2018

Individual Ability to Learn a Parallel Processing Technique and Musical Aptitude.

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Abstract

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MS, Pacific Graduate School of Psychology 2008

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

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Abstract

Correlations between music training and psychosocial skills, sensory abilities, and aspects of intelligence, are sorted into primary or secondary effects. Correlations between these areas of human development and music training lack support pertaining to the underlying cognitive networks that these processes rely on. Thus, this study was based on the work of Baddeley and Hitch's model of working memory, and implemented a test of parallel processing (Articulatory Suppression Task, AST), which measures proficiency of working memory systems. Individual differences therein, were compared with music aptitude. Participants were gathered throughout urban and rural regions of the state of Oregon. Half the participants received specific training on how to excel on AST, the other half received no training. The training was based on research showing musicians to be more proficient in rhythm, the phonological loop, and mental imagery. Group AST pretest/posttest scores and the Drake Musical Aptitude test scores were analyzed using 2-tailed *t* test and regression models for within-group and between-group variation. No significant difference between musical aptitude and participant ability to increase proficiency with parallel processing was found, however, the results indicated that music training influences proficiency with parallel processing in general, and there were indicators that a ceiling effect may have confounded the pretest-posttest range in scores. This supports findings of previous research that musical training has beneficial influences on mathematics, socio-emotional awareness, motor skills, language, and general intelligence, highlighting that positive social change may result if music were a core class in K-12 education.

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Dedication

This dissertation has been motivated in part by educational reform and the resulting reductions in educational funding. Specifically, degradation in the richness of the education our children receive, especially in the realm of music training and art appreciation, has prompted me to analyze the effects of these reductions. Whether a clandestine act or an ill side-effect, the American Paradox and thus the lowering of our collective awareness, it is anticipated that via presentation of the following research we find motivation to not only demand, though to understand, that accountability be upheld for the moral responsibilities of the corporations that now run our government. There exists strong evidence that removing music training from K-12 education may result in significant inhibitory effects on development throughout our lifespan.

Acknowledgments

This dissertation has been extrinsically motivated via guidance and support of Dr. Thomas Edman, and Dr. Chris Kladopoulos and through the support of my immediate family via monetary assistance and psychosocial support throughout the multiple major life events and hardships. Completing a dissertation via distance learning, without the cocoon of brick & mortar protecting the student from the many additional challenges of being completely in regular world settings, is an under-appreciated task. Thus, to acknowledge the assistance of the above-mentioned individual's support will surly go unduly recognized.

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Chapter 1: Introduction

Music Proficiency and Psychosocial Functioning: How Music Training Promotes Development

Whether taking structured classes or being self-taught, becoming proficient in music performance, regardless of instrument, may benefit psychosocial development to a much greater extent than commonly acknowledged (Cheek & Smith, 1999; Fujioka, Ross, Kakigi, Pantev, & Trainor, 2006; Pallesen, Brattico, Baily, Korvenoja, Koivisto, Gjedde, & Carlson, 2010; Reimer, 2004; Shellenberg, 2006). Advantages attained through music training show an inverse correlation to age of initiation (Simons, 2001), and benefits that are compounded further when practice is intrinsically driven (Shore, 2010). Anthropological theorists have proposed that music (structured tones and percussive sounds in order to portray emotion and story) predated language as a means of communication originating within Neanderthals (Mithen, 2005). Music perception was a means of natural selection; higher music perception implied further development of cognitive substrates associated with language, emotional intelligence, and symbolic/analytical reasoning, thus, music both stimulated and promoted cognitive development in early evolutionary history (Mithen, 2005). Music is recognized as a universal form of communication with fundamental qualities inherent throughout all cultures, and until the latter years of the industrial revolution and into modern-day, song was prevalent throughout all aspects of life.

As our self-concept is clarified, we become fluent and confident in skills and behaviors, respective of that self-identity. Music is a primary ability of humans (Mithen, 2005), which means music fluency is one aspect of human development that largely contributes to self-concept (Kennelly & Brien-Elliott, 2001; & Baker, Wigram, Stott, & McFerran, 2008), and has vast implications on many areas of cognitive development. In this study, I provide evidence how these skills may in-turn lead to developmental gains that are not a clear and direct result of music training. Efficiency of neural-processing and larger cognitive reserve through the development of inherent music ability could expand individual awareness and adaptability.

Music and Identity Achievement

Creative self-expression outside of school or work is crucial for improving self-esteem and forming unique aspects of identity, as well as promoting resilience by developing attributes not dependent on external motivation (Santrock, 2007). For instance, proficiency in an art (e.g. music, painting, drawing, dance, theater, ceramics, etc) provides positive self-expression when life events are steady. However, when life becomes challenging, the arts become therapeutic tools from which an individual may productively and positively project, often achieveing existential developments along the way (Smeijsters, Kil, Kurstjens, Welten, & Willemars, 2011). Thus, development of skills to creatively express thoughts and feelings in an idiosyncratic way, promotes identity formation, psychological wellbeing, identity achievement representing maturation of self-esteem, self-concept, emotional intelligence, and intrinsic motivation. These skills build resilience and positive psychosocial functioning.

Before television and radio, music held a place of deeper value and meaning in society. Music has been a vehicle for religious and philosophical message, an art form and therapeutic outlet, a metronome for soldiers in battle, and was a standard in the workplace in order to promote morale and productivity (Le Roux, 2005). According to Le Roux's (2005), the developmental effects of music training may have been hidden from the scientific scrutiny of early psychological researchers.

The Decay of Music Proficiency and the Rise of the American Paradox

The social perception of music changed from that of a common human quality to a specialized skill, as a result of the industrial revolution and the simultaneous rise of psychology as a science (Le Roux, 2005). Musical proficiency became viewed as a form of entertainment, and because early researchers had no way of investigating the neurological effects of music training. Music proficiency may have appeared to be a product of fundamental processes instead of being the foundation from which sound replication, speech, timing, coordination, and even recognition of facial expressions of emotion develop (Grewe, Nagel, Kopiez, & Altenmuller, 2007; Shore, 2010; Spajdel, Jariabkova, & Riecansky, 2007).

Skills developed and goals set throughout our lives, are merely products of the available options for self-exploration, respective to our environment. In Western society, the majority of individuals may consider themselves lucky to be confined only by their means. Citizens of Westernized nations have a mass of entertainment, restaurants, shopping malls, and more, however, educational poverty and staggering rates of identity diffusion has become all too common (Kroger, 2007). Education reform has consistently reduced availability of learning opportunities via cuts in funding, representing a primary ingredient to the American Paradox. Increased media attention on superficial goals act as the second ingredient catalyzing the American Paradox, and keep individuals from know what more they could be explorning (Freedmon & Schustack, 2009). What good is having all this ready-made, if self-esteem comes from self-awareness, self-concept, and ultimately self-expression; products of creative experience resulting from development of skills in music and the arts? First-world ideals regard learning to consist of the three R's (Read, Writing, and Arithmetic) leaving little room for self-exploration and ironically a nonsensical acronym. To evolve out of this paradox is to learn skills from which individuals may create within an introspective space and in turn validate self-worth, which nurtures intrinsic motivation. Thus, findings showing Westernized cultures as being most concerned with image and simultaneously experiencing a high frequency of depression (Freedmon & Schustack, 2009) may not come as a surprise.

Identity formation in America is often highly influenced by superficial ideals and may be a driving force behind the high rates of discontent currently measured within our society (Freedmon & Schustack, 2009). With such high pressure on individualistic identity it seems logical to provide our society with outlets for self-exploration and expression (e.g. arts & letters) as it is noted that major contributions to identity achievement come from the realization of skills and abilities that represent the autonomous aspects of the self (Vignoles, Regalia, Manzi, Golledge, and Scabini, 2006).

Comparing Musicians to Nonmusicians

Several researchers have reviewed intelligence, attention, and motor control, in musicians and nonmusicians, and have found apparent cognitive enhancements are achieved through music training (Cheek & Smith, 1999; Helmbold, Rammsayer, & Altenmuller, 2005; Lang, 1999; Magne, Schon, & Besson, 2006; Patston, Hogg, & Tippett, 2007; Rauscher & Shaw, 1993; Schellenberg, 2006). Additionally, researchers using a variety of biological techniques such as, neural-imaging, cross-sectional, and short-term longitudinal studies have found evidence that music training advances neural development as well as scholastic achievement, general intelligence, motor control, and even the acuity of auditory perception (Goycoolea, Mena, Neubauer, Levy, Gerz, and Berger, 2007; Moreno and Besson, 2006; Nordstrom and Butler, 2006; Patston, Hogg, and Trippett, 2007). However, a large deficit for true experimental data exists and should be acknowledged when considering conclusions formed in light of current research. This is especially important when analyzing research where claims are made that musical proficiency improves performance on non-musical tasks.

In this study I investigate the fundamental working memory systems underlying those skills reported to be superior in expert musicians. These include the phonological loop, the visuospatial sketchpad, and the central executive. Respectively, these systems account for verbal processes, mental imagery, and the mediation of these processes (Baddeley, 2002; Baddeley, 2003; Buchsbaum & D'Esposito, 2008; Gregg, Freedman, and Smith, 1989). The phonological loop accounts for all verbal processes, memory and encoding respective to speech, and related auditory and motor skills. The Visuospatial sketchpad accounts for three dimensional space scanning and creating mental representations, as well as memory and encoding of such information. The central executive is the component that sifts through the information within the phonological loop and the visuospatial sketchpad, and integrates and determines what information requires more attention and thus long-term potentiation (e.g. the prospect of being held in long-term memory).

The above findings, and my personal experience, led to the research questions,

RQ1: Is an individual's ability to increase proficiency on a task of parallel processing, via guided instruction vs. no instruction (group assignment), dependent on musical aptitude?

RQ2: Does music aptitude account for differences among individuals in their ability to perform a task of parallel processing?

In this study, I utilized the Articulatory Suppression Task (AST), which has been used to measure parallel processing proficiency. The AST inhibits an individual's ability to complete a counting task due to interfering with verbal processing. The measurements in the following experiment consist of performance on the AST, which is proposed to be dependent on a second measure, Musical Aptitude. Taken together it is assumed that musical aptitude will have an beneficial influence on proficiency with parallel processing. Thus, in comparing groups on their ability to perform this task, I approached the need to enrich the explanation for how and why musical training has been positively correlated with a number of skills and cognitive processes.

Background of the Study

Researchers have found musicians have superior skills in visuospatial reasoning (Brochard, Dufour, & Despres, 2004), language skills (Moreno, 2009; Sluming, Brooks, Howard, Downes, & Roberts, 2007), as well as attention and reaction time (Hughes, & Franz, 2007; Nordstrom & Butler, 2002). Musicians have extensive training with rhythm and timing, thus they may tend to adapt these aspects of their development to other tasks. By measuring the extent to which musicians utilize the respective skills required to increase proficiency on the AST, I examined how these skills may transfer more broadly to functioning on nonmusic tasks. Specifically, the test of articulatory suppression is a test of parallel processing primarily in the realm of verbal processing, which may be made easier if incorporating a separate aspect of working memory along with rhythm.

I first instructed participants to perform a task in which they repetitively verbalize a word, while simultaneously counting the number of words in a sentence. I then instructed participants in the experimental groups to complete the task in a rhythmic manner while using mental imagery to count, and were measured for their ability to increase proficiency on the counting task. This measured an individual’s ability to adapt certain skills for use with fundamental processes of cognition, skills of which should be superior in musicians based on previous research that has examines correlations between music training and specific skills.

By creating a task that incorporated visuospatial reasoning simultaneously with activation of the phonological loop (mental imagery and verbalization), I aimed to measure to what extent differences among proficiency with these cognitive processes creates benefits to nonmusical tasks. The validity for this measurement was based in the fact that cognitive processes are primary components of our working memory system, which underlies all aspects of development. If the independent variable of musical ability truly influences the working memory systems in use during the tasks described above, then performance on the AST (dependent variable) should provide evidence for or against current correlative research findings that report musicians to be more proficient with abilities that fundamentally rely on these systems.

Problem Statement

The current lack of experimental research on the effect of musical training and aptitude on human development does not support music training as a primary area of development and education. Thus, I sought to determine whether a correlation exists between music aptitude and the cognitive processes that underlie all the abilities and skills that have been correlated to music training. If a correlation exists at this level, then musical aptitude may be correlated with active manipulation of those fundamental cognitive systems. In the following section, I will elaborate further on this gap in the current research, by examining the correlations between music training and areas of human development.

Previous researchers have highlighted how attentional differences (Hughes & Franz, 2007; Patston, Hogg, & Tippett, 2007; Pallesen, et al., 2009), superior language and sound processing (Brattico et al., 2008; Franklin, et al., 2008; Marques, Moreno, Castro, & Besson, 2007; Moreno, 2009; Schon, Magne, & Besson, 2004), and visuospatial reasoning/mental-imagery abilities (Brochard, et al., 2004; Sluming, et al., 2007) all combine to increase full-scale intelligence quotients (Schellenberg, 2006) and advanced academic performance in general. Additionally, psychosocial development, as evidenced by accelerated socio-emotional awareness (Grewe, et al., 2007), and self-concept development (Deniz, 2007) provide support for far-transfer effects of music training. Brochard et al. (2004) and Helmbold et al. (2005), found musicians consistently outperformed nonmusicians on tasks of visuospatial reasoning, while Moreno (2009) and Marques et al. (2007) found musicians to have a more robust and proficient phonological loop. These two working memory systems form a viable place to base an experiment which examines to what extent these differences might transfer to non-musical tasks. Nordstrom and Butler (2001) and Hughes and Franz (2007) found musicians to have smaller deficits on tasks of reaction, a finding that was consistent across unimanual and bimanual exercises. Building further on the reasoning for using the two memory systems in parallel to reduce cognitive demand on the AST, Sluming, Brooks, Howard, Downes, & Roberts (2007) and Lidji, Kolinsky, Lochy, & Morais (2007) both found that musicians activate regions implicated in verbal working memory during visuospatial reasoning tasks. Therefore, learning an instrument such as piano or violin promotes spatial representation of sound, thus intertwining neural circuitry between the two memory systems.

Regardless of the many correlations discovered over the past couple decades pertaining to music training and enhanced development in verbal, spatial, mathematical, general IQ and other domains of cognition (Chen, Penhune, & Zatorre, 2008; Franklin, et al., 2008; Magne, Schone, & Besson, 2006; Marques, Moreno, Castro, & Besson, 2007; Ragert, Schmidt, Altenmuller, & Dinse, 2004; Schon, Magne, & Besson, 2004; Watson, 2006), some skeptics still debate the degree to which music training aids the development of abilities outside those specific skills learned via music training (Helmbold, Rammsayer, & Altenmuller, 2005). Due to the lack of experimental research on this topic, many opponents of research findings that elude to increases for general intelligence and/or emotional intelligence, or any factor termed to be a *far-transfer effect*, criticize and point to confounding variables as accounting for results of any significance between musicians and nonmusicians (Helmbold, Rammsayer, & Altenmuller, 2005). Thus, in order to investigate the validity of correlations between music training and areas of development, experimental research must be initiated.

Purpose of the Study

The purpose of this study was to test an individual's ability to perform (as well as learn) a parallel processing task in relation to musical aptitude. Authors of several correlative studies have found musicians to outperform nonmusicians on a wide variety of cognitive tasks. However, previous research has been limited in validity as the overwhelming bulk of studies are surveys and/or correlative, thus calling for the research community to formulate experimental approaches to testing this effect. In this study, I attempted to provide experimental data for this field of study, as well as combine previous findings in order to measure the extent to which differences directly related to music training may extend to tasks outside the realm of musical tasks.

Baseline measures were established for the AST by instructing participants to complete the AST both as quickly and as accurately as possible to the best of their ability. In the experimental phase, participants were instructed to complete the AST rhythmically while segregating the two tasks that make up the AST into separate cognitive systems in order to increase attention and reduce reaction time. More specifically, participants in the experimental groups were instructed to use mental imagery for the counting task, thus visualizing numbers ascending, while engaged in the verbalization aspect to the AST. I placed participants into control and experimental groups. Each participant performed the AST in order to get base rate data. Participants in the experimental groups then were instructed on how to incorporate mental imagery via visuospatial reasoning in order to reduce demand on the phonological loop. This was necessary due to the AST being crafted in such a was as to create the expectation that one must use two verbal processes simultaneously in order to complete the task. By teaching the participants to use two separate cognitive functions, individuals with superior functioning in those domains should be better equipped to perform the task using the respective processes. Thus, perform the articulatory suppression task with greater efficiency.

The control groups went through the same number of trials over the same time frame as those in the experimental group, however, the control groups did not receive instructions for performing the task in a specific manner. This group provided the reference for a general measure of performance proficiency via practice effect. This was important for determining the validity of the learning task and respective performance on AST when completing the task under specific guidelines.

Nature of the Study

The nature of this study was experimental, and analyzed whether underlying mechanisms of working memory will persist under a task of non-musical competence. This is based on by Baddeley & Hitch's (1974) three component model of working memory, which accounts for the positive correlations presented above between music proficiency and various areas of cognition. Comparisons were made between participant musical aptitude scores and ability to utilize these attributes to overcome a task of cognitive demand. Proficiency with parallel processing of verbal and spatial working memory systems was thus measured. As such, it was anticipated that individuals with high musical aptitude would outperform those low in musical aptitude due to extended development with these working memory systems, and extended development with rhythm as a positive influence on maintaining synchronicity while parallel processing. Another perspective was that a correlation discovered between music aptitude and performance on the AST, confounded suggested baseline and thus ceilings were initially reached respective of music aptitude. Thus, this research attempted to gauge the extent to which those skills shown to be further developed in musicians may be generalized to tasks that are not musical in nature. In approaching this, it is hoped that this research has helped determine to what extent current correlations may generalize to other aspects of cognitive functioning as well as the influence that music training may have on the more controversial far-transfer development of skills via music training.

Research Questions and Hypotheses

RQ1: Is an individual's ability to increase proficiency on a task of parallel processing, via guided instruction vs. no instruction (group assignment), dependent on musical aptitude?

RQ2: Does music aptitude account for differences among individuals in their ability to perform a task of parallel processing?

Because music training is a complex task, in which motor, auditory, verbal, emotional, mathematical and other systems must operate in harmony, it represents a holistic exercise of the brain. According to Bullmore and Sporens (2009), no task is segregated to a specific region in the brain; rather, multiple areas of the brain are active in even the simplest of tasks. Thus, it has become increasingly evident that the brain, like every other organ in the body, once exercised becomes more efficient not only in the task from which it became strengthened, but in separate tasks that require the use of respective regions. Specific to the research question at hand, benefits found to be correlated to music training might all rely on robustness of one's ability to encode and process respective information; efficiency of memory systems. Thus, we measure performance on tasks that require the simultaneous use of memory systems to examine if efficiency is correlated to music aptitude test scores, and one's ability to learn skills for consciously applying parallel processing when performing tasks that require two proposed memory systems. This line of reasoning has been the basis for research comparing musicians and non-musicians on cognitive variables and is as well the basis for the following hypotheses.

Musicians were expected to be both quicker and more accurate in completing an Articulatory Suppression Task (AST) (e.g. lower response times and high accuracy). This effect was anticipated for both baseline measures and post-test scores that followed guided instruction to segregate tasks among memory systems (verbal and mental imagery) while approaching the task rhythmically; post-learning measures. Thus, the independent variable of musical ability, as measured via aptitude or achievement test scores, was hoped to be positively correlated with the dependent variable of accuracy, and inversely correlated with the dependent variable of response time, on the AST. This presumption was backed via research identifying musicians as superior in linguistic ability (Marques, Moreno, Castro, & Besson, 2007), verbal memory (Franklin, et al., 2008) visuospatial reasoning (Brochard, Dufor, & Despres, 2004), reaction time & attention (Huges & Franz, 2007; Nordstrom, et al., 2006), emotional intelligence (Grewe, et al., 2007), and intelligence in general (Schellenberg, 2006). We also anticipated finding an alternative hypothesis, in that, one does not have to be a musician in order to perform well on the AST, and that a positive correlation could exist between musical aptitude and/or achievement and performance on the AST. Lastly, we kept in mind that we could as well discover that no correlation exists between performance on the AST and musical aptitude.

Performing music is an exercise in parallel processing (e.g. simultaneous tactile manipulation, reading, and often singing as well). Thus, because of an increased proficiency with rhythm and practice incorporating multiple cognitive domains, musicians should be better able to incorporate other skills that involve verbal fluency, visuospatial reasoning, and reaction time/attention. This was expected to be displayed on the task of AST and thus musicians were expected to be able to more efficiently segregate tasks between verbal and visual processes in order to increase accuracy and decrease reaction time. Specifically, musicians were expected to be able to adapt the skills of visual processing/mental imagery and verbal processing, to the AST in a rhythmic manner in order to visualize numbers (for counting) while using verbal processing to vocalize the task that relies on the phonological loop (verbalization of a target word). In sum, participant musical aptitude score was expected to positively correlate to performance on post-learning measures of speed and accuracy, in which participants in the experimental groups were instructed on how to segregate the constituents of the AST into separate memory systems. Moreover, the control group was expected to have little or no change in performance, as they were to receive no additional training, and were to rely on innate ability/practice effect. Alternatively, these processes may receive developmental gains via other/non-music related experiences, thus reducing the ability to discriminate between musicians and non-musicians in their ability to benefit from explicit training for utilizing separate memory systems simultaneously for increasing proficiency with the AST. Moreover, it is possible that music training-promoted development on a given system is dependent on type of training (instrument(s) of proficiency, ability to site read, and other variables), thus, secondary qualitative measures were incorporated. However, it was as well assumed that the cognitive processes underlying musical performance are misunderstood and/or that proposed cognitive systems on which the experiment is based are as well misunderstood, thus the idea of parallel processing may be viewed as null by researchers who adhere to alternative theories of cognition.

AST was chosen because it is a task that initially is assumed to require the use of the phonological loop for two tasks, though upon further analysis, it may be made easier for individuals who are able to incorporate rhythm and mental imagery for counting during the verbal task, thus displacing some of the demand placed on the phonological loop (e.g. the challenge of performing two verbal tasks at once) into a non-competing memory system; the current research assumes that the incorporation of visuospatial memory may free up the phonological loop and enable more efficient processing via parallel processing. It is important to note that while we can verify the extent to which a participant may use rhythm by monitoring the rate of verbalization or by instructing them to tap their hand or foot, we cannot verify the use of mental imagery as the technology necessary for displaying mental images is still in its infancy and inaccessible. This means of divided workload was anticipated to be uncommonly applied without further guidance, since the performance of these two tasks reasonably falls under a verbal process (counting and speaking) upon first consideration. AST has proven to be a difficult task for most individuals because our verbal working memory is not designed to process more than one task at one time (Chein & Fiez, 2010; Eiter & Inhoff, 2010; Larsen & Baddeley, 2003). Research on the phonological loop, as well as other components of working memory, concludes that the amount of information able to be stored for delayed recall is relatively short, and as unrelated information is to be simultaneously remembered, content able to be stored is further reduced (Baddeley & Larsen, 2007). However, attention faculty and verbal fluency have been positively correlated with abundance of information able to be held in working memory (Loaiza, McCabe, Youngblood, Rose, & Myerson, 2011). Following from these findings, one might speculate that due to musicians' consistent elevated scores in verbal fluency (Franklin et al., 2008) and attention/concentration (Hughes & Franz, 2007), as compared to nonmusicians, not only might those participants who score higher on the musical aptitude test out-perform those participants who score lower on tasks requiring the use of these systems, they should be better equipped to combine systems during tasks that require parallel processing. Thus, if measures are valid and reliable, though no significant differences are found among participants in relation to musical aptitude, on the measures described, we must assume the null-hypothesis. The null-hypothesis in the current design was determined to be that if the developmental benefits of music training and factors underlying high musical aptitude are strictly confined to musical performance, tonal and rhythmic awareness, and learned behaviors that can only be implemented while practicing a musical instrument, those behaviors learned via music training would not to transfer to cognitive and behavioral realms outside those of music performance. As such, it was predicted in the null-hypothesis that musical aptitude would play no role in the proficiency of an individual's utilization of the visuospatial memory system with the verbal memory system in a parallel processing task.

Finally, it was important to note that because high musical aptitude may better equip participants to perform the AST, it is possible that high musical aptitude could result in outscoring those low in musical aptitude on pre-test measures by implementing those skills that will be introduced in the experimental phase, or simply via mere working-memory efficiency differences. For this reason, a control group was implemented to measure for differences in learning without the explicit instruction that was part of the experimental group procedure. This was to help with determining to what extent musical aptitude could lead to exceling on the AST without any explicit training for dividing the tasks into noncompeting memory systems.

Theoretical Base

Previous studies examining proficiency differences between musicians and non-musicians did not include a quantitative measure of music proficiency for assigning individuals to a respective group. For instance, most researchers have employed a self-report measuring a few specific variables such as years of music-training, average hours per week spent practicing, and age at which music training began (Hughes, & Franz, 2007; Schellenberg, 2006; Patston, Hogg, & Tippett, 2007; Wong, Skoe, Russo, Dees, & Kraus, 2007). Thus, in order to more thoroughly measure differences thereof, this study will take quantitative measures by administering a musical aptitude test, instead of relying only on a self-report. This study will as well implement a self-report measure to determine to what extent music training may have contributed to aptitude, since it is logical to assume increased proficiency is attained via music training, though high aptitude may not be dependent on music training. Thus, removing the confounding variable of individuals whom have innate musical talent, in turn showing superior performance on the musical aptitude test, though in other designs would have been lumped into the non-musician group without any means of making within-group discrimination.

As mentioned above, the variables of interest, regarding proficiency differences between musicians and nonmusicians, have been determined to be quantitatively significant between the groups (e.g. Hughes & Franz, 2007; Patston, Corballis, Hogg, & Trippett, 2006l; Schellenberg, 2006). Thus, the theoretical basis for this realm of research has been substantially developed, though has yet to be integrated into an experimental design as applied to musical ability. It is the focus of the current study to further the field by examining whether or not musical aptitude can account for assumed developmental gains in verbal and visual working memory systems and attention, concentration, and reaction time in a controlled experimental approach.

Definition of Terms

Amusic: without ability to perform and/or replicate musical phrases via instrument, voice, or simple bodily rhythmic feedback.

Articulatory suppression: Using mental imagery to perform a task, such as counting, when the verbal memory system is engaged in a separate task.

Central Executive: One of the three components of Baddeley and Hitch's (1974) model of working memory, encompassing the top-down processing of information entering working memory, and encoding or removal thereof.

Far-Transfer: As applied to music training, the secondary cognitive and behavioral gains achieved via music training (e.g. verbal fluency and general IQ).

Frequency tracking: The practice of hearing a note or tone and verbally reproducing it.

Near-Transfer: As applied to music-training, motor and cognitive gains directly related to practicing music (e.g. dexterity, tone & chord discrimination, rhythmic ability).

Phonological Loop: One of the three components of Baddeley and Hitch's (1974) model of working memory, encompassing verbal processes. The component dealing with memorizing, constructing, and working will verbal/auditory information.

Visouspatial sketchpad: One of the three components of Baddeley & Hitch's (1974) model of working memory, encompassing mental imagery. The component of working memory dealing with two and three-dimensional information, that is visual and imaginary, and the memorization and manipulation of this information.

Limitations & Assumptions

Limitations

To what extent an individual can utilize the phonological loop and the visuospatial sketchpad simultaneously, cannot be substantially measured. This means that we cannot be sure that participants will be engaged in the mental imagery task since we cannot observe the mental images of participants. Thus, reliance on the research findings that the articulatory suppression task reliably inhibits one's ability to use the phonological loop represents one way to mitigate this limitation, since data thereof is compelling enough to assume that utilizing this task for the aim of suppressing one's use of the phonological loop will be accomplished. Similarly, self-report measures of music training and instrument(s) of proficiency are as well subject to validity concerns, thus, we chose a test of music aptitude that was found to have both the highest validity and reliability measures.

Another concern to keeping mind is that because of the limitations of previous research (e.g. definition of music proficiency based on self-report), the current proposal assumed that the results attained from participant groups of previous research would hold if these groups were determined based on valid tests of music aptitude. Thus, this proposal assumed that the groups to be formed in the current proposal would be reflective of the groups in previous research where significant differences were found pertaining to the variables that were measured in the current proposal. This is one reason for applying a similar music proficiency questionnaire along with an empirical test of music aptitude. This not only provides a measure of validity for the questionnaire, though helps measure the validity of previous studies.

Pertaining to the model of working memory, of which we base measures of cognitive function, while the constructs we rely upon have been widely accepted as having strong theoretical basis, there are other theories of memory that are as well accepted throughout the field. Because the theory of working memory relied upon throughout this design is also the basis for a number of cognitive measures that relate to the far-transfer effects of music training, such as intelligence quotients and attention, the design continues with the same assumption that this theory, though may evolve, will fundamentally remain a strong basis for the means in which the brain processes stimuli.

Assumptions

It was assumed that participants would initially try to perform the AST via phonological memory systems only. It was also assumed that participants would be able to understand and follow the directions for implementing a mental image for counting the number of words in a sentence, while verbally repeating a single word or even reading the respective sentence; visuospatial and phonological memory in order to segregate the tasks of the AST. Other assumptions include the expectation that participants would be sober, physically/relatively healthy, rested or relatively not stressed/distracted, and that participants would perform the task honestly.

Delimitations

This study was based on neuropsychological, developmental, and cognitive models as applied to music proficiency, attention, and working memory. The phonological loop and visuospatial sketchpad are means of measuring an individual's proficiency with parallel processing, which may alleviate demand on the verbal processing network during a task that would otherwise be severely difficult if utilizing the phonological loop alone (Murray, Rowan, and Smith, 1988). More specifically, when attempting to allocate two tasks within a single working memory system, that system becomes taxed and accuracy in performance is often greatly compromised (Larsen and Baddeley, 2003). I attempted to instruct participants to divide the two tasks that compose the AST (a) verbalizing a word or reading a phrase presented via monitor or flash-card, while (b) simultaneously counting the number of words contained in the sentence, into two separate memory systems. Using separate cognitive abilities for completing the tasks (verbal/vocalizing the respective word/phrase and mentally visualizing numbers for the counting task) may be useful for measuring differences in efficiency of said working memory systems as reflected in response time and accuracy on the Articulator Suppression Task.

Some further implications of having applied a more stringent procedure, in the analysis of variables of significance with regard to music proficiency, include accomplishing assistance in building the current theory and/or dispelling certain assumptions gathered from previous research which was correlative in design. I believe that the current research may as well help to define the delimitations of future research, possibly helping to better define variables of interest.

Significance of the Study

Broad implications of this research, in line with the prospect of positive social change, have to do with providing empirical analysis of current correlations pertaining to music training and the areas of cognitive and behavioral skills reviewed above in which musicians are reliably more proficient than non-musicians. This may help determine to what extent music training should be reinstated as a core area of primary education. This is noted because under current education standards, only those disciplines that have been empirically tested to provide educational benefits to core skills receive the bulk of funding under the No Child Left Behind Act (NCLB; Beveridge, 2010), and due to the law stating that schools will be held accountable and punished if students do not perform well in the areas deemed empirical by the NCLB, schools spend more time and funding on core discipline areas, and have thus been cutting music and arts programs (Grey, 2010). This problem is exacerbated by the additional money spent on testing and accountability implemented by NCLB, as schools must pay for testing and auditing out of their annual budget, thus further stripping funding from curriculum not deemed important by NCLB (Beveridge, 2010; Grey, 2010; Pederson, 2007). This research anticipated that the use of an experimental approach for examining to what extent the proposed benefits of music training transfer to settings not directly associated with music proficiency, could help both the scientific community and policy makers determine more confidently whether or not music training is in itself an area of novel curriculum that promotes unique cognitive development that is imperative to critical thinking.

For instance, music training has consistently been correlated with extensive benefits for verbal memory, pitch perception, phonological perception, and verbal intelligence in general (Franklin et al., 2008; Magne, Schon, & Besson, 2006; Marques et al., 2007; Schellenberg, 2006; Schon, Magne, & Besson, 2004). Thus, it is reasonable to speculate that via strengthening the fundamental components of sound processing, we in turn increase fluency of attention to tonal stimuli as a result of having a richer and more efficient neuronal representation of sound stimuli. This is supported via Hughes & Franz's (2007) research and Nordstrom, & Butler's (2002) research on musicians and reaction time, and through the research of Patston, Hogg, & Tippett, (2007) in which musician displayed superior attentional capacity over non-musicians. In the following design, participants were examined on whether or not these differences hold during non-musical tasks. This would in turn provide further evidence that systems within the brain that receive extended development via music training, in turn function more proficiently when used for tasks other than music performance.

In line with defining the delimitations, determining to what extent far-transfer effects have an impact on verbal, analytical, motor, psychosocial, emotional, and other forms of development throughout the lifespan, this study may hold a degree of clinical significance. While this review will not elaborate on the clinical applications and efficacy of music, it is important to briefly note that music therapy, which can take place passively as when listening and meditating to music (Uyar & Korhan, 2011), is a well developed and empirically supported form of therapy. Music therapy can take place spontaneously as a free associative exercise, or in active construction purposefully creating a song that represents an inner conflict, ambition, loss, belief, or any number of experiences and/or emotions (Kooij, 2010). Music therapy can be applied as both a preemptive and clinical technique for processing stressors (Kim, Park, Choi, Im, Jung, Cha, Jung, & Yoon, 2011) and pain management (Sen, Yanarates, Sizlan, Kilic, Ozkan, & DaGli, 2010), while simultaneously supporting identity achievement (Deniz, 2010) and cognitive efficiency (Hughes, & Franz, 2007; Nordstrom, & Butler, 2002; Patston, Hogg, & Trippett, 2007).

To reflect positive social change, the implications of music training are vast. The broader influence of this research is the contribution of knowledge to the general public regarding development of fundamental cognitive and behavioral skills and abilities, and the contribution of music as a means of self-exploration. Without a strong identity of one’s self, direction, motivation, and purpose in life, general advancements are stifled, opening the door for existential-based problems such as depression, anxiety, and other conditions that are detrimental to psycho-social development (Kroger, 2007). Self-awareness is fundamental to building self-esteem, which in turn enriches our self-concept and increases the prospect of identity achievement (Freedmon & Schustack, 2009; & Schwartz, 2000). When an individual is highly self aware, the individual can accurately create goals and have a better understanding of how to perform in order to complete those goals. Completing goals, having one's choices and behaviors lead to expectations realized, in turn raises self-esteem (George, Dixon, Stansal, Gelb, & Phrei, 2008).

As applicable to research conclusions regarding verbal fluency and music training, language is a vehicle from which to explore and bring "color" to our introspections, thus, as Waterman, Kohutis, and Pulone (1977) concluded from their research analyzing the impact of varying forms of writing exercises on ego development, identity formation may have a positive correlation to language development; proficiency in abstract concepts promotes both identity formation and positive psychosocial development. Moreover, it has been noted that ethnic identity among displaced individuals is often dependent on fluency in native language (Kim & Chao, 2009). Thus, it is not a big step to conclude that language is a vehicle for extended identity development (Joseph, 2004). In this way, music training does not only provide benefits in an array of cognitive domains, though instills resilience by providing existential balance via promotion of identity achievement.

Summary and Transition

Music is deeply ingrained in human development. However, very little experimental research has been performed, examining the specific skills developed through musical training. Though once we began comparing individuals who had received music training with individuals who had not, it became of interest to understand if the significant differences found in many facets of human development were in fact due to the skills developed through music training. In the following chapter this theme will be addressed via literature review, and the correlations between music proficiency and other forms of development will be examined in detail.

Chapter 2: Literature Review

Neurophysiology of Sound and Music Perception

A large amount of research on music training and development has been devoted to neurophysiological processes, greatly aiding in understand the interconnections between auditory, motor, and executive pathways and how developmental effects come about due to these complimentary networks. Thus, this chapter will begin with an overview of the neurophysiology of sound perception and the influence of music training on this sensory system so as to accommodate the reader to processes that will be presented latter regarding neural imaging. Moreover, because the topic at hand is multifaceted and touches on a number of cognitive processes, research on working memory systems will be included. Specifically, the phonological loop and visuospatial sketchpad, as these were implicated in the experiment and thus should be well understood before going into rich detail regarding the main topic of the effects of music training on development. Therefore, the final two of sections of this chapter will discriminate between the direct and indirect ways that music training has been correlated with development; near-transfer and far-transfer effects of music training on development. Lastly, the information contained below was largely obtained via EBSCO search engines such as *Academic Search Premier, Psych info, ERIC,* and others similar databases specific to psychological research and educational research. Other routes used to obtain information included the University of Oregon Knight Library and Music Library, APA services, Psychology of music website http://pom.sagepub.com/, and other similar services.

Case Studies

When modern researchers first developed an interest for looking into the effects of music on development, researcher designs were confined in their approach due to a lack of technology. Many designs relied on a correlative approach to gathering data, and often focused on individuals who had experienced some form of neural infract, and the resulting reservation or degradation of musical ability, in order to start creating a basic neural map of where music might be seated in the brain. For example, unilateral lesions of the temporal lobe including Heschl's gyrus, consistently produce contralateral deficits in auditory processing for most musical sounds, including speech recognition (Kimura, 1961). However, when Heschl's gyrus was spared, normal speech recognition was unaffected, though music perception was still compromised (Milner, 1958). While studies such as these provide insight into starting points for mapping music-cognition, they were crude and relied on haphazard incidents that could provide data, and are thus unable to be recreated due to obvious ethical concerns.

At the same time, we have not completely ruled out this approach as a viable means of mapping. Thus, as cases pop up that present more localized damage, they can provide further insight. Steinke, Cuddy, and Jakobson (2001) discovered an individual who became amusic following a right-hemi stroke. These researchers were able to further discriminate the right/left hemi-specific functions of music perception, after the individual lost the ability to perceive pitch as well as reproduce rhythms of even simple structure. This presented as the individual having a combined loss of melody perception. However, language related abilities remained intact due to Heschl's gyrus remaining unscathed. It was thus concluded that the areas of damage (right-fronto-parietal & areas within the cerebellum) were specific for encoding and storage of instrumental or pitch-related information. And the planum temporal was specialized for encoding and storage of lyrical content, as evidenced by the individual having retained the ability to recognize songs only via lyrical content. Interestingly, in a separate case study, an individual lost the ability to discriminate percussive and piano timber after experiencing extensive deterioration of the right superior and middle temporal lobe (Kohlmetz, Muller, Nager, Munte, & Altenmuller, 2003). Findings of malfunction due to infract may help build general hypotheses, though the bulk of case studies therein are void of participants representing a prior ability of high music proficiency, and thus may not generalize to musicians. And as we will see below, differences in one's level of musical proficiency consistently positively correlates with developmental effects on efficiency and robustness of functioning during perception and reproduction of sound in general.

Looking at Sound

It has long been a popular notion that the brain is largely lateralized and thus segregates function according to hemisphere and specific function. Some researchers of sound perception implemented a dichotic listening design in order to measure accuracy of sound-type recognition between hemispheres. For instance, Hoch and Tillmann, (2010) presented music and language related sounds randomly to either the left or right ear, via sound canceling headphones. Due to the contralateral nature of sound encoding within the auditory pathway, most individuals more readily discriminate music related sound when presented to the left ear, and non-music related sound when presented to the right ear (Hoch & Tillmann, 2010). However, this effect is reduced nearly to the point of non-existence in musicians (Spajdel, Jariabkova, & Riecansky, 2007), which was a preliminary line of evidence and thus a motivator for implementing neural-imaging techniques for studying neural-anatomical differences between musicians and non-musicians.

With respect to increased bilateral activation via music training, increases in the size and density of the corpus callosum were suspect as an underlying factor leading to this phenomenon (Schlaug et al., 2009). To test this hypothesis, participants were administered two to five hours of instrumental practice each week, over the course of twenty-nine months. After this timeframe, Schlaug and colleagues (2009) observed significant increases in corpus callosum fiber tract density that projected to the prefrontal and premotor corticies as well as the supplementary motor areas. While this finding is not without the prospect of confounding variables, these increases in axonal densities are strongly suggestive of one primary variable underlying bilateral activation of music and language processing, which is commonly seen in musicians though void in individuals having not received music training.

Wong et al. (2006) uncovered evidence that lemniscal and non-lemniscal neurons, which encode sound-signals originating from the cochlea within the ear, gain efficiency via music training, and thus promote fine-tuning of the inferior colliculus due to high demand for complex sound discrimination. Specifically, it was discovered that musicians were superior on tracking frequencies. This was portrayed via exact cortical representation during frequency tracking exercises. Meanwhile, nonmusicians neural-images displayed gross inaccuracies in frequency tracking, even though individual reports of accuracy made by non-musicians were to the contrary, showing lack of inability to even be aware of slight changes in frequency. In a similar line of research, Magne and colleagues (2006) also concluded that children who experience rich music training were both quicker and significantly better able to recognize variations in pitch, as recorded via event-related brain potentials (ERPs). And Brattico et al. (2008) found this effect to be present for chords as well as dissonant sounds. Moreover, a bilateral distribution of processing was present for children receiving music training, and the common hemi-specific distribution of processing, as noted above, was seen in nonmusician children.

While ERPs represent a topographic function, it has been suggested that the underlying pathways (from PVCN, to lateral lemniscus and inferior colliculus) are strengthened, enhancing encoding and precise sound representation (Zendel & Alain, 2008). Thus, it was concluded that these lower-level benefits are foundational for enhancements seen in language processing and phonetic store since a strengthened subcortical auditory pathway leads to more precise discrimination of sounds as well as a general increased proficiency with information processing throughout the auditory cortex, as well as adjunctive areas of the cortex and neo-cortex. Seither-Preisler et al. (2007) also found musician’s sound-processing to be more accurate than those without music training, Musician’s perception of changing pitch and timber was remarkably more sensitive than that of individuals reporting as nonmusician.

This lower-level developmental strengthening provides encoding benefits, as well as increased robustness to executive functioning; strengthening primary networks results in developmental gains to neo-cortical regions. Evidence comes from Wong and colleague's (2006) conclusions regarding enhanced executive interactions, resulting from more robust encoding. Instead of wondering whether sound awareness benefits come from strengthened lower-processing, resulting in richer encoding, or enhancements to neo-cortical regions which in-turn provide additional awareness and meaning to sound-source, we could just as easily assume both systems receive gains via music training, which provide mutual benefit. Perhaps more interesting is that while non-musicians believe they comprehend precise changes in sound quality, research shows this to be incorrect, and that non-musicians lack the executive and/or sub-cortical processes for such awareness. This means that a non-musician's perception of the sounds within their environment, and thus the continuum for which sound discrimination is judged, is constricted. This is due to the formation of specific neurological faculties having never been developed, and thus comprehension and/or awareness of certain sound qualities, and possibly certain sounds in general (e.g. being aware of the sounds of a foreign language, that are absent in one's native tongue), will be impossible and the individual, and the person will thus be completely ignorant of these aspects of sound within nature.

As seen above, initial neurophysiological research aimed to investigate melody, motor-systems, and lateralization effects of music training. This research uncovered developmental variations in prefrontal (specifically dorsolateral), parietal, cerebellar, corpus collosum, and various frontal regions, as well as general areas of sound processing localization. Strikingly, out of all this research examining neurophysiological effects of music training, metacogitive-music surfaced as a secondary discovery. In a compelling line of research, Goycoolea and colleagues (2007) showed how all of these regions come together to produce auditory sensations in the absence of external cues. Here it was found that the entire sample of musicians, 100 participants, could evoke music mentally and nearly all could modify a respective song at will. However, less than twenty percent of the non-musician sample could evoke, let alone modify, music mentally. Via single photon emission computed tomography, it was found, that for participants to be able to perform the task, the prefrontal cortex had to become very active (specifically areas 45 & 46), as did the primary auditory cortex, Wernicke’s area, and frontal executive cortices (areas 9 & 10) during a mental-music task. These results were expected, though invigorating none-the-less, considering the executive nature of the task. More interestingly though, the visual association area, thalamus, and cingulate gyrus, (31, 32, 45, & 46) displayed significant activity as well; the cingulate gyrus had an inhibitory effect on area 38 of the temporal lobe, which implies that for mental representations of music, the primitive auditory regions may have to be blocked.

In sum, the combined evidence above implies that music training, by increasing the accuracy and efficiency of sound encoding, reduces strain on the subcortical networks. This in turn provides richer perception of stimuli for the development of cortical regions and executive functions that are both closely related (e.g. frequency tracking) and more distantly related (e.g. mental music manipulation, language development) to processes evoked during music training. Because our sense of sound is such a fundamental aspect of the human experience, just as exercising the body benefits physical ability, and thus provides a number of secondary gains, so too is it logical to conclude that refining sound perception via music training would have vast benefits for immediately related and otherwise distant neural processes.

Working Memory

A major aspect of the research design below was based on the evidence that working memory systems have a baseline of operational proficiency throughout the majority of individuals having been tested. More importantly, that people can maintain efficiency while operating these subsystems simultaneously. Thus, as critics of far-transfer effects of music training will propose, and as would be inline with the null-hypothesis of the current research, there should be no difference between people of varying music aptitude during simultaneously processing information within working memory systems, systems which underlie all aspects of intelligences. However, because the evidence points toward increased proficiency in all subsystems of working memory via music training, we should expect musicians to show superior performance in accuracy and processing speed when comparing performance on tasks aimed to measure these systems. Thus, at this point the topic will shift to focus on the specific model of working memory that will be of use in the research at hand, and each component of that system will be examined so as to bring clarity to the importance of working memory as a variable behind far-transfer effects of music training.

A handful of competing theories exist as to the specific components and/or subsystems of working memory, though it has been Baddeley and Hitch's (1974) theory that has received widespread acceptance and empirical validation throughout the field of cognitive neuroscience (Gregg, Freedman, and Smith, 1989; Baddeley, 2002; Buchsbaum & D'Esposito, 2008; Baddeley, 2003). Because of its extensive history of enduring scientific scrutiny, this three-component model continues to provide a base from which research hypothesize about working memory (Aboitiz, Aboitiz, and Garcia, 2010; Baddeley, 2003; De Beni, Pazzaglia, Gyselinck, and Meneghetti, 2005). For this reason, Baddeley and Hitch's (1974) construct of working memory to be an efficacious concept to apply in this study.

The three main three-components of this system are the visuospatial sketchpad, the phonological loop, and the central executive (Baddeley & Hitch, 1974). Respectively, the phonological loop retains sound related information and meaning thereof (Baddeley & Larsen, 2007), the visuospatial sketchpad represents three-dimensional viewing; our "mind's eye" or imaginative capabilities (Logie, Pernet, Buonocore, & Sala, 2011), and the central executive mediates attention paid to a given stimulus, sorts information by relevance, and mitigates innate responses (Kiss, Pazderka-Robinson, & Floden, 2001). As information enters the working memory system, it is encoded respective of content and subjective importance, and is segregated to either the phonological loop or visuospatial sketchpad. Almost instantaneously, relevant information is encoded and manipulated executively, enhancing its viability and thus probability of integrating with long-term memory. Simultaneously, information is continually deemed irrelevant and discarded in order to increase capacity of cognitive reserve (Loisy, & Roulin, 2003).

The phonological loop and visuospatial sketchpad sustain linguistic and visual information, respectively, for a period of time, seemingly respective of both subjective and objective importance (Baddeley, 2002; Baddelely, 2003), which both determine attentive resources allocated toward a given stimulus. This is important to keep in mind, since recent research has provided evidence that attentional capacity is a distinct component of working memory (Buehner, Mangels, Krumm, & Ziegler, 2005). In short, this helps validate the idea that we are able to direct out attention executively, as a tool, without interfering with the operations of working memory. Thus, the importance of the stimulus determines to what degree information will be maintained in working memory, and the attention paid to the stimulus is largely a conscious decision. It is important to clarify that some information is destined to extrinsically demand our attention and even move from working memory into long-term memory regardless of individual differences in attention paid. For example, witnessing a catastrophe, or experiencing an amazing work of art or live performance, each person would no doubt remember the event, though the details that make it to each individual's long-term memory will be strongly influence by subjective importance, the individual's level of suggestibility, and (as noted above) the individual's developmental capacity to comprehend the stimulus (Henry & Gudjonsson, 2007; Peters, Hock, & Krohne, 2012).

Incoming information of this quality reaches working memory in a raw form via neuronal projections that bypass the core components of the auditory and visual processing systems. These signals arrive in the prefrontal cortex, sent from basal regions, ahead of the initial stimulus-information that receives detailed encoding on its way toward executive regions. Thus, in some instances we are alerted that a stimulus requires attention well before we are consciously aware if it. A good example of this would be the baseball pitcher who throws a ball from the mound only to find the ball instantly in his mitt inches from his face in response to the batter hitting the ball right back him; subconscious perception within working memory. However, for the purposes of the current research, it is the top-down processing that we will be most concerned with, as the task of articulatory suppression is an executive exercise of parallel processing.

Phonological Loop

The phonological loop is subdivided into the phonological store and subvocal rehearsal, which represent phonological capacity and the function of speaking without vocalizing (i.e. internal voice), respectively. These two components determine the robustness of an individual's verbal working memory (Baddeley, 2002). For the majority of individuals, the phonological store may have a somewhat small deviation around the upper-limit for the amount of information able to be held within. People with superior phonological capacity appear to be more efficient with both subvocal speech and directed attention, evidencing the current hypothesis that aside from other external variables regarding robustness of working memory, the phonological store is time-sensitive, thus the quicker one's subvocal rehearsal the more efficient the store (Baddeley, 2003; Buhner, Mangels, Krumm, & Ziegler, 2005). This hypothesis has evolved out of research implementing techniques aimed at suppressing one's ability to access the phonological store, the most often used technique being articulatory suppression, in which an individual is asked to repetitively vocalize a given word or string of words while simultaneously attempting to memorize a second set of written or audio-presented words (Gregg, Freedman, & Smith, 1989). The phonological store is reliably suppressed via articulatory suppression, irrelevant auditory stimuli, random interruptive pure tones, though interestingly, the phonological store appears to be uninhibited when white noise is used as an interruptive stimulus (Jones, 1993). This suggests that the central executive and/or the phonological loop discriminate between meaningful and non-meaningful auditory stimuli for entry into the phonological store, and ultimately encoding into long-term memory. Moreover, factors such as phonological similarity among to-be-recalled stimuli and irrelevant sounds and speech, have an impact on the phonological store and subvocal rehearsal, respectively, inevitably affecting the amount of information able to be held in the phonological loop (Baddeley, 2002; Buchsbaum & D'Esposito, 2008; Baddeley, 2003). These variables burden the phonological loop, and regarding phonological similarity, fundamental coding errors within the system that may otherwise be in place for efficiency ultimately reduce recall due to oversimplification (Baddeley, 2002). An example of this would be attempting to memorize a list of words, in which select words are presented multiple times. Here it is much easier for our working memory system to maintain each unique word in the phonological store, though the duplicates seem to be chunked together, thus, memorizing how many times each word is presented is a much more difficult task.

A number of studies have implemented articulatory suppression in order to examine whether or not the phonological loop can encode new information when subvocal rehearsal is engaged in a separate task. All of which found that effectively blocking new information from entering subvocal rehearsal drastically reduces the amount of information able to be recalled (Gregg, Freedman & Smith, 1989; Rowan & Smith, 1988; Saeki & Saito, 2004). For this reason, it is theorized that the phonological store relies on subvocal rehearsal for the maintenance of information (Larsen & Baddeley, 2003; Franssen, Vandierendonck, & Van Hiel, 2006; Murray).

Because the phonological loop encompasses verbal working memory, which is a system unique to humans that can be easily researched through observed verbal tasks, it is viewed as more accessible to researchers than the visuospatial sketchpad (Aboitiz, Aboitiz, & Garcia, 2010). Moreover, the phonological loop has reliably been mapped through neural-imaging, many aspects of which have been verified by rigorous tests that simultaneously implement techniques such as fMRI and EEG (Chein & Fiez, 2010; Kiss, Pazderka-Robinson, & Floden, 2001). Broadly speaking, this system includes the superior temporal lobe, Broca's area, and the inferior parietal region. The latter of which are hypothesized to mediate subvocal rehearsal and context-specific storage, respectively, and a number of direct and indirect fiber tracts that connect said regions (Aboitiz & Garcia, 1997; Smith & Jonides, 1998).

Visuospatial Sketchpad

The visuospatial sketchpad is the network in charge of monitoring spatial and visual information, allowing for the creation of mental representations in the form of 3-dimensional images (De Beni, Pazzaglia, Gyselinck, & Meneghetti, 2005). Like the functional capacity of the phonological loop, the subsystems of visuospatial memory can process simultaneously, enabling an individual to mentally manipulate an object while coding simple spatial information (e.g. navigating the environment while monitoring for specific cues). Also similar to the phonological loop, these subsystems cannot reliably perform more than one spatial task per subsystem (Hyun, & Luck, 2007), thus one cannot reliably memorize a maze if concurrently brainstorming on the construction of a painting or performing a mental rotation task, which will be elaborated on below. Furthermore, it is important to keep in mind that visuospatial proficiency is significantly influenced by genetics; sex differences appear as universal and respond respectively to environmental stimuli such as SES and education, a trend observed throughout more than fifty countries (Lippa, Collaer, & Peters, 2010), and consistent when using a variety of measures (Titze, Heil, & Jansen, 2010).

Unlike the ease with which researchers have approached the measurement of the phonological loop, the visuospatial sketchpad is more elusive and constructing tasks from which to measure it have to been more difficult to achieve (Quinn, & McConnell, 1996). For instance, if we aimed to measure storage capacity of visuospatial memory by asking participants to memorize a number of pictures, we would immediately run into reliably issues since we cannot be assured that participants will be able to suppress subvocal rehearsal. Even if participants try to abstain from this act, speech is so powerfully engrained in the means with which we process the environment, the act of attempting to shut it off might interfere with our ability to efficiently use the visuospatial sketchpad alone (Anderson, 1998). As we will see, specific tasks such as articulatory suppression may be utilized to increase the reliability of visuospatial measurements since the phonological loop cannot perform two verbal tasks at once. And as researchers have noted, the phonological loop and visuospatial sketchpad may be accessed simultaneously without causing significant interference in each working memory system (Baddeley & Hitch, 1974), which is a critical piece of information concerning the design at hand.

One of the more common means of measuring visuospatial working memory is the task of mental rotation. This involves viewing a three-dimensional picture, usually an object composed of a dozen or so cubes connected to form a random shape. A participant is instructed to choose which shape from a list of similar objects, which would represent the exemplar when rotated a certain number of degrees to the left or right. Here the participant must be able to form a mental replica using the visuospatial sketchpad, and then rotate the mental image in order to determine how the object would appear if repositioned a given number of degrees (Hyun & Luck, 2007). This task has become a mainstay for measuring visuospatial proficiency due to the ease with which it may be implemented, its reliability, and most importantly, its validity since the task requires no phonological processing. Other means of measuring visuospatial proficiency appear to have evolved from tasks created for testing phonological capacity. For instance, similar to the irrelevant noise/word task, in which interference from competing sound places demand on the phonological loop, researchers have adopted an irrelevant pictures task for placing demand on the visuospatial sketchpad when measuring visuospatial capacity (Quinn & McConnell, 1996).

A thorough comparison of processing efficiency between the phonological loop and visuospatial sketchpad, has been performed by De Beni, Pazzaglia, Gyselinck, & Meneghetti (2005). These researchers compared the effects of spatial recall during either spatial or phonological interference, and vice versa for phonological recall. The results were equal between systems. As portrayed in previous research, interference of spatial encoding, via participants performing a secondary spatial task led to decreased encoding and thus reduced recall of spatial information, though minimal decrements when the secondary task was phonological. Results of which were identical when testing the phonological loop similarly. This line of research provides strong evidence that these two systems have an equal capacity for encoding information, and while they are able to simultaneously operate, if multiple stimuli enter the system, encoding becomes compromised.

Central Executive

Underlying the phonological loop and visuospatial working memory in the central executive, which helps sort and encode information respective of quality and importance. Structures within the prefrontal cortex and basal ganglia work together, forming the central executive component of working memory. The prefrontal cortex is of prominent importance for retention of verbal and spatial information in working memory, as displayed through experiments in which the prefrontal cortex in monkeys had been cooled, thus effectively inhibiting metabolism, resulting in reduced recall (Shindy, Posley, & Fuster, 1994; Bodner, Kroger, & Fuster, 1996). Meanwhile, the basal ganglia directs task-relevant sorting of information, thus mediating which information should be kept in working memory and which can be dissolved (O'Reilly & Frank, 2006). It is in the basal ganglia where the ascending connections that bypass the more in-depth encoding, which were covered in the section on sound processing, originate and thus project signals to the prefrontal cortex ahead of the primary signals that are represented in the bottom-up processing and are then manipulated consciously. These bypass-circuits are what we experience as extrinsic reaction, directing our attention toward stimuli that require our immediate attention. Because the central executive organizes and maintains information, deficits thereof lead to gross shortcomings in one's ability to not only encode information into long-term memory, though reduces one's ability to maintain attention on a given stimulus or task. Commonly, deficits are experienced in the form of top-down processing, as opposed to bottom-up (prefrontal vs. basal operations). This is experienced as an inability to efficiently sort information by relevance, encode with subjective importance, and most importantly, exercise executive mediation over the basal ganglia, which reduces the ease with which an individual maintains attention on a given stimulus (Karatekin, 2004; Laine, Toukkola, Hiltunen, Vorobyev, Bliss, Baddeley, & Rinne, 2009). A deficit in the central executive, in which environmental stimuli may overload the phonological loop and visuospatial sketchpad, is more commonly characterized via disorders such as ADHD and bipolar disorder.

Various delayed recall tasks have been combined with fMRI in order to provide a physiological measure of working memory, among individuals with ADHD and individuals without ADHD (Fassbender, Schweitzer, Cortes, Tagmets, Windsor, Reeves, and Gullapalli, 2011; Rapport, Alderson, Kofler, Sarver, Bolden, & Sims, 2008). Fassbender et al (2011) found that prefrontal activation, which represents maintenance of information during delayed recall, was nearly absent in people with ADHD. This led to speculation on the possibility that working memory tasks had been assigned to other regions of the brain that were inferior for information maintenance and storage. Moreover, the lack of executive control over the basal ganglia would explain the inability of individuals with ADHD to maintain attention on a given stimulus. Gibson, Gondoli, Flies, Dobrzenski, and Unsworth (2010), confirmed this effect in people with ADHD, differentiating between immediate recall and delayed recall, and noting that it has been recoded across both verbal and spatial memory. Thus providing further evidence that a third component, the central executive, is compromised in people experiencing ADHD. This is an important piece of information to keep in mind, as ADHD represents a confounding variable that may need to be controlled for when applying working memory research to a given population.

Music Training and Near Transfer Effects

Music proficiency and development can be sorted into two categories, near-transfer effects (those developmental effects that are directly related to music training and are thus hardly disputable) and far-transfer effects (indirect increases in skills not commonly regarded as related to music). Near-transfer effects include, though are not limited to, increased tactile ability (Ragert, Schmidt, Altenmuller, & Dinse, 2004; Watson, 2006), rhythmic fluency (Chen, Penhune, & Zatorre, 2008), and fine-tuning of pitch perception (Magne, Schone, & Besson, 2006; Schon, Magne, & Besson, 2004). Far-transfer effects have been reported for language development, and include such results as increased phonetic store, and verbal intelligence (Franklin, et al., 2008; Marques, Moreno, Castro, & Besson, 2007; Moreno, 2009; Moreno & Besson, 2006). Other researchers have reported advantages for visuospatial ability (Brochard, Dufour, &

Despres, 2004; Lang, 1999), perceptual reasoning (Helmbold, Rammsayer, & Altenmuller, 2005), attention and concentration (Patston, Hogg, & Tippett, 2007), parallel processing via cognitive tasks such as the Stroop test, and even benefits to reaction time have been significantly correlated to music proficiency (Franklin et al., 2008; Hughes, & Franz, 2007; Nordstrom, & Butler, 2002).

The larger focus of research pertaining to near-transfer effects has been in the form of examining the strengthened auditory processing and correlation to positive effects on language development, in relation to music proficiency. Moreno and Besson (2006) examined the degree to which music training would increase pitch processing, as a measure of reaction time via electro-encephalograph recordings. Here, children having biweekly music training, for 40 minutes per class, were found to develop superior efficiency for pitch processing, as reflected in both reaction time and cognitive demand (reduced EEG output), when compare with children who did not receive the music course and went to a painting class instead. In a very similar research design utilizing EEG recordings, children's who have had three to four years of music training were found to have a significantly greater ability to discriminate pitch violations in music as well as language Magne, Schon, and Besson (2006). These findings were reflective of differences found to be in adult musicians, when comparing to people without a history of music training, though the participants in this study were merely 8 years of age. Moreover, while children who are taught music consistently outperformed non-musically trained children on the tasks of pitch identification for both music and language violations, there was an impressively large discrepancy between groups for error rate on identifying violations that were set-up to be less noticeable, thus showing that small discrepancies are largely unnoticed, or generalized in neural processing, for children who have not received music training.

Extending this research design, Marques, Moreno, Castro, and Besson (2007) compared expert musicians to non-musicians on ability to discrimination phonetic/pitch variations when listening to a foreign language. Again, musicians significantly outperformed non-musicians when discriminating among phonetic variations of subtle pitch difference, results of which were confirmed via event-related potentiation in the neurological readouts showing musicians to have sorted the phonetic information more efficiently than non-musicians. Though unlike previous designs, the researchers excluded a comparison of pitch-processing for music, and instead examined the ability of previous findings to generalize to novel stimuli (e.g. unfamiliar phonemes and morphemes). Thus, extending the pitch-processing benefits found via music discrimination trials to language. These results suggest that the underlying organic changes achieved via music training, set the stage for accelerated learning, thus accounting for far-transfer effects.

Some of the strongest research to date, pertaining to the effects of music training and language related development, came from Prio and Ortiz (2009). These researchers measured language proficiency throughout the school year, from beginning to end. Here they compared two groups of second-grade elementary school children, one having piano lessons throughout the year, the other having no music training. This study was well constructed, as other variables such as SES, parental educational level, educational curriculum and extracurricular variables were held constant among participants. The preliminary measures (starting point scores) found no differences in language proficiency among the groups, though at the close of the school year, the group having music training gained an average of three points on the verbal portion of the Meeker Structure of Intellect test, while the non-music training group had less than half a point gain on average. Being that the participants received the same education throughout this study, researchers concluded that these findings provide strong support for the influence of music training on verbal proficiency.

Because near-transfer effects are pertaining directly to the skills learned via practicing a music instrument, thus logical results from training, it is no surprise that individual gains thereof are not only commonly found when group comparisons are made. Near-transfer effects are thus readily accepted by even those who are highly skeptical of far-transfer effects of music training. Moreover, because research findings that find positive correlations between music training and near-transfer effects are seen throughout the field as being common sense, many attempting to provide empirical evidence thereof, incorporate neurophysiological data into their designs, so as to provide an organic reflection of respective developmental gains. Hyde, et al. (2009) preformed one of the first longitudinal studies examining the effects of music training on development. At the outset, two groups of 6-year-old children were measured on tactile and auditory fluency in respect to neurological development, mapped via fMRI. Following these preliminary measures, one group received music training and the other did not, holding all other variables constant, as similar to the study by Prio and Ortiz (2009) cited above. The children were reassessed after 15 months and were found to differ significantly on a number of measures. First, the music-training group scored superior on the tactile (right hand) and auditory measures, and while the left hand approached significance, performance scores thereof were barely under the threshold. More compelling was the finding that the music-training group had a significant increase in the development of their right precentral gyrus, right primary auditory region, and corpus callosum, thus mirroring the behavioral findings. While the researchers did not find any significance between the groups on full-scale measures of intelligence, or neurological development, having such strong results after a mere 15 months suggests the need for longer-term studies in which brain formation and behavioral changes could be more extensively analyzed. Such studies may help researchers account for the far-transfer effects in which adults, who have had extensive music training, outperform individuals who have no music training on a number of cognitive measures.

Another line of research came from Brattico, et al. (2008) utilized magnetoencephalography in order to provide topographic representations of individual differences between musicians and non-musicians for chord discrimination. This research concluded that musicians had superior recognition of mistuned chords, and as of neural representation, musicians tended to have more localized representation, thus implying more accurate encoding as well as reduced cognitive demand. Following from these results, Pallensen, et al. (2009) concluded that musicians were better able to complete a working memory task of increasing complexity, due to larger cognitive reserves going into the task. This was reflected via positive correlation to prefrontal cortical activation, which, upon initial consideration, appeared contrary to the general theory that decreases in activity are reflective of improved executive efficiency due to stronger, specific, and localized encoding. However, in this study, it was concluded that increases in cognitive activation reduced generalization of task procedures and thus enhanced adaptation as the task became more complex. And the increased prefrontal activation was due to superior neuronal density, rather than increased generalized activation, as has been concluded in other fMRI research involving people who have been through extensive music training (Hyde et al., 2009; Goycoolea et al., 2007).

In a similar line of research, Chen, Penhune, and Zatorre (2008) applied a rhythm reproduction task to musicians and non-musicians. While musicians were consistently found to have completed the tasks making fewer mistakes on the three task-levels of increasing difficulty, the overall results failed to produce significance regarding accuracy. The interesting finding, via fMRI, was that musicians appeared to learn the task executively, as displayed via increased activation of the dorsal lateral prefrontal cortex, while non-musicians portrayed the classic music-relevant auditory pathway activation, thus relying on bottom-up processing to reproduce the stimuli.

An enduring theme throughout the above research is that of positive correlations between music training and processing efficiency, music training and verbal fluency, and music training and neuronal densities. Increased neuronal density expands the range of cognitive output, enhancing executive functions by reducing generalizations when necessary and/or maintaining acute awareness of sound and rhythmic stimuli via more localized discrimination via top-down processing. Individuals become better able to perceive subtle variations in stimuli, in-turn gaining direct benefits for language processing and acquisition. Moreover, from a top-down perspective, both executive and primitive networks receive developmental gains via music training, and those pertaining to executive functions may be more beneficial for both near- and far-transfer effects. These findings also help explain Schellenberg's (2006) conclusion that music training produced long-term positive effects on intelligence quotients, likely due to increases in prefrontal neuronal densities, and thus an efficiency in processing that should far-transfer as benefits to fundamental aspects of cognition such as working memory and attention (Chen, Penhune, & Zatorre, 2008).

In sum, the neurological benefits of music training increase efficiency of both bottom-up encoding and top-down processing. And while enhanced sound discrimination is the most obvious benefit of music training, hence the term near-transfer, due to the requirement of parallel-process during music performance, so too do the motor and temporal components of development receive gains. This leads to the controversial topic of far-transfer effects of music training. Because it is logical to suggest that exercising a muscle using a certain device or machine will not confine that muscle to be strengthened only for the task of operating said machine, it should not be ill-logical to suggest that benefits regarding executive functions taking place in the precentral gyrus (Hyde, et al., 2009), dorsolateral prefrontal cortex (Chen, Penhune, & Zatorre, 2008), corpus callosum (Schlaug et al., 2009), superior parietal and many other connecting regions (Goycoolea, et al., 2007), all of which are implicated during sequencing and tasks of temporal complexity, should not be confined to the task from which they were strengthened. This leads to the next section investigating the effects of music training on human development; far-transfer effects.

Music Training and Far Transfer Effects

As noted above, near-transfer effects have been readily accepted among researchers as logical results of music training, far-transfer effects tend to receive criticism due to multiple confounding variables when considering correlations between music proficiency and increased performance in areas not apparently directly related to music training. For example, Schellenberg (2006) compared Wechsler Intelligence Scale for Children third edition (WISC-III) test scores and the Kaufman Test of Educational Achievement (K-TEA) among children of ages 6 to 12 years, to number of hours spent in music training. Here, a strong positive correlation was found among most composites of each of these tests to hours of music training. Interestingly, while music lessons and parents' education produced similar correlations to WISC-III and K-TEA scores, processing speed was found to correlate positively to music training alone. Results were compared to family income as well as nonmusical extracurricular activities, both of which held little or no significance. Of the more persuasive findings from Shellenberg's (2006) research were the results gathered in phase 2 of the design, in which the same methods were applied to college students, though with testing instruments respective of adult functioning (e.g. the Wechsler Adult Intelligence Scale third edition, WAIS-III). Here, correlations between intelligence quotient and parents' education were dramatically reduced, significance found only with verbal comprehension, and barely thereof. However, the variable of playing music regularly correlated significantly with nearly all measures of intelligence and academic performance, though for college students processing speed was found to have no significant correlation. This finding was inconsistent, being that in the first phase of this research with the groups of elementary school children, the strongest correlation was between music training and processing speed.

In another study, Goyocoolea, Mena, Neubauer, Levy, Gerz, and Berger (2007) found that adult musicians, as compared to adult non-musicians, had superior Flexibility of Closure (FLC) and Perceptual Speed (PS) scores. However, FLC and PC represent only a fraction of the domains measured with the WAIS-III, and when taking full-scale intelligence scores, researchers often find insignificance in scores between groups since the full-scale quotient is regularly held at a higher degree of significance than the subtests. Thus, it can often be confusing when analyzing the data and finding significance among scores between participants on subtests, though when all subtests are combined the data concludes results to be insignificant. While the reasoning behind this decision has some degree of subjective determination, the fact remains that the strongest correlation is often between music training and perceptual speed. However, Schellenberg (2006) found these variables to be insignificant among adult musicians, which further muddies the collective data regarding how and to what extent music training contributes to the development of general intelligence. Perhaps depending on which side of the far-transfer fence a researcher sits, determines to what degree significance is achieved in the results. Moreover, due the inconsistency for which domains of intelligence are found to have positive correlations to music training, it may be necessary to further distinguish which are more or less consistent and then look for correlations to type of music proficiency, as much of the research to date regards the title of expert musician to be broadly defined under the qualification of at least a decade of formal training.

The findings regarding differences in general intelligence are both compelling and controversial, thus it is important to dissect the research for specific systems underlying our construct of intelligence. Brochard, Dufour and Despres (2004) formed a study in which musicians and non-musicians performed a task of visuospatial reaction time. Here participants went through two phases of testing, one in which they had to press a button respective of the placement of a dot to a vertical or horizontal line, and in the other phase, participants had to determine the placement of the dot, though the dot would appear a short while after the line had disappeared, thus participants had to use mental imagery in order to perform the task accurately. In all phases of the experiment, musicians performed around 25% quicker than non-musicians and had smaller deviations in both speed and accuracy. In a similar line of research, individuals were measured for reaction time in response to a green dot being flashed on a computer monitor, Hughes and Franz (2007) found that musicians' reaction time was significantly quicker than that of non-musicians', an effect of which that was found to be inversely correlated with age of onset for musical training.

Research findings that musicians are quicker and more accurate that non-musicians when tested on tasks other than sound-specific discrimination have been further elaborated by the research of Patston, Hogg, and Trippett (2007). In this study, participants were asked to perform a visual response task where the placement of a simple stimulus (e.g. where a dot appears in relation to a vertical or horizontal line presented on a computer monitor) had to be determined valid via motor response. Results here followed with the above theme, showing that musicians outperformed non-musicians on speed and accuracy of response. This is another tasks that has been directly correlated with neurological research comparing musicians' neurophysiology/anatomy to that of non-musicians'. Thus, the research by Spajdel, Jariabkova, & Riecansky, (2007), Patston, Corballis, Hogg, & Trippett (2006) and others mentioned above in the section on neurophysiology, which displayed musicians as having significantly less hemispheric segregation of processing, as opposed to non-musicians for whom the classic notion of *left/right brain segregation of tasks/stimuli* applies, provides strong evidence that neural-developmental changes due to music training enhance cognitive-behavioral functions. In general, as previously mentioned, those regions receiving functional gains via music training, thus operate more efficiently with tasks and abilities not directly related to musical performance.

Enhanced motor regions, as displayed via larger and/or more robust neuronal density and corresponding regional efficiency (Zendel & Alain, 2008), reduced generalization of activation therein (Wong et al., 2006), combined with similar anatomical/physiological changes within the auditory cortex and corpus callosum (Schlaug et al., 2009), provide foundational evidence of an organic nature for far-transfer findings that music training can sharpen non-musical skills due to a general strengthening of respective regions. However, this proposal that music training results in far-transfer effects (e.g. significant gains in general intelligence) has hardly been approached in a complete manner by most researchers. This has left the door open to many critics who continue to voice a loud opposition, though often having failed to undertake extensive and broad review of the literature on their own.

One component of intelligence commonly overlooked, reflective in the current nature of the intelligence quotient, is the idea of emotional intelligence and its relation to both music and the standard idea of intelligence as measured via WAIS-IV or Stanford Binet. It has been well documented that the prefrontal cortex provides executive oversight for a number of processes within the brain respective to memory and thus directly applicable to intelligence, as information processing and retention relies heavily on one's working memory (Quintana & Fuster, 1992; Rainer, Rao, & Miller, 1999). Moreover, research on affective disorders, in which genetic predisposition has been positively correlated with neural-degeneration over the course of the disorder, a shrunken prefrontal region, a condition in which executive control of the basal ganglia is apprehended, reduces the brain's ability to regulate emotion. Because music training has been shown via fMRI research to result in richer development of frontal/prefrontal regions (as in the form of robust glial and synaptic densities) for children who experience music training as opposed to those who do not (Hyde et al., 2009), and in light of research findings that musicians have more extensive development of emotional intelligence (Grewe, Nagel, Kopiez, & Altenmuller, 2007), we may conclude that neurological research on the effects of music training provides strong evidence that music training accounts for far transfer benefits to both emotional and general intelligence by providing developmental gains in regions that overlap in function, regions responsible for processes respective of music, memory, emotion, and other executive functions.

Further evidence of the elevated executive utilization within the musician's brain comes from the research of Goycoolea et al, (2007) who found musicians as not only able to evoke spontaneous music via executive means, as displayed via neuro-imaging (SPECT), though musicians were also able to change the composition of a mentally-evoked song at will, a skill that only 17% of non-musicians were able to report, which was verified from the neuro-imaging data. If we combine these findings with the philosophical writings of Reimer (2004), in which it is argued that music fluency not only contributes to the richness of the human experience, as an extension of the increased self-awareness attained in response to increases in emotional intelligence via learning the emotion latent within sound, though it as well expands our conscious experience, making us more aware of the inherent value of sounds in general, thus aiding our understanding and awareness of the world and enriching our general intelligence. Moreover, exercising the prefrontal regions in such a primitive (as respective to emotion) yet abstract manner (also as respective to emotion), should as well have far-transfer effects to other skills that rely on executive control for increased precision, as similar to what we have seen with motor skills, verbal fluency, and reaction time. This then is a means to understanding the controversial research showing music training to have a positive correlation to general intelligence.

Now that some light has been shed on the underlying mechanics attributing to far-transfer effects, it may be of further interest to consider some of the implications of music training for emotional intelligence. Affective disorder studies have consistently concluded that the prefrontal cortex is either smaller and/or less robust as a result of genetic predisposition or other neural degenerative processes, usually as monitored episodically as an individual cycles during their lifespan (Strakowski, DelBello, and Alder, 2005). The effect of an over-active amygdala and thalamus over-excites neuronal processes by flooding networks with a toxic level of neurotransmitters, due to the lack of executive control (whether conscious or sub-conscious as described earlier), thus further harming the brain while the person exhibits self-destructive behaviors that are often burdensome for the individual, the people he/she calls family, and the community in which the individual resides (DelBello, Zimmerman, Mills, Getz, & Strakowski, 2004). As we see above, music training is a means of increasing synaptic densities within the prefrontal cortex, and has been shown to provide significant developmental gains in both attention and emotional intelligence, two abilities that directly relate to prefrontal cortical efficiency. Moreover, individuals who score high on measures of emotional intelligence tend to exhibit traits that are considered to promote psychological resilience for traumatic events and other events that may be adverse to development such as living in poverty. Specifically, traits such as efficient desensitization to repeated stressors via lower coritsol response and absence of rumination have been found in individuals displaying high resilience (Salovey, Woolery, Stroud & Epel, 2002). It is important to note that the main variable behind coping with stressors is not merely desensitization and or refraining from ruminating on a given event and/or emotion. Ramos, Fernandez-Berrocal, and Extremera (2007) discovered that in order to effectively place our own emotional response in objective introspection, we must have clarity into the moods of other individuals as well, and from there develop the ability to generate multiple perspectives on a given event or stressor; harboring a developed sense of empathy. Logically, perspective-taking is an exercise in objectivity, thus promoting resiliency since this process, referred to as *repair* by Ramos, Fernandez-berrocal, and Extremera (2007), is found to be the one enduring skill most commonly utilized by individuals with high emotional intelligence.

Thus, the proposal from those who are skeptic of far-transfer effects, that cognitive strengthening should be only beneficial for the immediate task that led to the strengthening, seems not only ill-logical, though concrete and naïve at best. It would be shallow to accept that increased neuronal densities for a number of neural-anatomical structures would be active only for the specific task from which they were strengthened. Acute discrimination and allocation of sound, increased efficiency of working memory systems, and enhanced motor and auditory cognitive networks, and the executive control memory systems that manage these networks must transfer gains into other networks. All neurological gains from exercising the respective networks via music training, cannot be confined to the exercise from which they received their developmental gains (Chen, Penhune, & Zatorre, 2008), just as exercising on a stair-climber will result in being better able to climb real stairs, do squats, jump higher, run longer, think clearer and achieve all the benefits of regular exercise.

Music as a Therapeutic Tool

Without proper knowledge of far-transfer effects, as proposed by research on music proficiency, while they are intriguing, they may be difficult to readily accept.

However, as this review has attempted to provide the reader with an in-depth review of the neural-physiological processes and research on those respective far-transfer processes that are proposed to be enhanced via music training. Thus, it is hoped that many far-transfer effects will appear not so distant, and in fact, as logical byproducts of neural physiological robustness gained via music training.

Of clinical interest, might music training become a means of providing resilience against psychological disorders, and/or a route to neuro-rehabilitation? Regarding the neurophysiological findings of the past couple decades as reviewed above, we can understand what physiological processes may look like when using music as a clinical tool.

In its most passive form, listening or meditating, music therapy has been validated as having efficacy for pain management and alleviation of depression, as recorded from research involving hospital inpatients (Uyar & Korhan, 2011). For example, music therapy was able to significantly reduce the frequency of self-administered pain medication in women who underwent cesarean (Sen, Yanarates, Sizlan, Kilic, Ozkan, & Dagli, 2010), and has been attributed to significantly quicker and larger reductions in depression following mastectomy and chemotherapy (Zhou, Li, Yan, Dang, and Wang, 2011). Interestingly, the effects of passive music therapy have been the center of large debate, mostly due to the proposal of The Mozart Effect. Rauscher & Shaw (1993) discovered that individual scores of spatial intelligence were elevated via listening to the music of Mozart. This general hypothesis of music-induced cognitive gain has been further evidenced by Rauscher, Robinson, and Jens (1998), who took four groups of mice and exposed three groups to white noise and/or no noise during development, and the fourth group to Mozart, and discovered that the Mozart mice significantly outmaneuvered the three other groups through a maze. Thus, it was hypothesized that even if the Mozart Effect is attributable to fundamental positive-experience stimulation, as experienced from music, there appears to be something specific to the structure of the sound, and that is what appears to be influencing the effect on spatial reasoning; attributable only to the quality and specificity of the respective sound(s) (Rauscher, Shaw, & Ky, 1993).

Research involving a more active approach to music therapy has shown to be more beneficial than the findings of Zhou et al (2011), in that using song, song-writing, vocal/tonal matching, percussive training, and other forms of music therapy, when combined with regular psychotherapy and antidepressant medication, reduce symptoms of depression in stroke patients significantly further than psychotherapy or antidepressants alone or combined (Kim, et al., 2011). Interestingly, in Kim et al's (2011) research, while there were significant reductions in Beck Depression Inventory scores for the group of stroke patients who had the adjunct of music therapy in their rehabilitation program, there were no differences between groups in Beck Anxiety Inventory scores. This is of interest because the more active form of music therapy has been employed to treat a wide array of severe mental illness. For instance, (Grocke, Bloch, & Castle, 2008) used a group-therapy form of music therapy in which patients with severe mental illness collaborated to write songs and latter record them. Here, significant increases in quality of life scores were noted and patients reported strong positive experiences related to discovering a sense of creativity and having a piece of artwork of which to share with others. A number of other studies have as well found that music therapy has a significant positive effect for individuals experiencing the depressive-state of schizophrenia (Kavak, Unal, and Yilmaz, 2016; Tseng, Chen, Lin, Tu, Wang, et al, 2016)

The Veterans Affairs branch of the military has produced preliminary results, from the program Guitars for Vets, that are positive for music therapy as a means of significantly reducing symptoms of PTSD and depression (Dillingham, & Zablocki, 2011). In this form of music therapy, therapy takes place in a group setting, and is active, thus patients receive guitar lessons and the write music based on their life experiences. One crucial aspect of this program is an element specific to war veterans. Because a basic facet of military service includes a high level of care given to the soldier’s rifle, and thus an enduring bond of empowerment and comfort developed between a soldier and the rifle, that same sense of security is assigned to the veteran’s guitar. Thus, as veterans within the program note, the musical instrument is similar in size and shape to their rifle, is held similarly, and thus provides tactile and psychological comfort while enabling an outlet for musical expression of problems that are otherwise difficult to voice.

The latter application, neural-rehabilitation, was brought into the mainstream by the horrible event in Tuscan Arizona in January of 2011, in which a mentally ill individual shot and killed a number of people during a political rally. Following this incident, music therapy became a first line approach for Congress woman Giffords, who developed extensive aphasia from head trauma brought on by one of the assailant’s bullets. Because of the vast representation of music throughout the brain, music therapy is a way to reorganize speech and thus reroute speech to other parts of the brain when

Wernicke's and/or Broca's regions have been damaged, as has been the reasoning behind the rehabilitation plan of Congress woman Giffords (Guest Author, 2011).

The next few decades will hopefully bring about more experimental research and meta-analyses of the far-transfer effects of music training, which may have the ultimate effect of reintroducing an extensive music training programs for K through 12 education, and help elevate the general intelligence and emotional intelligence of the American people, in turn leading to a more creative/innovative culture, thus propelling the strength, richness, health, and awareness of our society.

Chapter 3: Research Method

Articulatory Suppression

Phonological robustness and language processing, attention, concentration, and visuospatial abilities are among the skills reported to receive positive developmental gains via music training (Brochard, Dufour & Despres, 2004; Marques, Moreno, Castro, & Besson, 2007; Patston, Hogg, & Tippett, 2007; Schon, Magne, & Besson, 2004). The following design implements the Articulatory Suppression Task (AST) as a means of drawing on all these factors in an experimental paradigm in which proficiency of parallel processing is tested under a non-musical context. More specifically, AST integrates repetitive verbalization of a word or phrase with the task of counting the number of words in a sentence, a sentence of which is unrelated to the word or phrase being repeated, and the meaning of the sentence is not expected to be a focus of attention. This creates competition within our verbal working memory system because if one attempts to perform the tasks simultaneously utilizing the phonological loop, cognitive resources within the phonological loop must be divided among the tasks (Larsen & Baddeley, 2003). Taking a more in-depth look, each verbal task has a different focus as well, the repetition task focuses less on tracking and meaning though more on motor aspects of verbal working memory, while during the counting task, the focus is on tracking and counting. In both tasks, one’s focus on content and/or meaning is assumed to be suppressed/avoided. In other words, the phonological loop’s efficiency is greatly taxed when forced into simultaneous linguistic tasks, possibly to the extent that two tasks cannot be processed simultaneously within the phonological loop with much if any accuracy and/or fluency.

In order to compensate for the cognitive load of a dual-task that appears to demand use of the phonological working memory system, participants were instructed to incorporate visuospatial working memory in order to use mental imagery for the counting portion. In turn, removing demand from the phonological loop via visualizing the numbers instead of attempting sub-vocal counting. Moreover, since musicians are reported as more proficient with verbal and visuospatial working memory systems (Franklin et al., 2008; Magne, Schon, & Besson, 2006; Marques, Moreno, Castro, & Besson, 2007; Brochard, Dufor, & Despres, 2004), the aim of this experiment was to examine whether or not an individual's musical aptitude score would predict performance, when being instructed to draw upon these systems simultaneously.

The classic AST involves stating one word (e.g. *the*, or *happy*) repetitively and as quickly as possible while maintaining clear pronunciation, though simultaneously counting the number of words in a sentence. In past designs this procedure includes sentences presented in large boldface print on strips of card-stock paper, and the present study employed this same method for presenting the word strings. The task is called AST because the act of verbalizing is supposed to suppress the entry of secondary information into sub-vocal rehearsal and thus reduce one's ability to count the number of words in each of the sentences presented. Moreover, by having the participants verbalize at a rate fast enough to remove any significant pauses between each pronunciation, and by monitoring participants for foot tapping and/or finger counting, participants were confined to attempt to use sub-vocal, or other internal means, for counting the number of words in the sentences presented. The efficiency of the articulatory system determines the robustness of the phonological loop, however, a larger working memory capacity becomes insufficient when simultaneous verbal tasks are required since the articulatory system is not built to execute duel verbal processes (Baddeley & Larsen, 2007).

The AST task implemented in this study was hoped to be divided into two forms. First, the classic (AST-C) task in which a single word is repeated as the articulatory suppression device, and second, which would have been novel to this study, an articulatory suppression task in which the participant must read each sentence (AST-R) while simultaneously counting the words being read. However, due to time constraints and complexity of data analysis, in this experiment I chose to abstain from using an AST-R, which would have required a second round of testing. For future purposes, it may be interesting to test participants with both the AST-C and the AST-R prior to a short brake which will be followed by the participants learning to use the visuospatial memory system for performing the counting task via mental imagery. Participants would then go through both the AST-C and AST-R utilizing the parallel processing method. In AST-R, the suppression device is the sentence itself instead of the word of repetition, which may have additional hypothetical implications such as further interference into visuospatial working memory. This is hypothesized since in the AST-C the word of repetition becomes a monotonous verbal chore, in which the participant may be able to reduce their concentration on the meaning and related images of the word and thus concentrate more so on the use of mental imagery for the counting task. However, in the second task, since the word suppressor is changing at the same rate, or an approximate thereof, the participant may have more trouble removing focus on word meaning and associated images, thus placing the participant in a task more reflective of parallel processing in an every-day-life situation. However, again in the current research design, only the AST-C was used.

Research Design

This experiment consisted of three quantitative measures; (a) music aptitude (b) baseline performance on the AST and (c) post-learning scores on the AST. Two additional post-test qualitative measures, (a) a survey inquiring about history of music training, and (b) a measure of perceived proficiency on the AST, helped to further differentiate individuals within-groups after the experimental data had been gathered. For example, it was of interest to examine whether, type of instrument, number of instruments of proficiency, mode of performance, and other musician-specific variables had an impact on parallel processing proficiency.

Thus, as a post-test measure, participants were asked to provide an ordinal ranking for each of the variables below,

- *Years of music training*: divided into 6 rankings
  - (0-2 years, 2-4 years, 4-6 years, 6-8 years, 8-10 years, and 10+ years).
- *Instrument(s) of proficiency*: ranking respective of fluency per instrument.
  - Thus, if the primary instrument is the piano, though the participant is fluent with strings as well, but to a lesser extent, they were assigned the piano a rank of 7 and strings a rank of 3 (on an ordinal scale of 1 to 7).
- *Course of music training*: determines how the individual achieved the current level of music proficiency and consisted of five variables

    - (Formal education, Self-Taught experimental, Self-Taught Books/Video, Informal Family/Friends, Distance Learning, Combination of variables, All of the above).

- *Reading fluency*: a measure of ordinal rank
    - (0 = cannot read musical script, 7 = expert).
- *Commencement of music training*:
    - (age; 2-5, 6-9, 10-12, 13-15, 16-18, 19-23, 24+).

Participants were as well asked to indicate if they ever stopped practicing music, and if so at what age(s) and for how long. Participants were asked to report what percentage of the time they perform/practice alone vs. in front of an audience, and were asked to report what percentage of time they spend practicing/performing alone vs. with a group. Participants were also asked to rate what percentage of the time they spend practicing compositions written by their self vs. compositions written by others. Each qualitative variable was ordinal ranked, thus providing a means to quantify these variables, creating statistical measures that could further differentiate participants with similar aptitude score.

Participants were administered a post-test survey inquiring about music in their environment. This survey consisted of questions pertaining to music at family gatherings, music socially (e.g. church/spiritual gatherings, bars, parties), early educational music experience, one’s desire to have learned an instrument, any periods of significant attempts to create music, and daily immersion in music (e.g. while in exercise, work, meditation, home, commute, relaxation, etc…). The music aptitude test was administered to provide quantitative measures of individual music proficiency beyond the self-report method. Generating a music aptitude score for each participant, regardless of subjectively reported music proficiency, was performed to test the hypothesis within the study; rhythm is a fundamental aspect of music proficiency and thus may be correlated with dividing tasks among non-competing memory processes. To speculate on the research cited in previous chapters (e.g. Hyde et al., 2009; Quintana & Fuster, 1992; Rainer, Rao, & Miller, 1999, etc…), respective of neural-physiological and neural-anatomical development correlated with music training, high music aptitude in a non-musician may signify pertinent physiological development within the brain that may have been achieved outside of music training.

After completing the survey and aptitude test, each participant was familiarized with the AST, and demonstrated understanding of the task by performing five trials. After proving a familiarity via pre-test trial fluency and reiteration of the process and objective of each task, participants then performed the AST under formal record.

The AST was administered in a quiet, well-lit room of a comfortable temperature (approx 68 to 72 degrees Fahrenheit), with the experimenter sitting directly across the table from the participant; facing the wall to the back of the participant. The participant was informed that speaking too slowly and/or using external means (i.e. fingers, or foot taping) to count, would void the respective trial. If a participant voided a trial, the participant was reminded that they must maintain a consistent and quick verbalization, and/or refrain from using means other than cognitive for counting the number of words in each sentence. Determining if the participant was attempting to use external means to count, and/or freeing up cognitive reserve via reducing rate of verbal repetition, was accomplished by having participants place both hands on the table in front of them, and rate of verbalization was monitored during the test round by the test administrator. Thus, rate of verbalization was a subjective analysis from the tester, as reflective of previous research, who was as well monitoring the participant's body for signs of external means of counting.

Since the aspect of this experiment consisting of sentence presentation and time-record keeping was implemented via computer, the experimenter was as well responsible for keeping track of which, if any, trial was found to be void after each round.

Participants completed the round of AST trials, which consisted of the participant being instructed on how to perform the task, followed by a 5-trial "warm-up", in which the experimenter monitored the participants and made corrections to rate of speech, use of external counting means, and/or quality of speech. Each participant was asked if they understood how to do the task and feel comfortable with the process, and they then began the 15 trials. Each trial was timed, and the participant commenced each trial by first beginning to repeat the target word, and then the administrator would bring up the first word-string. As soon as the participant had counted the number of words in the sentence, they stated the number, in turn the administrator would stop the timer and remove the sentence from in front of them. At this point the test administrator recorded the number stated, and speed with which it took to complete the trial.

Following completion of the first AST, participants had a short brake, after which point, all but the control group began the learning phase of the study. The control group consisted of participant's chosen at random, and was in place to measure for any presence of a practice effect. As the experimental group went through the learning phase, the control group went through an activity stage, which was equal in length to the time it took the experimental groups to complete the learning phase, though consisted only of getting up, walking around, and getting a cup of water. Participants in the control group then went through another practice round of the AST followed by the trial round of 15 recorded trials. Following the completion of the AST tasks, participants in the control group were given the post-test surveys asking them to rate how well they believed they performed the AST and what, if any, *tricks* they used to help complete the tasks, and music history and proficiency questions.

In the experimental group, during the learning task, participants were familiarized with theory underlying AST, specifically that the phonological loop is not wired to perform multiple tasks, and thus in order to more efficiently perform the AST, incorporation of mental imagery in a rhythmic manner may be necessary. For example, the test administrator began by telling each group of participants that "research on the verbal networks of the brain has concluded that engaging in two verbal processes at the same time is extremely difficult, if not impossible. However, scientists have found that people can use their imagination while talking, also referred to as mental imagery, with little interference between tasks." Instructing the participants to count rhythmically in line with the verbal task is believed to be dependent on music aptitude, as well as practice in performing the AST. This is as well similar to the way in which musician's count and/or read while performing. For example, musicians will tap their foot while counting in their head, though they might tap their foot twice as fast as they ascend numerically and rhythmically. Additionally, musicians may be visually reading written music script and simultaneously transferring that information through the hands (and often passionately with the rest of their body) unto the instrument they are holding.

After participants were familiarized with the specific process of applying parallel processing to the AST, participants went through a practice round. Specifically, participants attempted to rhythmically verbalize and use mental imagery in order to repeat the target word and count via mental imagery, respectively. Each participant had the opportunity to practice this means of performing the task for 5 trials, then went through the ASTs once again, though this time using mental imagery for counting. Participants were again measured on speed and accuracy and were subject to the same rules against using external means of counting.

Each participant completed a survey inquiring how well they believe they performed on AST, as well as asking to describe how they completed the task. Asking each participant to describe the means they implemented in order to complete the AST helped in determining whether or not they innately applied two separate working memory systems prior to being instructed to do so. For example, if a participant reported that they were able to "see" the numbers in their head, it was concluded that they were using the visuospatial sketchpad in order to mentally visualize the counting task, thus, applying the visuospatial working memory in order to more efficiently perform the parallel processing task. Moreover, asking their subjective analysis of perceived performance provided insight into participants' metacognitive awareness, and provided further measures between and within the groups, as reflective of the research mentioned above regarding musicians having more accurate measures of self-awareness.

Setting and Sample

This experiment drew on the general population of adults (18-64). Participants were recruited via flyers posted and leaflets handed out throughout both rural and urban regions of the state of Oregon. The design consisted of two groups of participants, one experimental group and one control group. Each group consisted of $n = 20$ participants [$a = .05$ (1-$\beta > .80$; r [d] $< .20$]. All parts of the testing were administered by this researcher, on college campuses or at local libraries, in a closed-room environment aimed to promote focus of attention and concentration; the rooms were well lit, quite, free of visual, auditory and noxious distractions, and of a comfortable temperature (approx: 70 degrees), and were congruent with general ambiance.

Instrumentation and Materials

Articulatory Suppression Task (AST) materials included 40 sentences typed in 14-point boldface Times New Roman. Participants completed 2 rounds of 15 trials. Each trial was times with a Harmon Kardon Cell Phone stop watch, and scores recorded to yellow line-paper.

The post-test subjective-performance questionnaire asked participants to rank how well they believed they performed on the AST and what technique they used to complete the AST. Subjective analysis of performance was converted into ordinal ranking scores with ease due to commonalities among reported techniques.

The Drake Musical Aptitude test (Drake, 1954) (DMAT) was administered after the AST task and measured music development respective of tonal memory and capacity to maintain tempo, via a set of pre-recorded sounds and beats with an accompanying instructor's directions. The Drake carries reliability coefficients of .70 to .94, taken from repeated trials, and has been validated by musicians and professors of music.

The survey instruments consisted of questions pertaining to music training history and post-test performance subjective analysis. Post-test surveys inquiring about music history and proficiency were administered to all participants. The personal history/immersion portion asked about informal training, personal musical practice, perceived abilities, and other musical influences. This survey also inquired regarding in-depth account of all music training and proficiencies in a number of environments and types of instrument. Respectively, the survey becomes progressively more specific to practicing musicians, all participants were instructed to write N/A for any question found to be not applicable. These scores were converted in to ordinal data as well, and will be described further below.

Ethical Treatment

Participants were solicited on a volunteer basis in collaboration with College IRB and an agreed upon time frame and participant number of 150 participants. Other participants were recruited via flyer and word of mouth in both urban and rural settings throughout the state of Oregon. All sites were public resource rooms within the public libraries or public colleges.

All participants were informed that personal information and contact information was kept confidential. Only participant's name and contact information were recorded, age was validated via personal identification prior to testing. All data and personal information was stored in a locking file cabinet, and the level of relevance data had to an individual's reputation was minimal and thus required no additional encoding or safety measures. All data was retained and stored respectively for possible addition to the research latter on.

At the end of all testing, participant's data remained anonymous, though they have been allowed to receive a copy of their aptitude/achievement scores as well as a copy of their performance scores on the AST, per request. Participants may also be given contact information for receiving a copy of published results if results in turn become published, and all data therein will remain anonymous. To summarize, the procedure will pose minimal risk to participants, and any personal information will be safeguarded and kept only for follow-up purposes to notify participants of published results, thereafter, personal information will be destroyed.

Chapter 4: Results

Introduction

This design was constructed to experimentally measure robustness of working memory systems with respect to musical aptitude. This was accomplished by applying two rounds (T1 & T2) of Articulatory Suppression Task (AST), with two approaches to the way participants were tested. One group received a simple test/retest for control purposes, the second group went through a learning phase specific to the components of working memory. This group of participants were instructed to use a specific parallel processing technique. Averaged performance scores of individuals within each group were measured by the Drake Musical Aptitude Test (DMAT). The DMAT consisted of two tests of musical memory (From A and Form B), as well as two different rhythm tests (RT1 and RT2).

The research hypotheses were as follows,

RQ1: Is an individual's ability to increase proficiency on a task of parallel processing, via guided instruction vs. no instruction (group assignment), dependent on musical aptitude?

RQ2: Does music aptitude account for differences among individuals in their ability to perform a task of parallel processing?

The complex processing task, more specifically, involved having to repeat the word *Happy* at a pace of about twice/second while counting the number of words in a sentence/word-string. Those in the group that received the instruction were specifically coached to use their visuospatial working memory to count, while letting the phonological working memory engage in the word-repeating part of the task. Participants in the control group received no training, coaching, nor encouragement, and merely went through the testing twice with a short break for water or “stretching of the legs” between rounds of AST.

Data Collection

Fifty-four participants were drawn from the general public throughout rural and urban regions of Oregon, though only forty participants completed the experiment. All participants were at least 18 years of age and no older than 64 years of age. Participants were primarily recruited via posted flyers, and leaflets handout flyers. Individuals who were receptive to this approach were tested in free pubic-use study rooms. All rooms met the criteria set out in the procedures section. Participants were randomly assigned to one of two groups, Experimental (group 1) or Control (group 2), each group consisted of n = 20 participants.

Changes in Procedures

Participant Retention

Though the original aim was to have N > 150, the testing procedure and availability of testing space made it challenging to efficiently and readily test participants. This resulted in a final participant count of N=40. More specifically, the Articulatory Suppression Task (AST) and Drake Musical Aptitude Test (DMAT) were initially administered at separate times, but 14 participants did not return for testing nor replied to follow-up phone calls. Thus, it became clear to after some time, that participants complete all testing in the same day. After a year-long effort to secure participants, it was decided that N=40 would be acceptable for moving forward with data analysis. At the finalization of the testing phase of this research design, elapsed time was exactly 1 year from initial IRB approval.

Testing Changes

It was initially anticipated that participants would be tested on an additional variation of the Articulatory Suppression Task, in which the participant would have to read the sentence while counting the number of words, instead of merely repeating a word while counting the number of words in a sentence. Upon outset of running the experiment it became clear that adding this additional task was extremely time-consuming and participants were reluctant to complete testing, it was thus removed from the procedure.

Data Cleaning and Outliers

All participant accuracy scores on the Articulatory Suppression Task (AST) were converted to percent correct. All speed scores (time to compete each trial) were converted to average speed for each round of AST, thus giving one average score to each participant, for both percent correct and speed of completion for the 15 trials. Participants thus completed the experiment with 2 sets of averaged scores, respective of baseline AST performance (round 1) and follow-up performance (round 2). Data pertaining to the AST performance, DMAT, and all surveys were double-checked for errors while being transferred from hard copy to computer program; SPSS. Drake Musical Aptitude Test (DMAT) scores remained raw scores, respective of how many missed answers a participant had, and recorded as negative numbers.

Between Group Performance

A boxplot analysis indicated that there were outliers in each group for most measures of performance. Figure 1 displays change in performance on AST with respect to accuracy, and Figure 2 displays change in performance on AST with respect to speed.

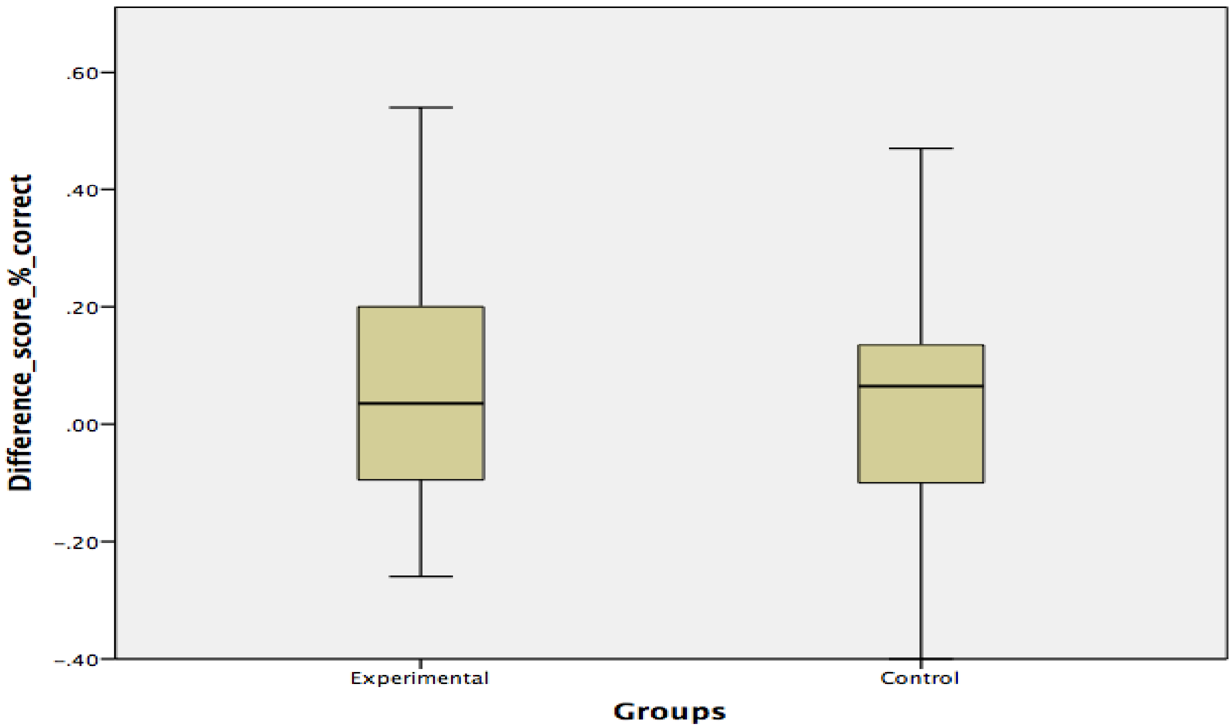

Figure 1. Difference in accuracy scores from test 1 to test 2 of Articulatory Suppression Task, between groups comparison.

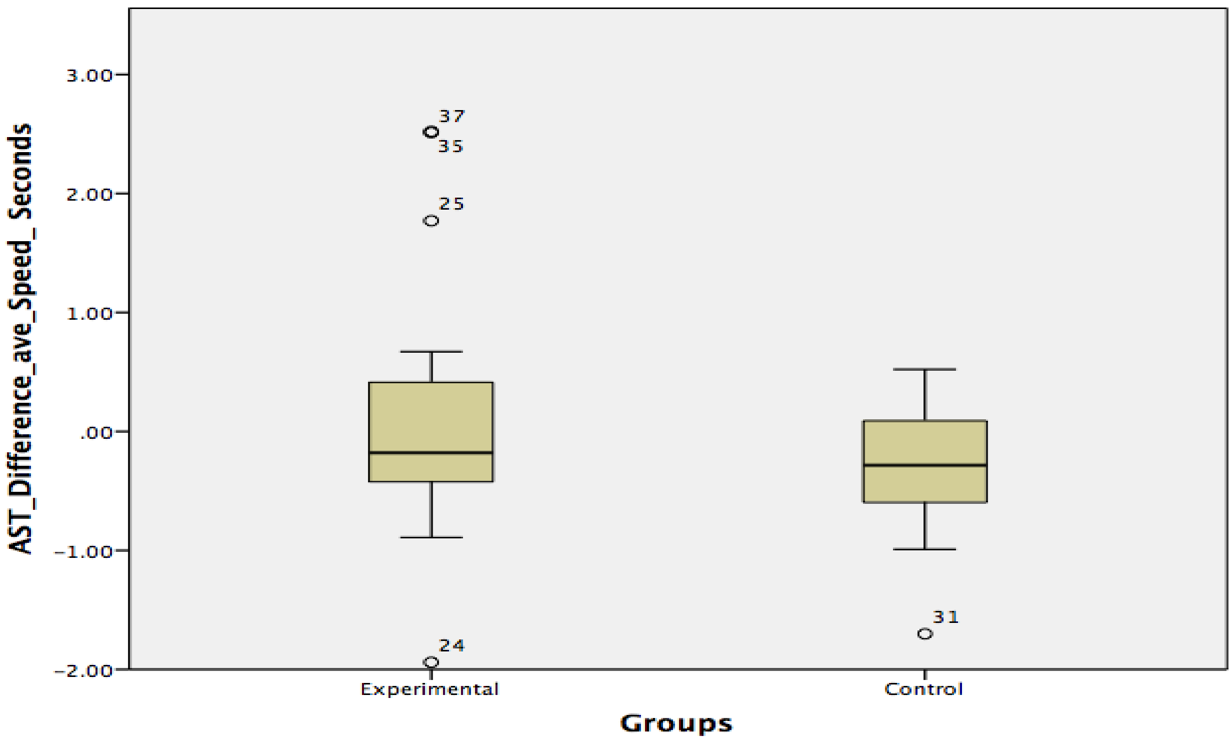

*Figure 2***.** Difference in speed (Time to complete each trial) from test 1 to test 2 of Articulatory Suppression Task, between groups comparison.

Research Questions:

RQ-1: Is an individual's ability to increase proficiency on a task of parallel processing, via guided instruction vs. no instruction (group assignment), dependent on musical aptitude?

For this research question, the data gathered were analyzed using an analysis of covariance (ANCOVA), in which each participant's accuracy score-change (DV) was compared by the independent variable of group assignment, and the covariate of either of 2 composite DMAT scores. I first took both DMAT Musical memory scores (Form A and Form B) and averaged them into a single score. For the main effect of accuracy score-change following guided instruction, in relation to the IV and covariate, no significant difference was found between participants who received training, compared to participants who did not receive training; F(2, 19) = .132, *p* = .87.

Second, the DV was compared against the IV with the covariate of DMAT composite again, though this time the DMAT composite was taken from the two Rhythm test scores (RT1 & RT2). Here it was as well found that no significant effect for group assignment and accuracy score-change existed, with DMAT composite (RT1 & RT2); F(2, 19) = 1.26, *p* = .29.

From here each subtest of the DMAT was compared in relation to score-change on accuracy; DMAT Musical Memory Form A [F(2, 19) = .14, *p* = .86] , DMAT Musical Memory Form B [F(2, 19) = .22, *p* = .80], DMAT Rhythm Test 1 (F(2, 19) = .12, *p* = .88], and DMAT Rhythm Test 2 [F(2, 19) = .23, *p* = .78], each as a single covariate in relation to group assignment and score-change for accuracy on the AST. Following the above trend, again no significant difference was found between group assignment in relation to any one constituent of the DMAT for participant ability to increase proficiency on accuracy with the AST.

Next I looked at participant's ability to reduce processing time, as a measure of proficiency, with the AST in relation to group assignment with each DMAT composite score (DMAT Musical Memory composite & DMAT Rhythm composite). Here as well, no significant differences among participants was found, as dependent on group assignment; F(2, 19) = 1.41, *p* = .25 for the composite of DMAT Musical Memory A & B scores averaged and F(2, 19) = 1.14, *p* = .32 for the composite of DMAT Rhythm T1 and T2 scores averaged. Moreover, due to the lack of validity of speed with which completion of task represents increased proficiency (i.e. lack of explicit time constraints thereof), I decided not to look at each constituent of the DMAT as it's own covariate for this aspect of the AST.

RQ2: Does music aptitude account for differences among individuals in their ability to perform a task of parallel processing?

For analysis of across-group performance on AST-T1 only (as I aimed to measure for baseline differences) in relation to all DMAT subtests (Musical memory Form A & Form B and Rhythm Test 1 (RT-1) & Rhythm Test 2 (RT-2)), I used a simple comparison of means. DMAT Form A with respect to performance on AST-T1[r(38) = .29, p = .06, displayed below in Figure 3), was not significant. DMAT Form B approached significance for being a predictor of performance as well, though too fell short (r(38) = .30, p = .05, displayed below in Figure 4). After looking at each constituent of the DAMT in relation to AST accuracy scores, I decided to look at the DMAT Musical Memory composite score (MM Form A and MM Form B, averaged), and found that when averaging participant performance on these two similar measures of Musical Memory aptitude, the composite score then was a significant predictor of performance on AST T1 accuracy (r(38) = .34, p = .02), as displayed in Figure 5). This makes sense because each constituent of the DMAT musical memory section were very close to being significant predictors of AST accuracy on their own, during AST T1, and reached significance during AST T2 as predictors of accuracy.

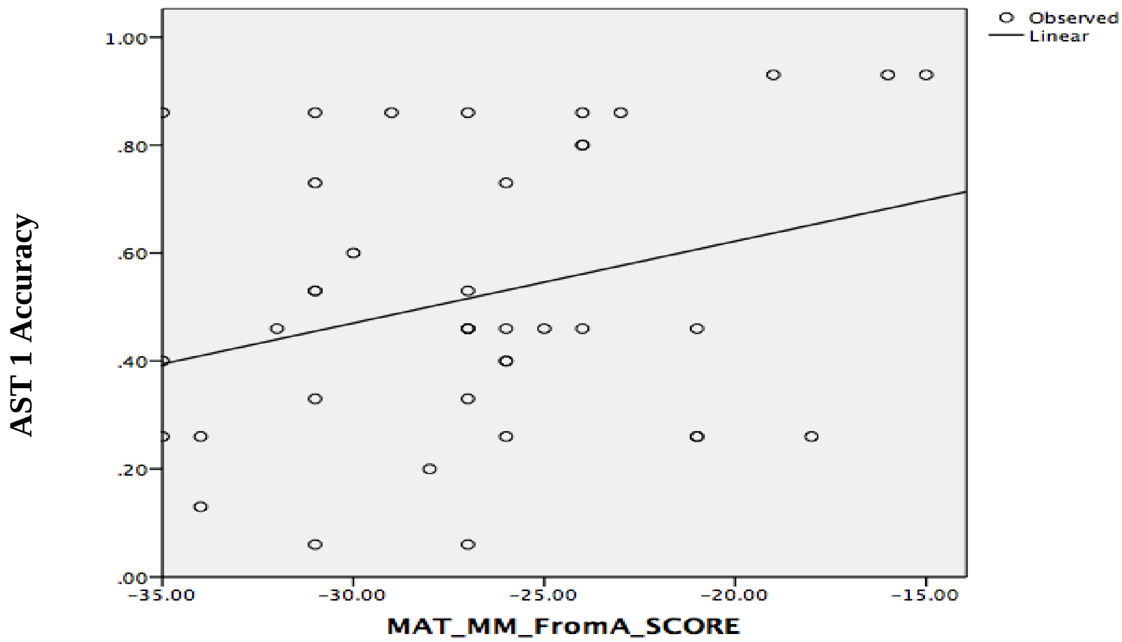

Figure 3. Regression line; AST_T1 & DMAT MM Form A

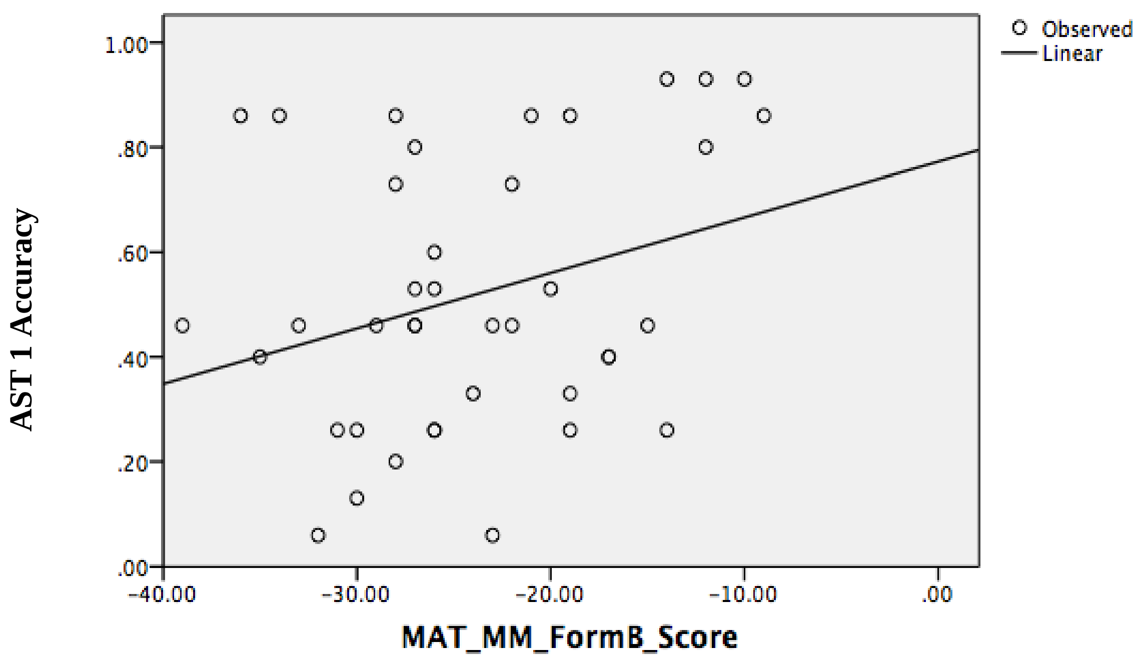

Figure 4. Regression line; AST_T1 & DMAT MM Form B

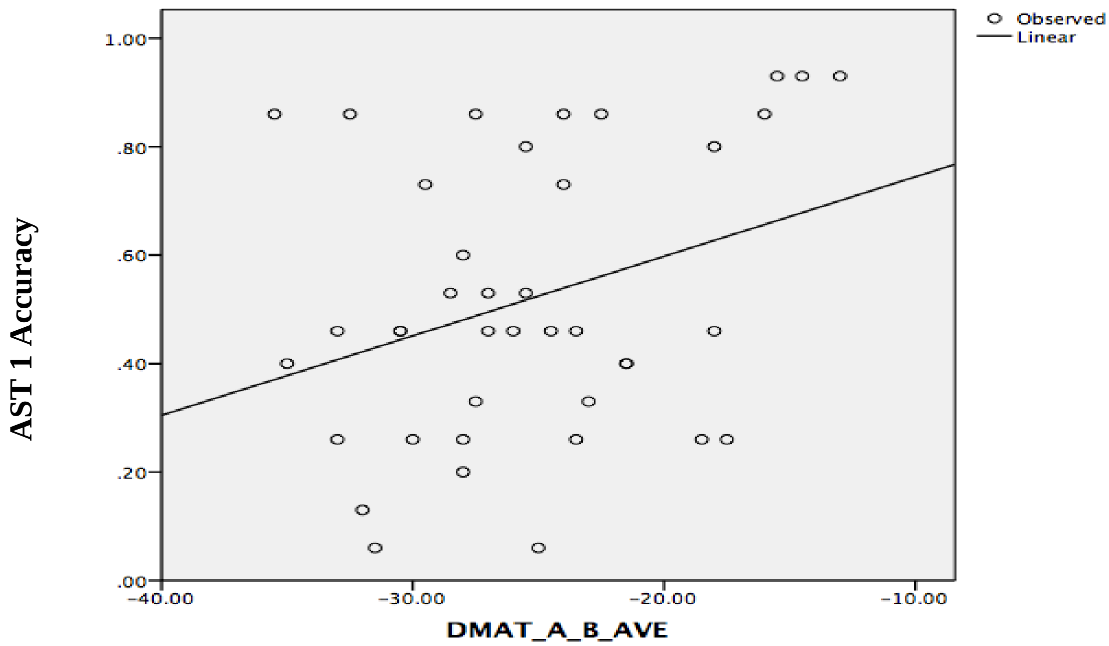

Figure 5. Regression line; AST_T1 & DMAT MM Composite (Form A & B averaged)

With respect to AST accuracy and DMAT Rhythm (RT-1 & RT-2), both of thee subtests were as well found to have no predictive value of participant accuracy on AST T1 [respectively, r(38) = .04, *p* = *.78* & r(38) = .09, *p* = *.55*]. Moreover, the composite score of DMAT RT-1 and RT-2 averaged was found to not be a predictor of accuracy on AST T1 (r(38) = -.15, *p* - *.34)* as well.

Lastly, AST-T1 speed scores were analyzed in relation to the composite scores of DMAT Musical Memory tests A & B averaged, as well as DMAT R1 & R2 scores averaged, here there was found to be no significant differences among participants. The DMAT was then broken down further into each constituent to measure for specific effects, as was completed with the other measures, and again found no significant correlations to any of the DMAT constituents and speed with which participants completed the AST during T1.

It is important to mention that there were significant correlations between AST Accuracy scores and DMAT Musical Memory, though only on AST T2, and only for across-group (not between group) comparisons. Thus, with respect to RQ-2, DMAT Musical Memory scores approached being a significant predictor of accuracy on AST T1 and then were found to be significant predictors for AST T2. It is worth presenting the data regarding this variable, due to the need for further exploration below in the discussion section. There will as well be some qualitative data presented that may help explain why there could be a significant correlation during AST T2, though not during AST T1 nor for score-change between AST T1 to T2. Thus, the preceding section presents the most pertinent statistical data respective of the variables to be discussed in chapter 5. Though this data was not specific to the research questions presented by the research design, this data was gathered due to the novel nature of this design and the intuition by the researcher that the design may encounter confounding variables and thus aimed to help provide routs to clarity if confounding variables were to surface and negatively impact the research design.

Further data analysis: Confounding variables and post-test data.

The strongest correlation found between AST performance, specifically that of accuracy, was found between the technique a participant reported using (reported technique) and accuracy on AST T1 & T2 ($r = -.49$, $\alpha = .001$ & $r = -.62$, $\alpha < .001$, respectively). Here, a 3 measure reporting system was used in which 1 related to the parallel processing technique specific to the experimental group, 2 related to an alternative technique, and 3 was no specific or no technique. As displayed in the data above, there was a strong correlation between using the technique that the experimental group was instructed to use, and accuracy on AST. Moreover, it is important to note that many participants discovered the technique prior to instruction (implemented during AST T1), also reflected in the data above.

The second correlation of interest came when looking at AST T2 accuracy and DMAT Musical Memory scores. Specifically, DMAT Form A was a significant predictor of AST T2 accuracy ($r(38) = .36$, $p = .02$), though DMAT Form B fell shy of significance as a predictor of AST performance respective of accuracy. Moreover, when combining DMAT Form A & B to get an average on these two complimentary measures of Musical Memory, that measure of musical aptitude remained a significant predictor of accuracy on AST ($r(38) = .34$, $p = .02$).

A third aspect that may have had a confounding effect came from assessing if DMAT scores were correlated with Reported Technique. This analysis was done to see if DMAT performance may have been positively correlated with a participant’s ability to discover the parallel processing technique that was to be learned, which was of interest due to the strong correlation between AST Accuracy and Reported Technique. Here, there was not a significant correlation between Reported Technique and DMAT Form A & B ($r(38) = -.26$, $p = .09$ & $r(38) = -.21$, $p = .18$, respectively). This aspect will be discussed further below due to the prospect of it having a significant influence if this research design had achieved the target sample size.

Chapter Summary

As reported above, participant data pertaining to AST performance and DMAT scores, was analyze across groups and within groups to measure for any effect that DMAT may have had on AST performance, as well as participant ability to increase performance on AST via applying specific parallel processing techniques. The DAMT scores were run against AST accuracy and speed score-change, separately, with DMAT sections combined and averaged, as well as each constituent measured against AST score-change. The data was then broken down further to measure for any effect DMAT may have had on performance with AST in general, across group, looking at combined DMAT score-averages, as well as each constituent against AST T1 (round 1) accuracy and speed scores.

While no effect was found for music aptitude on an individual's ability to increase proficiency with a parallel processing task was present, as measured through pre-test/post-test scores with respect to a guided instruction on performing the specific parallel processing task, an individual's general proficiency on the AST was predicted by DMAT Musical Memory scores during Round 2 of AST. Because this finding appears to conflict with the initial finding of no significance, it will be important to include analysis of additional qualitative measures, and respective confounding findings, in the discussion to come. Additionally, due to the apparent ceiling effect suggested in the correlation between musical aptitude and accuracy on AST, this is one conclusion as to why there may be an effect of music aptitude on performance in AST T2, though lack of increased proficiency in relation to DMAT scores. Which would adversely effect the ability of the group of participants who received explicit training in use of memory systems to increase proficiency with parallel processing.

Also, while this research design did report on speed (i.e. time to complete each task), this measure may not have been accurate due to lack of constraints for time in which participants were encouraged to complete each task, and individual differences with aligning the parallel processing task. This may have resulted in some participants counting slower while maintaining the necessary rate of repetition for verbal response, while others may have counted faster; a variable of which was not surveyed for in the qualitative measures.

Below I will briefly discuss the findings above, as well as go into more depth regarding the confounding variables that may have negatively influenced this approach to testing the effects of DMAT on participant proficiency with parallel processing as measured via performance on AST. These influences include, participant use of the specific parallel processing technique prior to learning (or with the control group), ceiling effect of positive correlation to DMAT-combined and performance on AST in general, and a possibility of DMAT having a positive influence on discovering the technique prior to learning. Additionally, I will provide suggestions for formulating a more reliable approach to this research, and provide possible evidence of the validity of continuing with this research focus.

Chapter 5: Discussion

Introduction

Working memory systems are largely responsible for the cognitive development of all complex tasks requiring sustained attention and logical reasoning (Quintana & Fuster, 1992; Rainer, Rao, & Miller, 1999). When humans experience regular training in music performance, this training is often found to be positively correlated with other complex tasks such as mathematics, tasks specific to intelligence testing, and emotional reasoning (Brochard, Dufour & Despres, 2004; Goyocoolea, Mena, Neubauer, Levy, Gerz, & Berger, 2007; & Schellenberg, 2006), even when many other psycho-social developmental variables are taken into account. However, due to the bulk of research on this topic being primarily correlative and/or relying on subjective reporting, a strong need for a more valid source of data has developed, and thus experimental designs that can add depth to just exactly what these correlations are truly telling us.

Purpose and Nature of the Study

Because of the prospect of multiple confounding variables influencing the correlations referenced above regarding previous research, this study aimed to measure participant's baseline proficiency with parallel processing (i.e. simultaneous use of phonological loop and visuospatial sketchpad), and compared baseline scores to fluency with learning, when using a specific parallel processing technique. To measure if music training has an influence on implementing specific parallel processing skills, measurements of these parallel processing skills were recorded and compared change therein with participant scores on a musical aptitude test. This was an attempt to show that if music aptitude has no effect on working memory proficiency, it would not account for other far-transfer effects. Simply put, one would not find a positive correlation between musical aptitude and performance on the parallel processing task, let alone the ability of an individual to increase performance via explicit training. It is important to note that music proficiency was measured as well, thus, encompassing music training, as the musical aptitude test administered is applicable to both novice and trained musicians, scores therein were noted by the Drake Musical Aptitude Test to reliably reflect history of training, and this design as well administered a survey to double-check this finding.

This design was a measure of pretest/posttest score differences, correlated with additional quantitative measures. In order to achieve a respectable level of power, it was hoped to have at least one-hundred and fifty participants. Since this was not achieved due to unforeseen influences on completion of the research, in discussion of the results it will be important to keep in mind the limitations of these results regarding sample size, which ended up reaching a mere minimum; forty participants.

Research Question-1: Is an individual’s ability to increase proficiency on a task of parallel processing, via guided instruction vs. no instruction (group assignment), dependent on musical aptitude?

No evidence was found for group assignment effecting participant accuracy and/or speed of task completion on the AST. There was a slight difference between groups regarding their proficiency with the Drake Musical Aptitude Test (DMAT), specifically the sub-test of Musical Memory, Form A, showing the nonexperimental group slightly dominant. Without other considerations this could imply more evidence against the above hypothesis, for if musical aptitude had any effect at all on proficiency with AST, the dominant group should've shown increased proficiency between AST T1 and AST T2. Though here superior scores on musical aptitude showed minimal influence on one's proficiency with learning a parallel processing skill, with respect to group assignment, due to the non-experimental group scoring higher, and thus topping out in ceiling, in contrast to the experimental group. This may account for the significant positive correlation between DMAT Musical Memory subtests and accuracy during AST T2, as well as the positive correlation across groups to performance on AST and DMAT Musical Memory.

When taking into account the confounding variable of the ceiling effect of DMAT proficiency on AST performance, I am forced to invalidate the approach and respective data pertaining to this specific research question. Thus, the group higher in musical proficiency will experience an inhibitive effect on room for improvement due to having higher rates of percent correct initially, and thus going in into round 2 with fewer opportunities as a group to make large upward changes in score. This line of reasoning is acceptable being that lower scoring was observed within the individuals who were assigned to the experimental group. Though the non-experimental group scored higher initially, reducing room for improvement, though no difference between groups was observed in ability to increase proficiency. This was very well possibly due to the fact that the experimental group, though lower in general proficiency with the DMAT, was not significantly lower, yet still proficient enough to reach a level of performance that was within the range of significance to have influence of a ceiling effect. Thus, while after instruction, the experimental group was able to increase their scores to the point that across-group correlation to DMAT performance on Musical Memory became significant, it was not so much that it created an "alert" that it was significant in relation to change in performance; hence, it was in the threshold of hitting the ceiling in round 1 of AST.

Research Question 2: Does music aptitude account for differences among individuals in their ability to perform a task of parallel processing?

It was found that across participants, individuals who were more proficient with Musical Memory, on the DMAT, correlated to higher scores of accuracy on AST. Specifically, AST-T2 was predicted by individual DMAT Form A performance scores. While this was the only DMAT measure that proved to be a significant predictor of AST performance, DMAT Form B approached significance for being a predictor of performance on AST-T1. These results provide further support for past research, which motivated this design, regarding the general finding discussed throughout this paper, that music training is commonly correlated with a diverse array of developmental benefits.

Moreover, because a correlation between music aptitude and a more specific and fundamental cognitive process was discovered, this research design adds more depth to the literature, while supporting all previous research in which music training and/or aptitude was found to be positively correlated with a human attribute. If one adheres to the design of cognition and memory being largely seated upon the working memory systems, and thus the "gateway" for intelligence and learning, it is quite exciting to find a correlation between musical memory and participant proficiency with working memory systems.

Research Questions 1 & 2 Confounding Variables: Possible Ceiling Effect.

Additionally, I looked at how musical aptitude may have effected performance while accounting for confounding variables that were not initially anticipated. For instance, it was found posttest that many participants reported using a similar parallel processing technique, prior to instruction (for the experimental group) or without any instruction at all (for the control group), which I referred to as *Chunking and Adding*. Participants who engaged in this technique (N = 26) included n = 9 of the participants being in the control group and n = 17 in the experimental group. Thus, nearly half of the participants in the control group used a very similar technique without any instruction, and n = 3 participants in the experimental group were unable to use the technique they were instructed to use during the learning phase prior to AST-T2. Due to the strong initial correlations between Reported Technique and AST Accuracy T1 & T2, it was necessary to include the influence of this confounding variable in the analysis of means. Moreover, it is of further interest in viewing these correlations respectively that there may had been a large increase in performance from T1 to T2 accuracy on AST for those who implemented this technique, if they had not discovered the technique preemptively during AST T1. This further supports the need for a revision of the approach to this research question, via surveying participants immediately following AST T1 and then sorting participants respectively into groups for further testing.

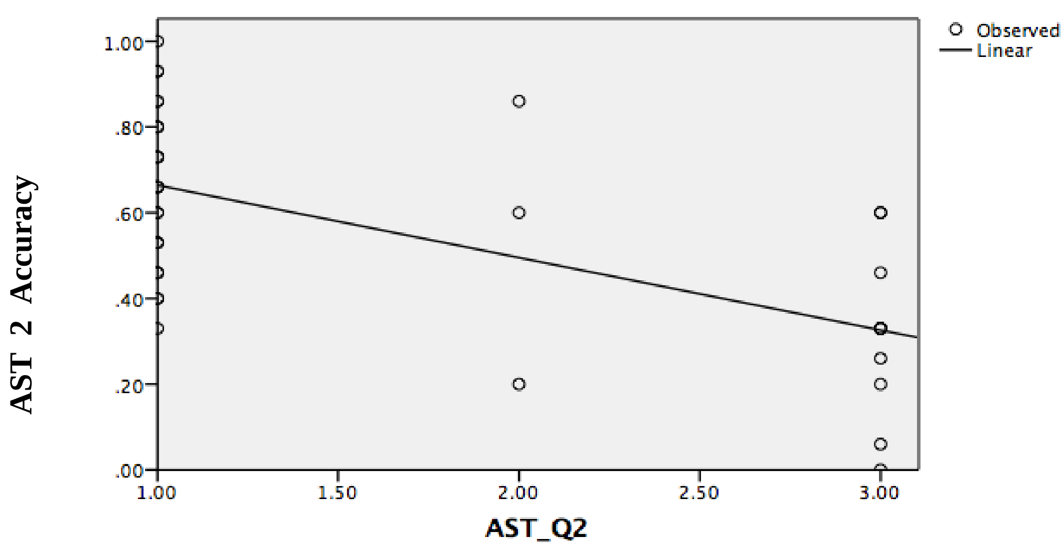

Figure 5. Regression line; AST_T2_Accuracy & AST_Q_2 Reported technique of use

There were also trends that failed to reach significance between Reported Technique and DMAT Form A & B, and though purely speculative, this finding suggests none-the-less participants who implemented the specific technique may prove to reliably score higher on music aptitude measures, if the design were able to achieve a larger sample size. This is reinforced by referencing Pearson's Table of Critical Values for r, in which the correlations found between reported technique and DMAT Musical Memory scores become significant as df approaches the initial aim of N > 100 with respect to a two-tailed t-test with $\alpha < .05$. The negative correlations indicate that those participants who were rated lower on the 1 though 3 rating scale for Reported Technique (1 = utilizing a parallel processing technique similar to the one that defined the experimental group), were more accurate on T1 and T2 of the AST, while showing a weak correlation with DMAT Musical Memory Scores Form A & B, that was not significant, perhaps due to lack of statistical power as described above.

Finally, multiple regression was applied as I sought to see if change in score could be predicted via combination of (A) Group-assignment, (B) Musical aptitude scores, and (C) reported technique. Here it was found that Reported Technique failed to be a predictor of change in performance. To further investigate the influence of utilizing the technique-to-be-learned on performance, I looked at the difference in DMAT means as a determinant of Reported Technique. Here, contrary to the above finding that Reported Technique was a significant predictor of accuracy on AST, there was no indication that Reported Technique could predict individual performance on any measure of the DMAT.

Further analysis: Consideration of qualitative variables of self-report measures. One other consideration came from the subjective reports of participants regarding number of years of practice with a musical instrument, as measured via two separate self-report methods. These reports, under the assumption of honest and accurate reporting, were significantly correlated with accuracy on both AST T1 and AST T2 ($r(38) = .363$, $p = .03$ & $r(38) = 36$, $p = .03$). Moreover, these two self-reports of (1) years of music practice and (2) number of instruments played, had the strongest correlations to Drake Musical Memory Forms A ($r(38) = .37$, $p = .02$ & $r(38) = .44$, $p = .005$, respectively), and Drake Musical memory Form B ($r(38) = .37$, $p = .02$ & $r(38) = .39$, $p = .01$), thus supporting the validity of the DMAT as a measure of one's implicit musical ability. While these findings provide further evidence that participants with a more extensive history of music training, were more proficient with AST, it as well confounds the results due to these participants having little head room for improvement when measuring effect of training. Again, due to implementation of a similar (or same) strategy within the preliminary round of the AST as the strategy that half the participants learned after AST T1, initial scores on accuracy were high enough to leave little to no room for improvement.

To recap, it is important to note that because accuracy on the AST (TI & T2) was positively correlated to some DMAT scores, and correlated with reported technique, many of the participants who were initially highly proficient with AST, had little room for improvement when progressing to the second round of AST. Additionally, many of the control group participants (n = 9), reported implementing a similar parallel processing technique to the one that participants assigned to the experimental group were instructed to use; a technique that was proposed as the means for measuring ability to adapt and use a specific parallel processing technique, which furthermore, was found to be a predictor of accuracy on the AST. This in turn may have significantly confounded the results due to initial implementation of a technique that acts as an aid in completion of the AST Task. This could in-turn led to not only a smaller margin of room for increasing accuracy on AST T2, but may result in the experimental group becoming invalidated because in procedure, almost half of the control group participants inadvertently became distinguishable from experimental group participants in procedure only in terms of exposure, though operating with very similar technique/skill.

Limitations and Recommendations for Further Research

Shortage of participant recruitment and retention represents one of the most influential limitations of the study. The initial aim for rejecting H0 was $p > .80$ via *Cohen's d* $> .30$, which would require N > 176. And to find $r < .20$ / $1-\beta$ $.80$, requiring $N > 193$. However, I decided to settle for $p > .75$ via *Cohen's d* $> .60$ & $r < .35$ / $1-\beta$ $.60$, due to the final N of 40.

The most notable difference between participants came from participant use of explicitly incorporating visuospatial working memory to count while their phonological loop was under demand, which was accomplished via AST. Correlations between implementing this parallel processing technique and AST accuracy T1 & T2, respectively, *(r(38) = -.49, p = .001 & r(38) = -.62, p < .001)* are quite notable and encourage further delving into this process for future designs. Since the majority of participants who reported using the technique, also stated that they had implemented it, or a similar technique, early on during round one of AST, follow-up research must include an extra step of participant-screening following AST-T1 in order to remove this confounding variable contributing to a ceiling effect.

In other words, while the results became confounded via participant use of the parallel processing technique, without having been instructed, the technique did prove to be a valid approach for benefitting participant proficiency on the AST. Additionally, multiple inhibitory events upon the participant gathering process, led to the design only achieving a much smaller sample size than anticipated. This even further Compounded our efforts, placing constraints on any attempt to adjust for the confounding variable of technique implementation. Thus, this design overlooked assigning exclusionary criteria to those participants who reported implementing the technique prior to instruction; failed to hypothesis the need for assignment of participants based on this confounding variable. This resulted in being unable to not only adjust group placement, though exclude outliers as well, and it became impossible to separate out this primary confounding variable in order to get a more accurate measure of ability to adapt the technique to increase efficiency. However, it is still intriguing to appreciate the implications in the current data that individuals with greater musical proficiency preemptively enact a technique for more efficient parallel processing than those with lower aptitude. This, in turn, clarifies the route for future research and discrimination of the correlations music training and proficiency has on working memory systems as well as various aspects of human development.

One might ask, *if musical aptitude was positively correlated to accuracy and using the to-be-learned technique of parallel processing was significantly correlated with accuracy, why was there no effect on one's ability to learn a parallel processing task for increasing parallel processing proficiency, with respect to musical aptitude?* On first look, it suggests that high musical aptitude should as well be correlated with change in performance, however, because so many participants used a technique to begin with, the learning phase was of little impact on performance. Initial proficiency was reflective of individual capacity for parallel processing regardless of musical aptitude, thus there was little room for improvement in score for those with higher musical aptitude. This confounding variable effected both the experimental and control groups, and became a valuable contributor to understanding how to approach this research design in the future.

What is more apparent from these findings in that to truly test the hypothesis, one would need to control for participants who were predisposed to using the technique for efficient parallel processing. Moreover, due to the moderate/high correlations between musical aptitude and performance on the parallel processing task, it may be necessary to implement a tougher parallel processing task due to lack of room for improvement for those high in musical aptitude. Here, the task that I had to forego implementing due to time constraints may actually be a more efficacious task for measuring score-change, or efficacy with parallel processing adaptation. Specifically, the Articulatory Suppression Task I hoped to implement was one in which participants had to read a sentence and count the words in the sentence simultaneously, rather than just count word stings while repeating a single word.

While the sample size may have been too small to adjust our analysis to account for the unforeseen confounding variable described above, the research was still able to contribute to the literature on the subject of music proficiency and development. This design is one of the few quantitative validations of a correlation between music proficiency and human development. Using the present design, there was a correlation between music proficiency with a general human attribute underlying many of the correlations in research leading up to this current design; music proficiency was found to be positively correlated with working memory proficiency. Up until now, nearly all correlations between music proficiency and development were qualitative on behalf of what qualified one as proficient with music (reported number of years of practice being the closets quantitative measure), and in nearly all designs, participants were divided into "musician" or "non-musician" groupings (Brochard, Dufour, and Despres, 2003; Hughes & Franz, 2007; Hyde et al, 2009; Patston, Hogg, and Trippett, 2007). This design showed that one does not necessarily have to claim to be a musician, one may have a high musical aptitude, respective of minimal history of music training, and still benefit cognitively respective of working memory processing skills akin to musicians.

As has been noted throughout this section, the generalizability of the findings may be quite limited, as an unforeseen confounding variable created a clear roadblock for validity of the learning aspect of the experiment. Thus, due to this and the low power that resulted from a small sample-size, one also cannot be confident in validating the finding of no effect and would recommend this experiment be re-run with assigned grouping respective of reported technique on round one of the Articulatory Suppression Task. Additionally, the Articulatory Suppression Task should be adjusted to increase difficulty since many of the participants who were high in musical aptitude also scored high in the initial round of Articulatory Suppression. One way to approach this procedural change, and thus effectively increase headroom for performance increase, would be to have all participants who reported use of the specific parallel processing technique during AST T1, to be sorted into a group for AST T2 in which the participants will have to read the word strings while counting and maintaining a target speed for articulation. This would increase the amount of attention paid to the word strings, as opposed to merely having to repeat a target word, and possibly reduce participant proficiency. This would as well, guarantee that the learning phase of the experiment will in fact present a novel skill, which will increase confidence that this design is actually measuring individual ability to adapt working memory systems under conditional in which time to adapt is restricted.

A second means of approaching the confounding variable of a ceiling effect could be to start out with a more complicated form of AST, a form of which that has been validated by other researchers. While this would not guarantee that participants within the experimental group are truly learning and attempting to adapt a novel parallel processing technique, it would at the least increase the chances that all participants would have room for improvement. However, similar to above, one could administer a survey following AST T1 and then assign participants to groups respective of their implicit ability to discover efficient means of completing the task via parallel processing technique. One such variation was presented by the research of Murray, Rowan, and Smith (1988), who took baseline measurements of performance via standard AST; participants repeated the word THE while having to memorize a set of symbols, which gave the researcher baseline scores of participant proficiency with the most basic and widely acknowledged form of the AST. Following baseline measurements, they had participants increase the depth of attention paid to the AST by first having participants repeatedly spell aloud the word THE while attempting to memorize a set of symbols, then participants were instructed to spell random eight letter words while attempting to memorize n eight visually presented symbols, articulating each letter as a new symbol was presented in a relatively short amount of time. These variations on AST proved to be increasingly difficult and in turn reduced participant accuracy.

In sum, there appears to be ample evidence to motivate the reconstruction of the current design in order to extinguish the influence of a ceiling effect. Additionally, administering a survey to participants following baseline measures (AST T1), inquiring techniques used to complete the task, will provide the ability to assign participants into groups, respective of implicit ability to discover technique and at what point in during AST T1 they discovered a technique. The current research will validate the assigning of participants, and thus sustain the power of the procedure. Taking these variables into account, if achieving a larger sample size, one might more clearly measure if musical aptitude effects one’s ability to learn and implement parallel processing skills. Due to the generalizability to human behavior and foundational aspect of the working memory systems, this in turn may approach the lack of solid evidence for or against previous correlative data pertaining to music training and other skills.

Application for Positive Social Change

Considering the positive social change implications of the above findings, our first clear influence of musical proficiency on society is the developmental benefits to working memory, as displayed in the correlation between parallel processing and musical aptitude. Because working memory system proficiency is a very accurate measure of robustness of cognitive processing (Shipstead, Harrison, and Engle, 2016; Tulsky, Carlozzi, Chevalier, Epsy, Beaumont and Mungas, 2013), if one's clarity and proficiency with working memory is more robust, so will be their propensity to retain information. This means that via increasing music aptitude, through music being a primary aspect of public education, due to it being akin to an exercise in simultaneous use of working memory systems, presumably the general public's proficiency with all tasks that rely on working memory systems may be increased. Contrary to this commonsense relation, music programs in schools have been defunded, degraded, and cut in some extreme cases over the past few decades (West, 2012), a trend that is not only confined to the Unites States of America, though observed to be taking place world-wide (Arostegui, 2016). In many instances this is a result of budget cuts combined with changes in academic policy, in which concrete and narrow focus on specific academic subjects have been given extreme emphasis and schools are being held accountable via standardized testing (Archer, 1996; West, 2012).

Anyone who's been through public education in the past quarter century knows that music training is considered an elective in middle and high schools that offer it, and a secondary class, as similar to library, in most elementary schools. Promoting the fundamental cognitive processes underlying intelligence should be a primary aim of the education system, yet we have chosen to narrow down the life experience gained via public education by having two math classes or additional time spent reading and writing. In turn, we are left with asking ourselves, how many excuses to the contrary can validate not having a robust program in public education for music development, and thus account for the lack of recognition of nearly thirty years of research?

Perhaps this more specific and generalizable correlation, found within our design, is providing an influence on positive social change. As the data adds up in favor of musical aptitude significantly correlating to more robust functioning among a wide array of human attributes (Goycoolea et al, 2007; Grewe, Nagel, Kopiez, & Altenmuller, 2007; Patston, Corballis, Hogg, & Trippett 2006; Salovey, Woolery, Stroud & Epel, 2002; Schellenberg, 2006; Spajdel, Jariabkova, & Riecansky, 2007) our society must eventually reach a place where society it should acknowledge the influence as basic to human development as reading, writing, and mathematics. Thus, finding significance between proficiency with parallel processing and musical memory, has profound implications due parallel processing being a more complex measure of working-memory's functional capabilities, and thus directly related to nearly all human activity. This may as well invite many more researchers to approach this dynamic from various other angles, and allow for more accurate measurements of how confident all researchers of this topic may be in our findings that musical training is commonly positively correlated with cognitive and behavioral abilities.

Further, with respect to the current findings' potential to inform future research designs that may better examine music proficiency in relation to working memory, having found some evidence that the design was compromised due to confounding variables, this researcher is compelled to adjust the procedures and re-run the experiment so that a clearer picture of just how influential music aptitude is on an individual's proficiency with working memory systems. Regardless of future prospects, the current research remains valuable in its findings due to further validation of previous findings and increasing clarity on exactly how to formulate a means of accurately sorting out the variables that have been correlated between musical development and other forms of development. Moreover, as applicable to procedural recommendations in the study of music training on human development, due to music aptitude (as measured via Drake Musical Aptitude Test) being considered a better predictor of performance on the Articulatory Suppression Task than personal report, it should be used as the primary measure above subjective reporting. In other words, if I had used a subjective reporting measure in this research, instead of a reliable and valid objective measure, I would have had much weaker and/or no differences between individual reports of music fluency (as discussed in Appendix B). I believe this qualifies the logic that an individual may study music for many years, yet due to lack of implicit skills, never actually benefit equal to his or her peers of higher implicit skill. And vice Versa, individual with high musical aptitude, though never having been in a nurturing environment for this skill, may develop superior processing skills as would be required for advanced musical proficiency. Though in either case, musical training may enhance each individual's proficiency with working memory, more so that without and only with the aid of our current education system for development therein.

In closing, this research provided additional support for the prospect of musical training and/or aptitude having a positive influence on development. Specific to our study, higher music aptitude resulted in better performance on a test designed to stress the working memory system into parallel processing. Unfortunately, this research was unable to account for specific confounding variables highlighted above, and in turn the main test, for participants to learn a specific technique, was corrupted. This will increase the likelihood of a more efficacious design in the future, due to having a clearer picture of possible confounding variables, research of which is warranted, having found a positive correlation among participants, between the variables of music aptitude and working memory proficiency, specifically parallel processing with the working memory network.

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Appendix A: Testing instruments

Figure 2: Music Hx Survey

Music Fluency History

1) Please circle ways in which music is or has been a part of your life.

Passive listening Singing in Church Singing Alone

Karaoke Meditation Singing @ family gatherings

Regularly seeing live music For falling asleep

Background noise @ home

2) **Please rate the following respective to what your environment consists of most: (1 being most 6 being least)**

__Listening to music __Listening to TV/other non-music __Silence/nature

__Social/non-music __Social music passive listening (background music at work)

__Social active participation w/music (actively acknowledging music in social situations or engaging in music socially)

3) **How musically inclined in your family?**

Number of people in your family who identify as *musician* ____

Biological Rundown: (only blood relatives please) Aunts/Uncles___

Cousins___ Mother___ Father___ Siblings___ Grandparents___

4) Please mark which are your preferred genres of music?

Blue Grass__ Classical__ Country__ Folk__ Hip Hop__ Jazz__ Rap__

Rock__ Rock Alternative__ Emo__ Progressive/eclectic__ Electronica__

Ambient__ Metal__ Easy Listening___

Music Training

1) **At what age did you begin your music training (Circle one)?**

(2 – 5) (6 – 9) (10 – 12) (13 – 15) (16 – 18) (19 – 23) (24 +)

(I have no training in music)

2) **Did you ever stop regular practice (if so, @ what age, for how long, and how many times)? If you stopped and never started again just write down age at which you stopped. If you never stopped mark "N/A". If you stopped multiple times for different periods of time mark each "block" as best as you can recall.**

Age: ___to___ Instrument_____________ Duration: yrs_____ months _____
Age: ___to___ Instrument_____________ Duration: yrs_____ months _____
Age: ___to___ Instrument_____________ Duration: yrs_____ months _____
Age: ___to___ Instrument_____________ Duration: yrs_____ months _____

3) **Circle one describing your music training:**

(Formally educated) (Self-taught without book or video)

(Informal from peers/family)

(Self taught with books/video)

(Distance learning/books and videos)

(Combination of a couple [circle those that apply])

(All of the above)

4) **Rate your fluency for reading music on a scale of 1 to 7 (0 = no ability 7 = expert)?**

Reading ability: _________

5) **How old are you now and how many years have you been practicing?**

Age:____ Years of practice:______

6) **How many, and which, instruments are you proficient with?**
If you do not play the instrument leave blank, otherwise rate from 1 to 7,

(1 = novice 7 = expert)

Percussion:_____
Strings:_____
Piano:_____
Horns:_____
Vocals:_______

Wood Wind:______
Aerophones:______
Bowed instruments:______

7) Do you more often play alone or with others?

(Always alone) (10 to 30% Group) (30% to %50 Group) (50% to 70% Group)

(70% to 90% Group) (Only play in a Group)

8) How often do you perform in front of an audience?

(Always alone) (10 to 30% Audience) (30% to %50 Audience)

(50% to 70% Audience) (70% to 90% Audience) (Only play for an audience)

9) **Please indicate how many years of music training you have received by circling one of the measures below.**

(0-2 years) (2-4 years) (4-6 years) (6-8 years)

(8-10 years) (10+ years)

10) Please rate the percentage of time you spend practicing compositions written by yourself, and compositions written by others.

% Self:_______ **%Others:_______**

Articulatory Suppression Task Questionnaire

1) How well do you feel you did on the articulatory suppression task?
Rate your fluency for this task on a scale of 1 to 7,
(0 = could not do the task 7 = performed perfectly)?

Score:_____

2) Please explain the technique you applied in order to complete the articulatory suppression task.

Appendix B: Discussion on Music Fluency and Proficiency Reporting Results

The music training survey and music fluency survey are both subjective report measures that have been converted to quantitative measures, weighted respective of implications that they may on music development, as determined by this researcher. The scoring criteria each variable of the Music Training survey are as follows, (For complete score-sheet see figures 1-4).

1) Age is reverse weighted due to earlier age of initiation having a strong effect on proficiency, especially if practice continues even irregularly throughout the lifespan.
2) Each instrument of practice is worth one point + number of years of practice
3) From values of 1 point to 5 points respectively: Self-taught without books or video, informal from peers and family, self-taught with books/video, distance learning, formal education.
4) Reading ability is multiplied by 2
5) Score = Years of practice – (age-4)
6) 1 pt/instrument + rating = score
7) From always alone to only in group (.1, .3, .5, .7, .9, 1.0)
8) Same scoring as #7
9) From 0-2 years to +10 years (2, 4, 6, 8, 10, 15) [+10 years gets 15 points due to implicating professional development]
10) Both % self composition and % Other composition are reported as separate variables.

Scoring determination for the Music Fluency History survey are as follows,

1) All active participation gets 10pts, all passive tasks get 1pt
2) All non-music get 1 point, all passive et 2 points, all active get 10 points, pick top three environmental descriptors for score, discard least three.
3) Multiple # of musicians by 4
4) 1pt for each genera of interest

Analysis of Correlations between Subjective Reports and Performance

The survey on music training, questions 1, 2, 8 , and 9 all displayed positive correlations (α *<.05)* to final score on AST, though not initial score or score-change. And questions 1, 2, 3, & 8 were positively correlated (α *<.05)* to DMAT Form A and Form B of the Musical Memory Tests, correlations thereof were between r > .31 to r > .44. These correlations were similar in effect as those mentioned in the body of research above with respect to performance on AST and Scores on the DMAT. Basically, these correlations validate the efficacy of the DMAT, as well as reinforce the evidence that those who have experienced more extensive musical training are as well found to have more proficient parallel processing abilities.

Moreover, these questions specifically related to age of initiation of music training and number of instruments the person reports having experience with. However, even though these variables were correlated with AST T2, these variables were not predictors of accuracy on AST T1, also they were not predictive of technique implemented, which was another variable that was strongly correlated with performance on AST T1 and T2.

These specific questions may be useful as a cross-reference for outliers in future research, and seem to provide some additional support for the DMAT, though the DMAT remained a better tool for measuring musical ability.