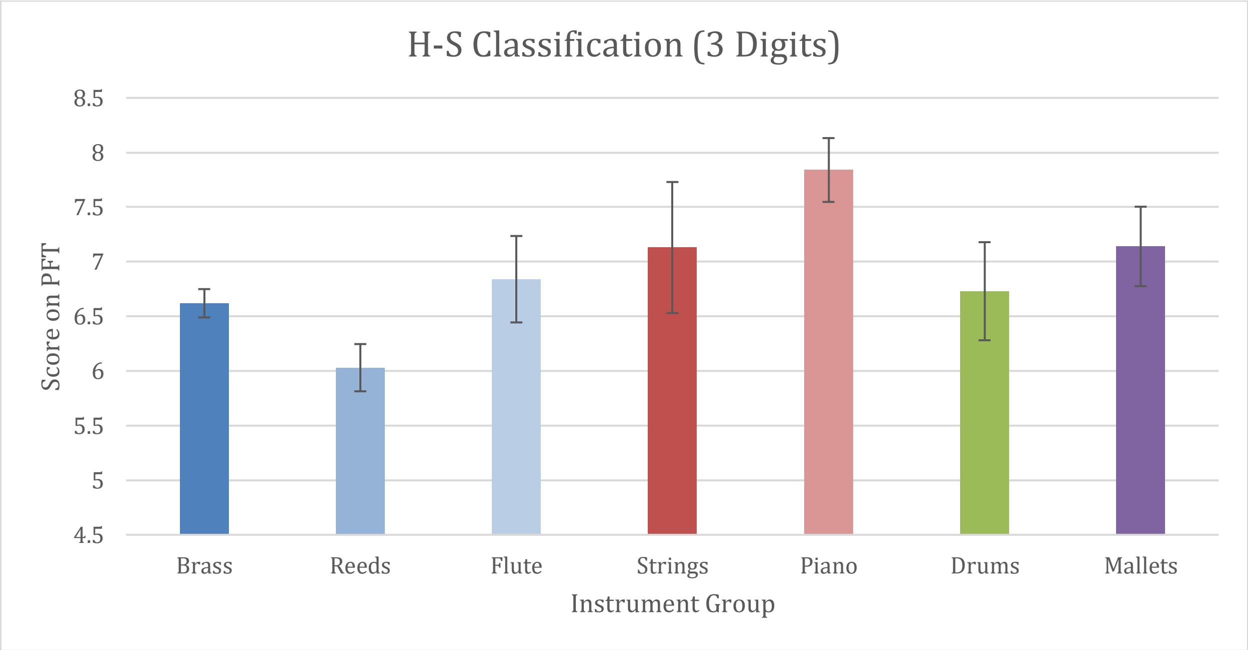

Figure 6: One-Way ANONA on Specified Hornbostel-Sachs Classification

To further explore the instrument size hypothesis, motor skill type and clef type were used to explore how instrument size may impact performance on spatial tasks. An ANOVA comparing motor skill type (fine motor only vs. fine/gross motor combination) with PFT score showed significant results [$F(1,286) = 8.59$, $p = .004$] with the fine/gross combination group scoring higher ($M = 7.14$, $SD = 1.97$) than the fine only group ($M = 6.36$, $SD = 2.27$). An ANOVA comparing clef type (bass vs. treble vs. alto vs. multiple clefs) with PFT score found no significant results [$F(3,284) = 2.18$, $p = .091$].

Additional Results

To help discover more about the potential directionality of music improving spatial skills (within the limits of this study's non-experimental design), self-reported years of experience was used as an independent variable to see how duration of time with music might impact performance on spatial tasks. No significant results were found when ANOVAs were ran comparing years of experience to CRT [$F(6,281) = 1.65$, $p = .133$] or PFT [$F(6,281) = 1.09$, $p = .368$]. How many instruments participants could play was also used as an independent variable to help explore this question, but it also did not show any significant results either for CRT [$F(8,279) = 1.48$, $p = .165$] or PFT [$F(8,279)= 1.60$, $p = .125$].

Reading musical notation has been shown in previous research to be spatial in nature, so the current study used self-reported sight-reading proficiency as an independent variable to look at its relationship with spatial ability performance. No significant results were found on performance of the CRT [$F(5,281) = 1.27$, $p = .277$] or PFT [$F(5,281) = 2.02$, $p = .075$]. Because of sex differences being cited in the literature, demographic variables were also explored further. Age and sex were looked at, but no significant differences were uncovered, implying that these factors did not heavily influence the results on the CRT or PFT. Finally, as an internal validity check, a Pearson correlation was run to show that scores on the CRT and PFT were positively correlated within each participant ($r = .31$, $p < .001$).

DISCUSSION

Spatial performance on the Specified Hornbostel-Sach's (H-S) classification (3 digits of specification) was significant for the Card Rotations Test (CRT) and the Paper Folding Test (PFT). This supports our underlying theory that unique instrumentation among musicians elicits unique levels of spatial ability. But when stepping back and only looking at the instrument "family" that a musician belongs to (defined as the Basic H-S classification), there are only significant differences on the PFT, but not on the CRT. The additional workload that the PFT and spatial visualization require (adding working memory) could explain why these results start to become apparent at a broader stage in musical instrument classification process. The PFT may be a more robust measure of spatial ability among the music community, which suggests that differences within wind, string, and percussion players are shared at a broader level, before even getting to the unique instrumentation in each instrument "family."

This difference in performance on each spatial ability test is not entirely surprising given that these tests measure slightly different aspects of spatial ability (CRT measuring spatial orientation and PFT measuring spatial visualization). This study tried to cast a broad stroke on this topic, but narrowing this research question down to one specific measure of spatial ability seems to be necessary when moving forward with future research. When considering the spatial layout of a musical instrument, and the fact that playing a musical instrument is an active and dynamic experience, focusing on the musician's performance of the PFT seems like the most applicable spatial measure to look at in future studies. This additional working memory component (i.e., the mental holding and manipulation of objects) seems to be important in the musical instrument experience (Suárez et al., 2016).

The big takeaway from this study is that, yes, there are differences that exist when looking at musicians by the instrument they play, not just the general label they share as "musicians." These preliminary findings provide evidence of fundamental differences that musical instruments have on specific cognitive tasks (i.e., spatial ability). Furthermore, the exploratory hypothesis of larger instruments scoring better on spatial ability tasks seems to explain some of these findings. The piano and idiophones (instruments like the marimba) are the largest instruments in the sample, and their performance on spatial ability tasks was consistently among the top scores on the CRT and PFT.

But, instrument size becomes an ambiguous subject as we start looking into other instruments. The size alone does not inherently mean that the performer utilizes the entirety of that space to play a said instrument. The tuba, for example, is the largest brass instrument, but the performer only has to worry about utilizing a set of valves that are relatively close in proximity to them. This is similar to many valved brass instruments, providing evidence that the size of the instrument does not directly determine its spatial properties. Another factor, or factors, should be looked at when we talk about the spatial nature of musical instruments. Potential factors could include hand distance from the body, hand movement from a general "home base" position, or specific hand utility in the playing process.

The current study was also interested in exploring other aspects of musical instrument playing— beyond the physical realm. Each participant's self-reported sight-reading ability was looked at, but there was no significant relationship to their performance on spatial ability tasks. Though Lee (2012) has documented the spatial nature of reading musical notation, our finding suggests that there are different underlying cognitive processes at play between everyday note reading and the ability to sight-read during a condensed timeframe. It is also worth noting that the current study did not find any significant sex differences on spatial ability tasks. This supports recent spatial ability literature and adds to the body of evidence suggesting that sex differences may be disappearing from spatial tasks altogether (e.g. Uttal et al. 2013).

The results also shed light on the "chicken-egg" debate among researchers, on whether music strengthens the brain or if a stronger brain increases musical ability. This directionality often supports the notion that music positively affects various cognitive processes (laying the foundation for the wide range of claims arguing that music enriches other aspects of our lives). The current study looked at years of experience, but found no significant effect on spatial ability performance. Given the correlational nature of this study, our results lack definitive causality, yet multiple inferences can still be drawn and provide unique context to this directionality debate.

One interpretation could be that any benefits that music provides to spatial skills take place during an individual's initial experience with music. The current study was only interested in formally trained musicians with at least four years of musical experience. Any growth that may take place before this timeframe would go undetected unless an additional sample of musicians with less experience were included in the final data analyses. Another interpretation could imply that music itself is not what strengthens spatial skills. It is possible that individuals that are already high in spatial ability seek out music, or are the ones that "stick with it," compared to individuals that are predisposed with lower levels of spatial ability.

In closing, this study helps open the door for future research, but independently, this study is just a small voice in the music and psychology community. Future studies should explore using experimental (for the purposes of causality) and longitudinal (for the purposes of increased control) designs to build upon these questions and substantiate some of these claims on a larger scale. If for nothing else, this research (like many others) hopes to start a conversation.

Researchers and music educators need to continue to work together to better understand this thing we call music. Whether it is our categorization of musicians as psychologists or our approach to instrument selection as music educators, there is room for improvement in both fields. Studying individual differences among various musical instruments adds a unique perspective to music and psychology literature, but most importantly, lays the foundation for bringing order to a frequently disorderly musical instrument selection process.

This research represents, what we believe is, the "tip of the iceberg" to a plethora of soon-to-be-discovered links that exist between various cognitive processes and their role from one musical instrument to the next. We must rethink our conventional notions about how we try to attack music's biggest questions. Throwing together all of the unique sounds of an orchestra into one room, with no rhyme or reason, will never let us hear the music, only noise. As we tackle these questions, we must take it one instrument and one cognitive process at a time—listening to the unique and distinct melodies that each musical instrument creates. Once we understand each part of the score, only then will we be able to piece everything back together and hear a beautiful, harmonious masterpiece.

APPENDIX A: DEMOGRAPHICS SCALE

Demographics Scale

What is your age? ________

What is your sex?

Male

Female

Prefer not to answer

What is your college major? (Please write as it appears on a degree audit) ________________

What high school did you attend? (Please write out the full name) ________________

What is the 5-digit zip code of your hometown? ________________

APPENDIX B: MUSIC EXPERIENCE SCALE

Music Experience Scale

How many different instruments can you proficiently play?

****Proficiency* will be defined as being able to play all 12 major scales or a similar level of instrument-specific mastery. For example, if you were asked to play it right now, you would be able to navigate around the instrument fairly smoothly given your experience with the instrument

***Percussionists: any pitched percussion instruments should be combined together to count as (1) type of instrument, and any non-pitched percussion instruments should be combined together to count as (1) type of instrument. Being able to play pitched and non-pitched percussion instruments (no matter how many of each) should account for no more than (2) instruments in your total instrument tally

1

2

3

4

5

6

7

8

9

10 or more

Please list out below the instruments you reported you could proficiently play (please spell as accurately as possible)

____

____

____

What is the primary instrument you play?

____

Why do you consider that instrument your primary instrument? Please limit your response to a few sentences

____

____

____

Is your primary instrument the same instrument you first started on?

Yes

No

If not, describe why you made the switch from that first instrument?

____

How many total years have you been formally playing musical instruments?

****Formally* will denote when you first took private lessons, were in a band class, or could play your first instrument at a relatively proficient level

Less than 4 years

4 years

5 years

6 years

7-9 years

10-12 years

13-15 years

More than 15 years

Compared to other musicians with a similar level of musical ability (that also play your primary instrument), how would you self-rank your sight-reading ability on a scale from 1-7?

1 Low sight-reading proficiency

2

3

4 Average sight-reading proficiency

5

6

7 High sight-reading proficiency

Did you ever stop playing music (at any age) for an extended period of time because of dissatisfaction with your instrument?

Yes

No

If you were involved in middle school band, please select how positive your experience was. If you were not involved in middle school band, please select “I was not in middle school band”.

Very negative

Somewhat negative

Neutral

Somewhat positive

Very positive

I was not in middle school band

If you were involved in high school band, please select how positive your experience was. If you were not involved in high school band, please select “I was not in high school band”.

Very negative

Somewhat negative

Neutral

Somewhat positive

Very positive

I was not in high school band

Have you ever participated in a season of drum corps (DCI or DCA) while playing a marching instrument? Respond “Not a marching member” if participation in drum corps was exclusively in pit, colorguard, or as drum major.

Yes

No

Not a marching member

Please describe, in a few sentences, how you selected your first musical instrument. If someone else (e.g., a band director, a parent, a friend) was involved in this decision, please include their role and any other relevant information on the topic. Be detailed, but concise when responding. Don’t take more than a couple of minutes to write a response.

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Please answer, in a few sentences, if you think there is a better way to “audition” students on their first instrument in the middle school setting (based on your experience). Feel free to elaborate on the pros/cons of the process you are familiar with. Be detailed, but concise when responding. Don’t take more than a couple of minutes to write a response.

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REFERENCES

Abeles, H. (2009). Are Musical Instrument Gender Associations Changing? *Journal Of Research In Music Education*, (2), 127-139.

Bayley, J. G. (2004). The procedure by which teachers prepare students to choose a musical instrument. *Update: Applications of Research in Music Education*, *2*(2), 23–34.

Boyle, J. D., DeCarbo, N. J., & Jordan, D. M. (1995). Middle/junior high school band directors' views regarding reasons for student dropouts in instrumental music. *Research Perspectives in Music Education*, *5*(1), 16-21.

Brandler, S., & Rammsayer, T. H. (2003). Differences in mental abilities between musicians and non-musicians. *Psychology Of Music*, *31*(2), 123-138.

Chablis, C. F., Steele, K. M., Dalla Bella, S., Peretz, I., Dunlop, T., Dawe, L. A., et al. (1999). Prelude or requiem for the ‘Mozart effect’? *Nature*, *400*(6747), 826–828.

Chen, S. M., & Howard, R. W. (2004). Musical Instrument Choice and Playing History in Post-Secondary Level Music Students: Some Descriptive Data, Some Causes and Some Background Factors. *Music Education Research*, *6*(2), 217-230.

Eros, J. (2008). Instrument Selection and Gender Stereotypes: A Review of Recent Literature. *Update: Applications Of Research In Music Education*, *27*(1), 57-64.

French, J. W., Ekstrom, R. B., & Price, L. A. (1969). Manual for Kit of Reference Tests for Cognitive Factors: John W. French; Ruth B. Ekstrom; Leighton A. Price. *Educational Testing Service*.

Gaser, C., & Schlaug, G. (2003). Gray Matter Differences between Musicians and Nonmusicians. *Annals of the New York Academy of Sciences*, *999*, 514-517.

Gouzouasis, P., Henrey, J., & Belliveau, G. (2008). Turning Points: A Transitional Story of Grade Seven Music Students' Participation in High School Band Programmes. *Music Education Research*, *10*(1), 75-90.

Hallam, S., Rogers, L., & Creech, A. (2008). Gender differences in musical instrument choice. *International Journal Of Music Education*, *26*(1), 7-19.

Hansen, M., Wallentin, M., & Vuust, P. (2013). Working memory and musical competence of musicians and non-musicians. *Psychology Of Music*, *41*(6), 779-793.

Harrison, S. D. (2007). A Perennial Problem in Gendered Participation in Music: What's Happening to the Boys? *British Journal Of Music Education*, *24*(3), 267-280.

Hutchinson, S., Lee, L. H., Gaab, N., & Schlaug, G. (2003). Cerebellar Volume of Musicians. *Cerebral Cortex*, *13*(9), 943-949.

Lee, H. (2012). Exploring the association between visual perception abilities and reading of musical notation. *Perceptual And Motor Skills*, *114*(3), 699-708.

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterization of sex differences in spatial ability- A meta-analysis. *Child Development*, *56*(6), 1479-1498.

McPherson, G. E., & Davidson, J. W. (2006). Playing an instrument. In G. E. McPherson, G. 0. McPherson (Eds.), *The child as musician: A handbook of musical development* (pp. 331-351). New York, NY, US: Oxford University Press.

Norton, A., Winner, E., Cronin, K., Overy, K., Lee, D. J., & Schlaug, G. (2005). Are there pre-existing neural, cognitive, or motoric markers for musical ability? *Brain And Cognition*, *59*(2), 124-134.

Pascual-Leone, A. (2001). The brain that plays music and is changed by it. *Annals of the New York Academy of Sciences*, *930*(1), 315-329.

Perham, N., Lewis, A., Turner, J., & Hodgetts, H. M. (2014). The sound of silence: can imagining music improve spatial rotation performance? *Current Psychology*, *33*(4), 610-629.

Pietsch, S., & Jansen, P. (2012). Different mental rotation performance in students of music, sport and education. *Learning And Individual Differences*, *22*(1), 159-163.

Rauscher, F. H., Shaw, G. L., & Ky, C. N. (1993). Music and spatial task performance. *Nature*, *365*(6447), 611.

Schellenberg, E. G. (2006). Long-term positive associations between music lessons and IQ. *Journal of Educational Psychology*, *98*(2), 457.

Sluming, V., Brooks, J., Howard, M., Downes, J. J., & Roberts, N. (2007). Broca's area supports enhanced visuospatial cognition in orchestral musicians. *The Journal Of Neuroscience: The Official Journal Of The Society For Neuroscience*, *27*(14), 3799-3806.

Suárez, L., Elangovan, S., & Au, A. (2016). Cross-sectional study on the relationship between music training and working memory in adults. *Australian Journal Of Psychology*, *68*(1), 38-46.

Tezer, M., Cumhur, M., & Hürsen, E. (2016). The spatial-temporal reasoning states of children who play a musical instrument, regarding the mathematics lesson: Teachers' views. *Eurasia Journal Of Mathematics Science And Technology Education*, *12*(6), 1487-1498.

Trainor, L. J. (2005). Are There Critical Periods for Musical Development? *Developmental Psychobiology*, *46*(3), 262-278.

Trehub, S. E. (2001). Musical Predispositions in Infancy. *Annals of the New York Academy of Sciences*, *930*, 1–16.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin*, *139*(2), 352-402.

Voyer, D., & Jansen, P. (2017). Motor expertise and performance in spatial tasks: A meta-analysis. *Human Movement Science*, *54*, 110-124.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, *117*(2), 250-270.