FORMAL TRAINING EFFECTS ON THE DEVELOPMENT OF ATTENTION IN YOUNG CHILDREN: INSTRUMENTAL MUSIC

by

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(Under the Direction of Stacey Neuharth-Pritchett)

ABSTRACT

The ability to selectively attend and maintain attention is a key cognitive function, the development of which undergoes significant development between the ages of four and six years. This study employed a quasi-experimental design to examine the relationship between formal instrumental music training and the development of attention in four- to six-year old children. After determining reliability of overall accuracy and mean response time of the Attention Network Test for Children, the attention development of children participating in instrumental music lessons was compared to that of children participating in other types of training and to a control group. Covariates included age, gender, household income, and intelligence. No significant between-group difference was found. No significant association between intelligence, age, and gain scores of overall accuracy or mean response time was found. No significant difference between gender or household income groups and gain scores in overall accuracy or mean response time was found. Small sample size and short duration of training inhibit the strength of claims of training effects. The results have implications in areas of attention, cognitive development, and music education.

INDEX WORDS: attention, development, cognitive, instrumental, music, training

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA
2020

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DEDICATION

To my sweet, sweet daughter, may you see yourself within these pages.

It was completed for you.

ACKNOWLEDGEMENTS

My time at the University of Georgia has changed my life and so many people have contributed to my growth. This journey has not always been easy and my faith has been tested and strengthened as a result. I thank my Heavenly Father on a daily basis for the opportunity to learn, to challenge myself, to better provide for my family, and for the stubborn will to see it through. It has been His grace and His grace alone that has allowed me to find a balance and persevere.

I must acknowledge the sacrifice and unending support of my parents and my family. For many reasons, the completion of this document and degree would not have been possible without them. They believed that I could and that I would. They selflessly worked alongside me so that I may achieve this goal. I will forever be in their debt. I thank Dr. Bonnie Cramond for taking a chance on me in the very beginning. I cherish her brilliant mind and her mentorship, teaching, guidance, and friendship. Thank you, Dr. Cramond, for being so supportive all of these years. I also thank Dr. Stacey Neuharth-Pritchett for stepping forward to guide me through my dissertation when we lost Dr. Marty Carr. Her sacrifice, guidance, hard work, and motivation were absolutely pivotal to my seeing this process through to the end. I will forever be thankful that she so kindly took this role. I want to thank Drs. Lu, Atkins, and Rohwer, for their patience over the years. I appreciate their hard work and guidance that enabled me to see this dissertation to its completion. To Dr. Carr, your model of professionalism, attention to detail, and scholarly rigor continues to guide my work and my goals. You are missed.

I cherish the friendships that I made during my time in Athens and others who have walked alongside me through this endeavor, old and new. Sureyya, Erin, Nicole, Amanda, Tonia, Brian, Shauna, Angela, Lisa, and many others. We may have scattered in the wind, some farther away than others, but I treasure the time we had and the memories we made. Outside of UGA, Emily, Teresa, Melissa, and J.B., thank you for your lasting friendship. You stuck with me, pushed when needed, encouraged, prayed, listened, and most importantly, believed that I could see it through.

Lastly, to my sweet Nathalie Grace. You came along in the midst of this project and, while you were not the reason I started, you certainly were the reason that I finished. What began as an intellectual exercise, was completed out of the desire to show you that although the world may try to tell you what you are or what you are not, God will write your story if you let Him. It may not always look like you planned, but the reward is so sweet for those who trust in Him. I can only hope that the life we create together using the opportunities that may come from this pursuit honors the blessings and grace that made it possible to begin with. I love you desperately, my dear.

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CHAPTER 1

Introduction

With implications in nearly all aspects of the human experience, the ability to selectively attend and maintain attention is an important and relevant skill. There are, therefore, myriad theories and models of the forms and mechanisms of human attention as well as a great deal of available research on factors that influence the function and development of attention. In recent years, advances in technology and sophisticated statistical models have been employed that allow us to image brain processes while performing tasks, to more closely examine the relationships between cognitive and neurological processes required for attention, and also to explore variables that may affect the development of attention skills: one such variable is childhood music training.

Musical training is hypothesized to improve the development of attention (Wang, Ossher, & Reuter-Lorenz, 2015), but there is limited research directly addressing the effect of music training on attention, particularly if introduced during crucial developmental periods for attention. Existing research focuses on brain structure and functions associated with music training (Bengtsson et al., 2005; Hyde, et al., 2009; Moore et al., 2014; Pantev et al., 2001; Schlaug et al., 2005; Slevc & Okada, 2014), brain activity in musicians during performance or practice (Parsons et al., 2005), and associations between music training and non-music cognitive abilities (Degé et al., 2011; Rodrigues et al., 2013; Schellenberg, 2004; Schellenberg, 2006; Strait & Kraus, 2011) and behaviors believed to be associated with increased attention skills (e.g., academic achievement; Costa-Giomi, 2004; Scott, 1992; Steele et al., 2012). Virtually all of this research is correlational and involves adult musicians. Change in attention skills are rarely measured as an outcome of musical training in children.

In a recent study, for example, adult musicians scored significantly better than non-musician adults on a temporal-discrimination measure of sustained attention and not significantly higher on a visual-discrimination sustained attention measure (Wang et al., 2015). Similarly, when compared to a group of adult non-musicians, adult musicians presented a significant effect of selective auditory attention on prefrontal evoked activity. This effect was demonstrated by a decrease in auditory-evoked response variability at the prefrontal cortex electrode sites in attended speech despite distracting background noise (Strait & Kraus, 2011). Further, the age at which musicians began training correlated with the extent of decrease in response variability. Such group differences are argued to be an effect of long-term musical training on selective auditory attention. However, because of the nature of the design of these studies it cannot be determined that these differences result from participants' music training or pre-existing differences in attention. It is possible that individuals with greater skills in these areas of attention might be drawn to, and be more successful in music and therefore, more likely to pursue music into adulthood.

Given the substantial development of attention in early childhood, there was a need for research to focus on the impact of music training during this time frame—as opposed to adulthood—on the development of attention. Research suggests that training effects are enhanced when they take place during early developmental or maturational periods (See Herholz & Zatorre, 2012; Moore et al., 2014; Wan & Schlaug, 2010 for review). In particular, the period between the ages of four and six is critical for the development of attention. Utilizing a magnetic resonance technique called diffusion tensor imaging, Bengtsson et al. (2005) investigated the associations between amounts of reported practice time in three phases (i.e., childhood, adolescence, and adulthood) of adult musicians and the organization of fiber tracts within participants' white matter. Regressing *fractional anisotropy* (FA; a measure of fiber tract organization) on total practice time during each phase, they found that increased myelination based on neural activity during piano practice (training) is correlated with increased white matter plasticity. The associations were especially strong when training begins early, during periods of maturation for the specific neural areas involved. Bailey and Penhune (2012) found that adult musicians (*n* = 15) who began their musical training before the age of 7 had better musical task performance than adult musicians *(n* =15) who began their training after the age of 7 even when controlling for years of formal training, experience, current hours of practice, and individual working memory abilities. Rodrigues and colleagues (2013) found that, within a sample of adult musicians *(n* = 38)*,* the onset age of musical training was correlated with reaction times on all visual attention tests. These findings hint at the importance of early music instruction but the correlational nature of the data makes it impossible to determine a causal relationship.

At this time, there is a dearth of research focusing specifically on the impact of music training via focused, private instrumental music lessons on the development of attention during early childhood. This study will employ Petersen and Posner's (2012) modified neurocognitive model of the human attention as a framework for a deeper investigation into the relationship between early childhood music training and the development of attention. It is hypothesized that each of the three attention networks (i.e., alerting, orienting, and executive networks) will be enhanced by early music training introduced during the crucial developmental period that occurs between four and six years of age.

Chapter 2

Literature Review

The construct of attention is quite broad, and its importance is evident across nearly all domains. As a result, the literature on attention is extensive and varied. Petersen and Posner's (2012) modified neurocognitive model of the human attention system assumes three networks of attention (i.e., alerting, orienting, and executive networks) and provides a well-established theoretical framework. This model is differentiated from others because of its focus on the attention processes that occur prior to target selection. In essence, the three networks described in the model are supporting functions that enable selection by priming for, orienting to, and resolving conflicting response tendencies to enable proper selection.

It is important to note that Petersen and Posner (2012) clearly delineate the difference between attention and information processing. This is a deviation from common themes in earlier models of attention that stressed the importance of information processing. Petersen and Posner posit an attention system that is anatomically distinct from information processing systems, which make decisions about how to handle incoming stimuli and produce outputs (Petersen & Posner, 2012). Two additional assumptions are that the attention system utilizes a network of distinct anatomical areas and that these anatomical areas perform specialized, complementary, attention-related functions that are described in cognitive terms (Petersen & Posner, 2012).

Alerting Network

At its essence, the alerting network is an individual's state of—or ability to maintain a state of—alertness and readiness to respond to stimulation. Such response readiness also aids in preparing an individual for subsequent effortful information processing, which is "an important condition in all tasks." (Rueda, 2014, p.297). Specifically, two types of alertness have been postulated: tonic and phasic alertness.

Tonic alertness refers to an individual's state of general wakefulness and is a top-down, intrinsic state of internal control of arousal not reliant on an external stimulus (Rueda, 2014; Weinbach & Henik, 2012). The level of alertness cycles between sleep and waking and between sluggishness and highly alert and, therefore, likely affects an individual's vigilance, or ability to sustain attention (Pozuelos et al., 2014; Rueda, 2014). To maintain high performance levels over a long period of time, particularly on novel tasks, higher order attention supervision has been found to be necessary (Langner & Eickhoff, 2013). For example, a student attempting to study all night before a test might find their ability to sustain attention will wax and wane as the night progresses because of increased drowsiness and nerves.

Phasic alertness is a short-lived, highly-alert condition in which response readiness is improved through bottom-up processing of salient external cues (Pozuelos et al., 2014; Weinbach & Henik, 2012). The resulting increased state of alertness in response to external warning cues makes possible an increased orientation and response speed to the target stimulus. This is the result of significant physiological changes that are thought to aid in the preparation for a rapid response by suppressing other ongoing activity (Rueda, 2014). An example might be the sudden, highly alert state resulting from hearing a car horn while walking down a sidewalk.

Orienting Network

The *orienting network* is the conscious perception of a target stimulus via the selection of a modality or location (Petersen & Posner, 2012). For exogenous stimuli, selection is often made possible by the overt orienting toward the location of the source of information through eye or head movements. However, orientation can also occur without such overt movements: covert attention is the orienting of an individual's attention only (Rueda, 2014). Orienting shares similar characteristics with the commonly known constructs of attentional control or switching: characteristics such as the disengaging of attention from a target, moving to new location or modality, and the re-engaging of attention.

Orienting also aids in the act of selecting a target stimulus through foveation. Within the field of attention research, foveation refers to the reduction of image quality in the visual field—covertly or overtly—around a target stimulus, which aids in subsequent processing of the target by optimizing orientation. Similarly, in audio attention tasks, foveation would describe the experience of sound fading to the background as attention shifts to another modality. Foveation also shares characteristics with the well-known constructs of spotlight theory and inhibition. In these constructs, inhibition acts to suppress or subdue irrelevant or distracting stimuli from the input field thus restraining neural activity related to these extraneous stimuli. Therefore, such suppression also allows for greater focus on the target stimuli. Contrary, and yet complementary, amplification or enhancement occurs when attention is oriented toward an object in the environment and information pertaining to that object is amplified by increased related neural activity. This amplification acts as a virtual spotlight allowing for subsequent processing.

When the two functions are combined in what is known as the dual mechanism model, the combination of opposing functions serves to boost attentional power. To illustrate, one might imagine a performer on stage. With all house lights on, it might be difficult to draw an audience's attention to the performer. Turning a spotlight on the performer can help but interference from the ambient house lights still inhibits focus. The combination of the dimming of the house lights with the addition of the spotlight has a greater effect than the spotlight alone. Such inhibitory mechanisms "assist in the efficient foregrounding of target information and reduce interference from competing distractors" (Dagenbach & Carr, 1994, p. 62).

Executive Network

The third component of the original human attention model presented by Posner and Petersen (1990; Peterson & Posner, 2012) initially referred to this network of attention as target detection. Upon revision, the focus of this network was shifted to describe not the detection of a target, per se, but the consciousness or awareness that accompanies detection and the resolution of conflict in response tendencies (Posner et al., 2012). Rueda (2014) further described this network as being "involved in the regulation of thoughts, feelings, and behavior" (p. 300) and contributing to the overall executive function (Mezzacappa, 2004). Further, self-regulation—by way of the executive network and the ability to resolve conflict—is crucial for socialization and is related to fewer instances of antisocial behaviors in adolescence by supporting the development of empathy and behaviors that support socialization (Posner & Rothbart, 2009). Research has identified that the anterior cingulated cortex (ACC), the lateral prefrontal cortex, and the medial frontal cortex are activated during this process and serve as a hub of activity during executive attention tasks such as conflict resolution, error detection, control of working memory, and regulation of emotion (Petersen & Posner, 2012; Posner & Rothbart, 2009; Posner et al., 2014).

Examining the effects of specialized training introduced during the preschool developmental years on executive attention, Rueda et al (2012) studied training effects on executive attention networks in preschool aged children pseudo-randomly assigned to training (*n* = 19) and non-training groups *(n* = 18). The groups were matched by gender, intelligence, age, and parental education and there was no significant difference between the groups on scores from the pre-training assessments. After 10 computerized training sessions over the course of five weeks, post-training results were modest but suggest an increased efficiency in executive attention skills and increases in alerting scores, although neither of which were statistically significant. Also, scores for the non-training group demonstrated a similar trend, which suggests that a portion of the effect is likely the result of practice effects. The relatively short time-span of the intervention also likely had an inhibiting effect on the results but, interestingly, there was still evidence of training effects in brain function two months afterward as measured in a follow-up study.

Attention and Working Memory

The interaction between attention and working memory (WM) is an important consideration as research suggests that WM both benefits from and contributes to an individual's attention abilities. WM utilizes “attentionally-based executive control”

(Baddeley et al., 2011, p. 3856; Knudsen, 2007) and relies on executive attentive skills to inhibit prepotent responses in favor of less dominant responses (Petersen & Posner, 2012) as it simultaneously accepts, temporarily stores, and manipulates information from the environment. The importance of these self-regulating abilities was so apparent that, in their model revision (2012), Petersen and Posner extended the model to specifically account for self-regulation.

Further, Engle (2002) argues that while greater WM capacity means that more information can be actively maintained, this maintenance has less to do with larger memory store and more to do with a greater ability to control attention to maintain or suppress information. Another explanation could be that greater WM capacity results in an increased ability to control attention and avoid distraction since goal-directed information can be more easily kept in working memory while completing task. Such control is often measured by tasks requiring a participant to respond to the target stimulus while simultaneously attempting to inhibit conflicting information or irrelevant response tendencies (e.g., Stroop tasks, Go/No-Go tasks; Weinbach & Henik, 2012). Conway, Cowan, and Bunting (2001) found that high-WM individuals were better able to block the distraction of name being spoken in non-attended ear while shadowing messages from the other. The high-WM participants reported hearing their name 20% of time while low-WM participants were less able to ignore distracting information and reported hearing their name in the unattended ear 65% of time.

Development of Attention

According to Petersen & Posner (2012), functional data from behavioral and resting states of attention suggest that the executive functions related to attention undergo substantial development between infancy and childhood. They proposed that attentional skills develop from being reliant on the orienting and alerting networks in infancy to a greater reliance on self-regulatory abilities in the executive network throughout middle and later childhood and into adulthood. While current research has honed in on these early years as salient periods of development, differing perspectives result in a lack of consensus, as yet, on an exact and generalizable developmental trajectory for each network.

This expansion of attention abilities begins in infancy when the alerting, orienting, and executive control mechanisms are less independent (Rueda, 2014) and studies utilizing factor analyses show significant development between the ages of 3 to 6 years. Breckenridge (2008; also Karmiloff-Smith et al., 2012) initially found that the factorial structure of younger children—between 3 to 6 years of age—fit with a two-factor model consisting of executive attention and sustained-selective attention. However, conducting a closer examination of that data, Breckenridge, Braddick, and Atkinson (2013) split the sample into two, more specific, age groups of 3 to 4.5 years and 4.5 to 6 years. Through the use of exploratory factor analyses, they found there was a significant change in the structure of attention during the course of this three-year period of development resulting in a shift from a two-factor model of attention to a three-factor model. The younger group (3 to 4.5 years) was better fit with a two-factor model comprised of sustained attention (alerting) and a combined factor with elements of selective attention and response control (orienting and executive). In contrast, the older group (4.5 to 6 years) was better fit with a three-factor model comprised of sustained attention (alerting), selective attention (orienting), and attentional control (executive;

Breckenridge et al., 2013). These findings showcase the bifurcation of the orienting network from the executive network into a three-factor model that more closely resembles that of adults. They are also indicative of a notable developmental period occurring during this time and is consistent with earlier work by Manly et al. (2001) who found that a three-factor model including sustained attention (alerting), selective attention (orienting), and attentional control (executive) better fit a population of participants aged six years and older. The better fit of two-factor models during ages 3 to 4.5 years and three-factor models--similar to adult models—starting between ages 4.5 and 6 years, suggests a significant developmental change across this time, particularly within the executive network.

The alerting network, in its most basic form, is present for most individuals at three months of age in the ability to maintain an alert state (Mezzacappa, 2004). A more nuanced component of the alerting network is the ability to maintain a state of readiness for intentional and effortful information processing: not the processing itself, but the state of preparedness necessary for efficient processing. Early studies (Levy, 1980) using the Continuous Performance Tasks (CPT) indicated a marked increase in the ability to maintain this state of alertness (vigilance) during the preschool ages of 3 to 4.5 years after which, there is a more protracted developmental trajectory that extends further into young adulthood likely due to a shared reliance on the development of mechanisms of executive control (Rueda et al., 2004; Posner & Rothbart, 2009).

Based on the relative ease of assessing orienting abilities, there is much more research in orienting to external stimuli. Regarding overt attention, the orienting network appears to be fully functioning by six months of age allowing infants to disengage their attention from a stimulus and move it to another. This ability to regulate plays a part in an infant's regulation of distress as higher orienting abilities are found to be associated with an easier temperament (Rueda, 2014). There is little difference between children and adults in terms of ability to shift attention to exogenous cues, but the speed of voluntary attention movement, the accuracy of termination of attention movements, and the ability to disengage attention appears to improve with age through childhood (Posner et al., 2014; Rueda et al., 2004).

The executive network begins to develop during infancy and early childhood with studies indicating evidence of error detection as early as five months of age (Wynn, 1992) and seven months of age (Berger et al., 2006) through studies of gaze and event related potentials located in the anterior cingulated cortex. Behaviors that more closely resemble adult error detection and executive attention (e.g., slowing down after an error) appear to begin developing between the ages of two and four years (Gerardi-Caulton, 2000; Jones et al., 2003). Anecdotally, these behaviors become evident in child development as the source of regulation transitions from the caregiver to the child. Further, attention becomes more goal-oriented (Rueda, 2014) through middle and late childhood and studies have shown evidence for development using response inhibiting go/no-go tasks with 6- to 13-year-old children (Casey et al., 1997; Casey et al., 1997). This prolonged development is likely a result of a reliance upon the development of the prefrontal cortex (Mahone & Schneider, 2012) and scholars in this area have proposed models addressing the overlap in development of attention and executive function and the development of the prefrontal cortex (Mahone & Schneider, 2012).

Effects of Experience

It is important to note that the development of attention is determined not only by genetics but also by experience. Known as experiential canalization, progressive myelination and cortical thinning help shape normal functional development in response to environmental demands. Much of the current research revolves around the effect of stress or adverse environmental conditions (e.g., poverty) on gene expression (see Blair & Raver, 2012 for review) and, ultimately, on behavior. Such pathological pruning of synapses hindered development (Mahone & Schneider, 2012). However, there are fewer studies on the positive outcomes of experiential canalization. One such study (Bengtsson et al., 2005) investigated the effects that extensive piano training had on the plasticity of a white matter fiber tract if introduced during a period of maturation. They utilized fractional anisotropy (FA), which allows the inference of structural properties in white matter. FA was measured using diffusion tensor imaging to compare a group of male concert pianists (*n* = 8; mean age at start of training = 5.8 years ± 1.4 years) to a control group of age-matched non-musicians (*n* = 8). The FA results were regressed on self-reported hours of practice during childhood (up to 11 years of age), adolescence (12-16 years of age), and adulthood (from 17 years of age to time of the study). Results suggest that increased white matter plasticity is linked to extensive piano training experienced during periods of maturation for the involved brain regions. Further, they found that time spent practicing during childhood was a greater predictor of white matter plasticity and that this system was less malleable in adulthood. These findings provide a foundation for the further proposition that this plasticity is caused by increased myelination based on increased neural activity in the fiber tracks involved in the training.

As with the other studies, Bengtsson et al. (2005) examined adults, which makes it difficult to determine when these changes occurred in brain structure. Given that much of this development occurs during childhood it would make more sense to assess changes within that age group. Furthermore, given the focus on cognitive outcomes it would make more sense to directly measure these changes in a study. The idea that experiences and opportunities such as early music training that occur during rich developmental periods might play a role in the development of attention via experiential canalization was the focus of the present study on music training during the preschool years.

Music and Attention

Even in early stages of training, instrumental musicians must attend to the myriad, concurrent, cognitive and physical demands required of playing an instrument as well as simultaneously remember and recall instructions and examples given by the teacher in order to emulate them during practice or performance. While not limited only to musicians, the trained ability to attend to multiple, simultaneous stimuli and inhibit distracting stimuli could be the impetus for the highly focused state of flow that musicians often report during a performance (Csikszentmihalyi, 1991; Parsons et al., 2005). Anecdotally, Storr (1992) described this experience as a mental state in which incompatible stimuli are inhibited, where musicians are protected from other external stimuli. This idea—that participating in music allows musicians to better inhibit distracting information—might not actually be as passive as described. The theory is that musicians, having honed their orienting skills, have trained their minds to not attend to distracting stimuli during a performance and might become better at inhibition in general.

Despite the assumption that musical training supports the development of attention most studies have involved adult participants only. One correlational study with adults examined both visual and auditory sustained attention in musicians and non-musicians. Wang, Ossher, and Reuter-Lorenz (2015) assessed sustained attention in a sample of 20 college-aged music majors and a comparison group of 23 college-aged non-musically trained students. The researchers purposefully chose to include tests of two domains of attention: one that they hypothesized to be closely related to skills often attributed to music training (temporal discrimination) and one not generally associated with music training (visual discrimination). This was to investigate the generality of any significant differences between the two groups of students. In both tasks, participants were asked to identify the “rare oddball” (p. 172) targets from a patterned, timed sequence of visual stimuli. The oddball targets were those that appeared on screen for a slightly longer interval than non-target stimuli for the temporal discrimination task and those that were slightly larger than non-target stimuli for the visual discrimination task. They found that the musicians scored significantly better on the temporal-discrimination measure of sustained attention than the non-musician group but no significant difference on the visual-discrimination sustained attention measure. The musicians were also more likely than the comparison group to employ time-keeping strategies such as keeping a beat in mind as well as mentally subdividing the beat or using a song to keep a tempo. These strategies are skills commonly learned early in musical training and could account for the difference in performance on the temporal measure by supporting an active state of sustained attention. Had the musician group demonstrated greater abilities in both attention areas, the idea of a general improvement of attention would be supported. The fact that the musician group scored higher on the temporal task and not the visual task (see also Roden et al., 2014) supports only an influence on areas of attention directly related to music training. However, it is difficult to determine whether the group differences are due to extensive music training or to pre-existing attentional skills. It is possible that individuals with greater temporal discrimination might be drawn to and more successful in music and, therefore, more likely to pursue music as a college major. A randomized selection and group assignment would allow for these confounding factors to be controlled.

Neurological research measuring musicians' brain activity while performing differing musical tasks may provide insight into how these physiological changes may facilitate a highly alert, attentive state. For instance, Parsons, Sergent, Hodges, and Fox (2005) compared PET scans taken of highly-trained musicians while playing bimanual scales, while playing a Bach concerto from memory, and during states of rest. They found greater deactivation during the more difficult musical task than the scales exercise when comparing each to the resting state. Specifically, 43 percent more areas of deactivation across the brain were observed when comparing the Bach concerto scan to a resting state scan than that which was observed when comparing the scales exercise scan to a resting state scan. Some of the areas of deactivation observed during the concerto performance are areas that are typically activated in resting states so this finding suggests an inhibition of potentially distracting cognitive processes during the performance of more difficult musical tasks.

Several studies have examined the correlation between attention and musical training in adults using technology designed to assess neurological activation. Measuring auditory-evoked, event-related potentials, Strait and Kraus (2011) studied the effect that auditory selective attention has on cortical auditory-evoked response variability between adult (aged 18-35 years) non-musicians (*n* = 12) and adult musicians (*n* = 11). Cortical auditory-evoked response variability is the variability of activation across regions of the brain associated with attention. Such variation is linked to lapses in attention and, further, variation taking place in the prefrontal cortex is interpreted as the failure to meet the goal of attention: to continuously and consistently support and maximize the processing of task-relevant stimuli (Strait & Kraus, 2011). While response variability was measured across 31 electrode sites, participants were asked to attend to only one of two recorded short stories being played simultaneously from speakers on either side of their head: one story on the right and another story on the left. The stories were paused every 8 minutes during which time participants answered a five-question quiz on the content of the attended story (a minimum score was required for study inclusion) and took a short break. Only the adult musicians in their study displayed a decrease in auditory-evoked response variability at the prefrontal cortex in attended—rather than ignored—speech despite distracting background noise. This decrease in response variability suggests that musicians might have a greater ability to maintain attention to attended auditory stimuli in the presence of distracting background noise. A next step would be to determine whether music training contributes to an increased ability to inhibit non-target stimuli in order to maintain attention on the target stimulus.

Rodrigues et al. (2013) assessed the relationship between music training and different forms of visual attention (i.e., selective, divided, and sustained) in adult musicians when compared to a group of adult non-musicians matched on age, education, and gender. They found that musically trained adults demonstrated greater performance on subtests of all three attention tests compared to non-musicians. These subsets included reaction times in the divided attention and sustained attention tests and accuracy in the selective visual attention task. Further, significant correlations were found between the age at which the musicians began musical training and their reaction times for the selective visual attention test, one of the tasks in the divided visual attention test, the sustained visual attention test, as well as a simple reaction time test (Rodrigues et al., 2013). Because this was a cross-sectional study, it is unclear whether early training affected the development of attention or whether other factors were in play. One alternative explanation would be that younger children who have better attentions skills are more likely to be placed in music lessons at an early age and, more salient, stay in those lessons over the years.

Several other studies have examined how attentional skills are related to music training in children. Expanding on the findings of Strait & Kraus (2011), Strait, Slater, O'Connell, and Kraus (2015) sought to determine whether the music-related effect they documented in adulthood emerges in childhood during crucial developmental periods for selective attention and inhibition. The researchers investigated the hypothesis that music training during early childhood is associated with a strengthening of neural networks that underlie auditory attention during mid-childhood and post-stabilization of attention development. They did so by, again, comparing groups of child musician and non-musicians' cortical auditory-evoked variability to attended and ignored streams of speech. These groups of musicians and non-musicians—matched on age, IQ, and sex—were further categorized into three age groups.

Pre-school: 3-5 years old (total *n* = 26, musician *n* = 14)

School-aged: 7-13 years old (total *n* = 29, musician *n* = 17)

Adult: 18-35 years old (total *n* = 23, musician *n* = 13)

Participants were presented with two different audio stimuli (i.e., stories)—one from the left side and one from the right—and they were asked to attend to one of the two stories. Periodically, an evoking stimulus was presented in either the attended or the ignored story and the evoked variability was recorded to assess the differences in evoked response variability between the attended and non-attended stimuli in and between groups. Their results revealed significant difference between musicians and non-musicians in the school-aged and young adult groups but no significant association of selective attention on response variability was found in the pre-school group. This is consistent with the literature and suggests that as attention develops, children with musical training develop better attentional skills—in this case selective attention. However, because this was a correlational study an alternative hypothesis that children with better attentional skills are more likely to continue in music cannot be discounted.

Similarly, Degé, Kubicek, and Schwarzer (2011) investigated associations among music training, executive functions, and IQ in a group of 9- to 12-year-olds (*n* = 90)—matched on fluid intelligence at the start of the research—with varying amounts of participation in music lessons. Participants' music training ranged from no formal training (32.6% of participants) to greater than 4 years of instrumental lessons (17.4% of participants). Executive functions were measured by the NEPSYII with subtests to assess set shifting, selective attention, planning, inhibition, and fluency. Degé et al. (2011) not only found that executive functions, as a whole, mediated the significant association between months in music lessons and intelligence but that the strongest contributors were the executive function subsets, selective attention and inhibition.

In a rare longitudinal music training study on children, Jaschke et al. (2018) studied the effects of two and a half years of music training on a group of young children (*M* = 6.4 years). One hundred and forty-seven participants were randomized into four groups: two music, one visual arts, and one control group. Children in the music group learned music fundamentals, learned to play instruments, and took lessons within class time from trained music teachers. The children did not take the instruments home, however, so training was limited to time spent in class. The results revealed significant between-group differences between the two music groups and the visual arts and control group on tests of verbal intelligence, planning, and inhibition: all cognitive functions that are theorized to underlie attention.

In a study examining a popular method of early childhood music education (i.e., Suzuki Method), Scott (1992) studied 80 three-to-five year old children (*n* = 16 per group) who were either participating in individual Suzuki violin lessons; enrolled in individual and group Suzuki violin lessons; enrolled in creative movement classes; enrolled in preschool activities or classes; or not enrolled in any organized preschool activities or classes. Suzuki students scored significantly higher on all attention task measures as well as measures of attending during instructional settings than the not-enrolled group and scored slightly higher than the other enrolled groups. However, involvement in Suzuki lessons might be a factor of parental interest in their child's development as these activities often require parental involvement in the actual lesson, and parents have many opportunities to enforce perseverance and persistence through daily at-home practice sessions. Another contributing factor may be parental socio-economic status as there is usually significant cost associated with participation in these lessons. In this case, the result might be a function of a rich home environment as opposed to the training itself.

A recent pilot study conducted by Pasiali, LaGasse, and Penn (2014) utilized a short music therapy intervention and pre/post-tests of the Test of Everyday Attention for Children (TEA-Ch) to study the effect of the intervention on attention skills (i.e., sustained, selective, and attentional control/switching attention) of high-functioning children with neuro-developmental delays (e.g., Autism Spectrum Disorder; ASD) within an age range of 13 to 20 years. This population is important for studies focused on attention as children with ASD tend to experience difficulty filtering out non-target stimuli and also switching attention from one source to another. Pasiali and her colleagues (2014) found significant improvements in the areas of selective attention and attentional control/switching attention after a six-week intervention consisting of eight 45 minute music therapy sessions. Results from this study provide some evidence of an intervention effect but are limited in generalizability because of the small sample size ($n = 9$) and the lack of a control group.

With the exception one study, all of the studies that link musical training to increased attention skills have been correlational or have used adult participants. It is not clear whether the music training produces better attention or whether better attention increases the likelihood of getting into a musical training program and staying with it. Furthermore, several confounding factors, such as sample size, functional ability levels, age, and research design make it difficult to generalize their results. An experimental design that allows for these confounding variables to be accounted for is needed to specifically test the relationship between music and attention. In addition, a study is needed that focuses directly on the effects of the introduction of music training as it is being introduced during crucial developmental periods for attention.

CHAPTER 3

Methodology

There has been a great deal of interest in the relationship between music training and the development of attention. Unfortunately, the majority of these studies do not focus on the early years during which attentional skills are rapidly developing. Also, to date, much of this research has been cross-sectional or lacking sufficient control of confounding variables. The current study focused on the effects of three months of music training introduced during a sensitive developmental period for attention—four to six years of age—on the development of the three key networks of attention (i.e., alerting, orienting, and executive networks). In an effort to parse out variability based on a general training effect, a comparison group comprised of children who were engaged in a similar dosage of training in sports were included as well as a control group of children who were not actively involved in any formal training.

As detailed above, children undergo significant cognitive development between the ages of four and six years, which may result in an expanded, more elaborate attention system. In question here is whether the introduction of musical training during this crucial time would have an effect on the development of the mechanisms of attention. It was anticipated that typical development from maturation within these years would have influenced the study so, age was considered. Also, research suggests that gender, socioeconomic status, and intelligence might play a part in the development of attention and the performance on attentions tasks so these factors were also considered.

The following research questions served as a framework for the current study and guided the data collection and analysis:

1. Does music training affect the development of attention?

The work of Pasiali, LaGasse, and Penn (2014) suggests it is possible to improve the attention skills of teenagers and young adults with neuro-developmental delays by providing music training. The current study differed in that it focused on training effects during early childhood, the assessment of training effects in typically-developing children, and utilized the strengths of the Attention Network Test for Children. Through the use of two comparison groups, the study also allowed a glimpse at specific domains of training experiences with young children.

Children between the ages of four to six years who participated in individual, instrumental lessons were expected to demonstrate increased scores on attention orientation measures when compared to same age children who did not participate in individual, instrumental lessons. Music instruction was expected to be particularly effective because during instruction and practice, the children must repeatedly attend to many varied stimuli, exogenous and endogenous, visual and auditory. The repeated practice of maintaining an alert state required to complete the many varied tasks associated with playing music while remembering and taking into considering musical direction from the teacher, was expected to positively affect the development of attention skills in young children. I expected that participants who received musical training would demonstrate a larger increase in the development of attention than the two comparison groups.

2. Is there an influence of age or gender on the changes in attention?

A study of developmental properties of the three attention networks in 5 to 7 year olds (4.97 to 7.27 years of age; Mezzacappa, 2004) indicated age to be a significant predictor of accuracy and response time (RT) in executive attention tasks ($p < .0001$ and $p < .0005$, respectively). The decrease in RT and increase in accuracy suggests that older students experience less interference from incongruent flankers in a flanker task. Age was also found to be a significant predictor in reductions of RT due to orienting cues ($p < .05$), meaning that older students witnessed a significant decrease in RT from location cues, given prior to the target, that assist in attention orienting. Also, age was a notable but not significant factor in alerting attention ($p < .054$). In the same study, gender was also found to have a significant association with overall reaction time ($p < .0027$)—with boys exhibiting significantly faster overall RTs—and with reductions in RT due to alerting cues ($p < .022$; Mezzacappa, 2004). I expect that the age of the participants would be negatively correlated with overall RT.

3. Is there an influence of intelligence on changes in attention?

General intelligence as a measure of general ability and also of working memory was assessed to control for basic cognitive abilities. As mentioned, research has revealed a relationship between WM and attention (Conway et al., 2001) but the literature is divided on the relationship between attention and intelligence. Studies by Weyandt, Mitzlaff, and Thomas (2002) and Tourva, Spanoudis, and Demetriou (2016) do not support a relationship between intelligence and attention whereas others (e.g., Shi et al.,

2013) have found significant associations. Because there is enough evidence that, in some circumstances, intelligence could be a confounding effect, this measure was included in the present study. Intelligence was expected to be a significant covariate of change in the development of attention from pretest to posttest.

4. Is there an influence of socioeconomic status on changes in attention?

Socioeconomic status (SES) is associated with attention. Attention deficit/hyperactivity disorder (ADHD)—and even subthreshold ADHD (Hong et al., 2014)—has been reported to be more prevalent in families with socioeconomic disadvantage (Russell et al., 2014). Studies such as Mezzacappa (2004) support this relationship by establishing a significant association between SES at infancy and multiple aspects of performance on attention measures (i.e., accuracy and RT in executive and alerting attention) in middle childhood (M = 5.96 years). Socio-economic status was expected to be a significant covariate of change in the development of attention from pretest to posttest.

Design

A pre- and post-test, quasi-experimental design was used with 3 months of music training between test administrations. The study was quasi-experimental because it was not possible to randomly assign participants to treatment groups. Instead, participants and participants' guardians self-selected a group training or to not engage in training prior to the start of their participation in this study. The dependent variables in this study were the overall accuracy and the mean response time scores across cue and flanker conditions on the attention assessment; the independent variables were the training group in which the child participated. Covariates included the participant's age, gender, general intelligence, and socio-economic status.

Participants

Participants for this study (*N* = 30) were composed of three groups of children between the ages of four and six: those participating in weekly, private, instrumental music lessons (Music, *n* = 5), those participating in other organized training (Other Training, *n* = 8), and a group not participating in any comparable training (Control, *n* = 17). Eligibility requirements for study inclusion were (1) no prior diagnosis of attention-related disorder; (2) limited prior (< 1 year) formal music, sports, or dance training; (3) no participation in another sport, dance, or music lessons during the 3 month duration of the study; (4) a commitment to remain in group training (or control) for the duration of 3 months. Parents or guardians were emailed a household demographic questionnaire to complete after their written consent for both their and their child's participation was collected. Participating children completed an assent form that was collected prior to the study.

Community music projects through various instrumental music programs, studios, and universities were contacted regarding their permission for the researcher to contact parents of new instrumental music students within the age range for their participation in this study. Similarly, community dance studios were contacted regarding the recruitment of dance students within the age range. Lastly, local pre-kindergarten and elementary schools were contacted to request similar permission to contact parents of children beginning their first season of organized dance or sports or for those not currently engaged in formal training. After the first year of recruitment and data collection, a small incentive ($20 giftcard) was added to the study in an effort to increase participation rates.

Some level of attrition was expected due to the nature and the extent of participation required. There were additional participants who were not able to complete the pre-test administration of either the IQ or the attention measure (*n* = 4), moved away during the 3 months of training (*n* = 1) as well as participants whose parent or guardian did not complete the household questionnaire (*n* = 4) were not included in any of the data analyses. In addition, some data collection was interrupted by the COVID-19 global health pandemic that resulted in participants not being able to complete their three months of training (*n* = 5).

Measures

Student and household factors included age, gender, parental education, household income, and parents' and siblings experiences with music and other sports training. These variables were included in the data collection as research suggests evidence of an association between these variables and performance on various attention measures (see Appendix A). For present purposes, age was measured in months to allow for more nuanced assessment of effect over time. Gender was categorized with a dichotomous variable, dummy coded as 0 for male and 1 for female. Family income, as a measure of the household socio-economic status (SES), was measured by the parents' or guardians' self-identification with one of five ranges of income in the parental questionnaire. The ranges of income were: less than $20,000, $20,000-$39,999, $40,000-$59,999, $60,000-$79,999, $80,000-$99,999, and $100,000+. Parental education was measured by the parents' or guardians' self-identification with one of the following levels of education as the highest attained for each adult in a parenting role: some high-school, high-school diploma, some college, associate's degree, bachelor's degree, master's degree, and doctorate/professional degree.

General Intelligence. Participants' general intelligence was measured using the Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman & Kaufman, 2004). The KBIT-2 was designed to provide a relatively quick (approximately 20 minutes) and valid measure of verbal and non-verbal intelligence in individuals from ages 4 years to 90 years. The test is comprised of three subtests: Verbal Knowledge, Matrices, and Riddles, all of which utilize color pictures as answers from which the participant must choose (Bain & Jaspers, 2010). Published reliability information included in the manual are calculated for 23 age groups within the 4 to 90 year-old age range. Split-half reliability coefficients for the Verbal scale ($M = .91$) and Composite IQ ($M = .93$) were high while the Nonverbal coefficients were slightly lower, most notably for 4 and 5 year olds ($M = .78$; Bain & Jaspers, 2010). This is of particular importance given the age range for the present study.

Attention Network Test. While most measures of attention assess the attention networks independently, the Attention Network Test (ANT) provides a way to measure all three networks in one assessment. This tool also allows for the examination of interactions between networks (Breckenridge et al., 2013; Pozuelos et al., 2014). The ANT utilizes Flanker tasks, which are a common test of inhibition and executive functioning and present a target stimulus flanked by distracting stimuli in a series of images. The control trials show the target and the distractors facing the same direction while in the conflict trials, they face opposite directions. Further, the ANT also incorporates the use of congruent and incongruent cues to simultaneously assess orienting and alerting attention.

The children's version of the ANT (Child-ANT; Rueda et al., 2004) uses a modified flanker task, which consists of a line of five colorful fish, the middle of which is the target fish. Children are encouraged to feed the fish by pressing a key that corresponds to the direction that the target fish is swimming. Cues about the location of the target fish allow for the assessment of orienting and alerting skills while conflicts due to congruent and incongruent directions of flanker fish are introduced to assess executive attention (Petersen & Posner, 2012; Rueda et al., 2004; Weinbach & Henik, 2012). The congruency effect, which is essentially the difference between mean response times of congruent trials and incongruent trials, is assumed to represent an effect of conflict and therefore a measure of executive control.

Although the ANT has become an increasingly popular assessment of attention, reliability information for the ANT is varied and sparse when considering children. Utilizing the original, non-child version of the ANT in a randomized controlled pilot study on the effects of physical education on cognitive function in young children (M_{age} = 6.2 years), Fisher et al. (2011) found the ANT to have significant, albeit low, reliability in terms of the intraclass correlation of reaction time (0.37) and also accuracy (0.60). Scarce information about the reliability of the modified Child-ANT has been found. Rueda et al. (2004), found highly significant split-half reliability correlations for overall RT (0.94) and error rate (0.93). Further, the executive network (0.59) and alerting network (0.37) were significant but orienting (0.02) was not. The non-significant correlation of the orientation network could be the result of a smaller number of trials available for each half of the orienting network items.

Reliability Study. To assess if there was appropriate reliability of this measure for children in the target age range for this dissertation, a test-retest reliability study was conducted. A group of four to six-year-old children were recruited from a local elementary school (*n* = 21) and tested twice, two weeks apart. Test-retest reliability indices were calculated using Pearson's *r* analysis within Statistical Package for the Social Sciences, version 24. Correlations were calculated between each of the component summary scores for alerting effect, orienting effect, conflict effect, mean response time, and overall accuracy. As displayed in Table 1, the results indicated non-significant correlations for each score except mean response time (GrandMean) and overall accuracy (Accuracy). A complete SPSS correlation table is provided in Appendix B.

Table 1

Correlations of Pre- and Post-Test ANT-Child Component Scores

	Pearson Correlation	Sig. (2-tailed)	Sum of Squares & Cross-products	Covariance
AlertEffect*AlertEffect2	-.086	.711	-11,425.81	4532.75
OrientingEffect*OrientingEffect2	.370	.098	50,336.10	2,516.81
ConflictEffect*ConflictEffect2	.323	.153	43,203.57	2,160.18
GrandMean*GrandMean2	.663*	.001	294,334.70	14,716.74
Accuracy*Accuracy2	.833*	.000	1,232.29	61.61

* Correlation is significant at the 0.01 level (2-tailed)

The non-significant results of alerting and orienting correlations seems fairly intuitive after repeated observations of children having difficulty maintaining their eye-gaze on the screen. Maintaining eye-gaze on the screen is essential in order to measure the effect of cue presence and cue locations presented prior to the target stimulus. However, guided by these results, I conclude that the ANT-Child is a reliable measure for overall accuracy and mean response time and used this test in the study.

Procedure

Pretesting and demographic data collection. Once parental consent forms were received, parents/guardians were emailed the household demographic questionnaire, schedules were created in conjunction with test sites and/or participants to administer the pre-test measures: the Kaufman Brief Intelligence Test (KBIT-2 and the ANT-Child). All pretesting was conducted individually in a familiar environment, either at the child's school or their home. The KBIT-2 and then the ANT-Child were administered in the same administration. All children were able to complete the KBIT-2, with some becoming increasingly uninterested by the end. There were many who struggled to complete the ANT-Child and some that did not complete. This test is long, typically lasting approximately 25 minutes. It consists of 168 total stimuli conditions across one practice round and 3 testing rounds with instructions prompting the participant and researcher to take a short break after each round. I found that providing small incentives such as stickers during the breaks often worked well to keep motivation high enough to finish. There were many times during the testing rounds that I would observe a child not paying attention or getting frustrated. In these instances, I would speak up briefly to encourage them or praise their efforts. Often, this was enough to motivate the child to continue.

Treatment Condition (Music). Instrumental music (i.e., piano, violin, or guitar) lessons at this age take place once a week and last about a half an hour. Children are expected and encouraged to practice at home between lessons to apply what information is taught and to continue to progress. At this age, typical lessons will cover skills such as body and hand placement, fingerings, tone production, musical scales, reading music notation, and elementary songs played solo or as a duet with the teacher. In an effort to measure fidelity, parents completed short, online reports every week to document how much time their child spent practicing that week and time spent in their weekly private lesson. These data were collected via Qualtrics administered weekly by the researcher.

It was expected that the majority of participants would be studying the piano or the violin as these are more commonly taught at the younger ages, however there was one participant who was enrolled in guitar lessons. There are differences—based on the instrument—in recruited motor skills, but the fundamental tasks remain the same (e.g., coordination between cognitive functions and motor skills and the ability to attend to multiple exogenous and endogenous stimuli).

Treatment Condition (Other Training). This group was comprised of children participating in group sports training and dance. Group sports at this age typically consists of weekly practices and typically at least one game or match. Typical practices cover basic motor skills necessary for the sport, rules of the game, team building exercises, and coach's feedback on all aspects. Participants were expected to practice these skills outside of team practice to master the feedback given during instruction. Dance classes and lessons were similar, covering basic motor skills, an introduction to rhythm and choreography, and the teacher's feedback on all aspects. Such classes typically meet once a week for an hour and work toward a final performance.

Control Condition. Participants in the control condition identified as not being involved in music or sports and not planning to begin training in music or sports during the 3 months of intervention. They were asked to refrain from starting a training program during the duration of this study and to notify the researcher if they did.

Posttest. After the duration of 3 months of music or sport training, a post-test administration of the Child-ANT was administered within two weeks of completion. All post-tests were administered at the child's school or home in a manner that closely resembles the pretest location for each child. The testing conditions mirrored the pre-test ANT-Child. I provided stickers for the breaks and encouraged participants, as needed, to complete the administration.

Data Analysis

Given the quasi-experimental research design and use of nonrandomized group assignment in the present study, careful considerations were made to account for as much variance due to pre-existing group differences as reasonably possible. In pre/posttest designs, this is often achieved by way of an ANCOVA that utilizes the pretest score as a covariate. In the present study, whether music training affects the development of attention was analyzed by comparing group means for response time and accuracy by way of an ANCOVA analysis using the pretest scores as covariates. Assumptions of ANCOVA related to measurement and nature of variables and independence of observations were held true in the present research design. Other assumptions regarding distribution of residuals, homogeneity of variance and regression slopes, homoscedasticity were addressed after data collection. The between-group differences of training groups on accuracy and mean response rates were further examined utilizing gain scores. Other variables of interest age, gender, intelligence, and SES were analyzed via correlation or ANOVA as the data determined. Gender was dummy coded as 0 for male and 1 for female. The factor for SES was an ordinal variable into which parents self-identified according to their household income. Because of sample size, the SES variable was reduced to three groups after data collection. The remainder of the covariates were either continuous or ordinal (i.e., pretest, age, and intelligence).

CHAPTER 4

RESULTS

Using the research questions as a guide in the analysis, a thorough investigation of the nature of the training groups was conducted first and included tests of distribution of IQ, household income, gender. I then conducted ANCOVA analyses to compare differences between training groups' post-test accuracy and mean response rate while controlling for the pre-test scores. For comparison's sake, I also conducted ANOVA analyses to compare differences between training groups' gain scores between pre- and post-test administrations for accuracy and mean response rate. All analyses were conducted using IBM's Statistical Package for Social Sciences (SPSS) version 25.

The results of the pilot on reliability of the ANT-Child revealed the ANT-Child was reliable only for the overall mean response rate and accuracy scores and not the component scores of alerting, orienting, and executive effect for this age group. So, I focused the analysis herein on the overall mean response rate and accuracy scores only. The dataset that resulted from the ANT-Child was robust, including individual test results for all 168 test prompts as well as subset scores for accuracy, response rate, and standard deviation for each permutation of cue type and conflict condition.

After detailing the preliminary, descriptive analyses to establish the distribution of salient factors between the three training groups, this chapter is organized following the research questions from Chapter 3, addressing analyses and results related to each in succession.

1. Does music training affect the development of attention?
2. Is there an influence of age or gender on the changes in attention?
3. Is there an influence of intelligence on changes in attention?
4. Is there an influence of SES on changes in attention?

Descriptive Statistics

To explore the distribution of salient characteristics between the participants and between training groups, preliminary analyses were conducted to determine the difference in distribution of salient characteristics such as age, gender, and the distribution of household income between the training groups as well as the difference in mean IQ scores between gender groups, age groups, and training groups. Additional data points not utilized for hypothesis testing are included in Appendix C.

To examine the distribution of age across training groups, I first calculated age as a continuous variable expressed in months. The calculation was simply the difference between each participant's age at pre-test and their birth date. An ANOVA was conducted to test the difference in means of age between the three training groups. There was one positive outlier in the control group, as assessed by a visual examination of a boxplot. A decision was made to leave that participant in the sample as the sample size was very small and ages were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$); however, the assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p = .004$) likely due to the uneven group sizes. Because of this violation, I utilized a Welch ANOVA, which is more robust and can better handle violations of this type. The Welch test result was non-significant F(2, 8.405) = 1.358, $p = .308$, which indicated no significant age difference between training groups.

Small sample size presented an issue when running Chi-Square tests for both gender distribution and household income group distribution between training groups. Even after transforming the six-level household income variable from the questionnaire to a three-level variable, both variables indicated high levels of expected cell counts less than five: four cells (66.7%) for gender and seven cells (77.8%) in household income group. A follow-up Fisher exact test was not an option as Fisher is limited to dichotomous variables only. However, examination of the descriptive statistics in Table 2 for gender reveals a fairly even distribution of gender across two of the training groups, Control and Other Training, and a male-heavy distribution in the Music group.

Table 2

Gender and Household Income Distribution by Training Groups

		Gender		Income Group			
		Female	Male	<\$20,000 -\$59,999	\$60,000- \$99,999	\$100,000+	Total
Training Group							
	Music	1	4	3	0	2	5
	Other Training	3	5	1	5	2	8
	Control	9	8	6	1	10	17
Total		13	17	10	6	14	30

Similar inspection of the household income distribution across training groups in Table 2 reveals that the Music group was more heavily distributed on the bottom income level (60%), the Other Training group was more heavily distributed on the middle income level (62.5%), and the control group is more heavily weighted in the top level of income (58%).

In sum, there were 17 male and 13 female participants. An independent-samples t-test was run to determine if there were differences in IQ between male and female participants. There were two outliers in the data, both in the male group, as assessed by inspection of a boxplot. IQ scores for each level of gender were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), and there was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = .629$). Male participants had a higher IQ mean score ($M = 112.41$, $SD = 14.586$) than female participants ($M = 109.08$, $SD = 12.312$), though not a statistically significant difference, by 3.335 points, 95% CI [-6.973, 13.643], $t(28) = .663$, $p = .513$.

A one-way ANOVA was conducted to determine if cognitive function as measured the KBIT-2 IQ test was different for the three age groups. Participants were classified into three groups: 4 years old ($n = 14$), 5 years old ($n = 11$), and 6 years old ($n = 5$). There were outliers within each group, as assessed by boxplot, but the decision was made to leave the participants in as the variable was still normally distributed and sample size was very small; data were normally distributed for each group, as assessed by Shapiro-Wilk test ($p > .05$); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances ($p = .970$). IQ score increased from the 5 years old ($M = 104.36$, $SD = 13.64$), to 6 years old ($M = 114.2$, $SD = 13.535$), to 4 years old ($M = 115.00$, $SD = 12.254$) age groups, in that order, but the differences between training groups was not statistically significant, $F(2, 27) = 2.256$, $p = .124$.

To further examine the association between age and IQ, I ran a correlation analysis between age (in months) and IQ. Surprisingly, there was no significant association found as displayed in Table 3 and Figure 1 below.

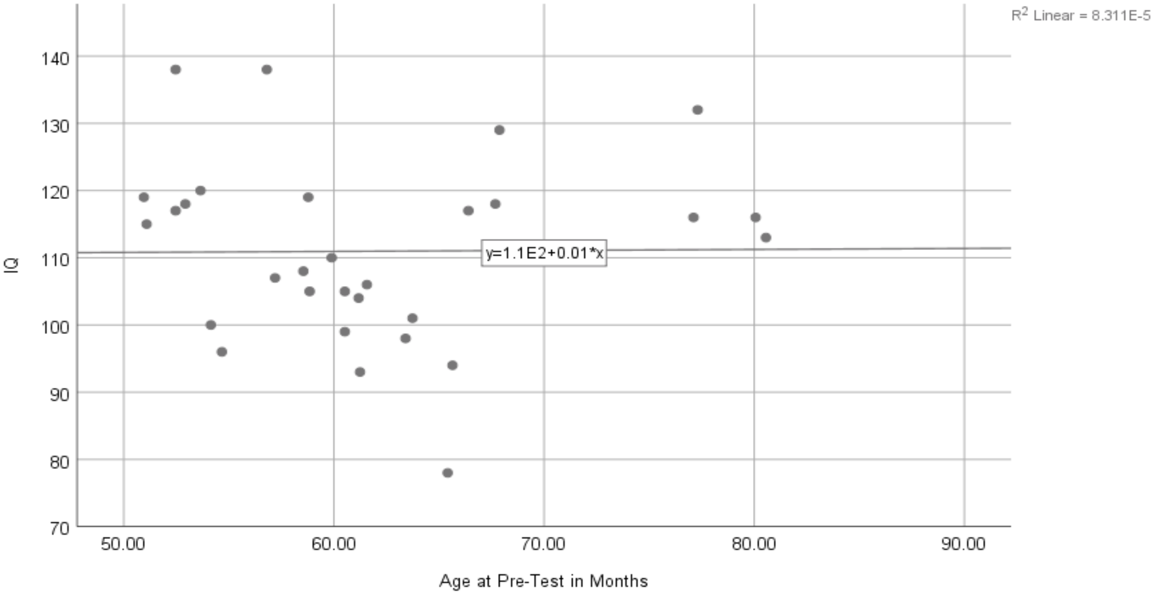
Table 3

Correlations Between Age and IQ

		Age at Pre-Test in Months	IQ
Age at Pre-Test in Months	Pearson Correlation	1	.009
	Sig. (2-tailed)		.962
	Sum of Squares and Cross-products	2030.398	29.919
	Covariance	70.014	1.032
	N	30	30
IQ	Pearson Correlation	.009	1
	Sig. (2-tailed)	.962	
	Sum of Squares and Cross-products	29.919	5304.967
	Covariance	1.032	182.930
	N	30	30

Figure 1

Grouped Scatter of IQ by Age at Pre-Test in Months



Next, a one-way ANOVA was conducted to determine if cognitive function as measured by the KBIT-2 IQ test was different for the three training groups. Participants were classified by training group: Music (*n* = 5), Other Training (*n* = 8), and Control (*n* =

17). There were 2 outliers in the music group, as assessed by boxplot, which were retained in the data; data were normally distributed for each group, as assessed by Shapiro-Wilk test ($p > .05$); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances ($p = .732$). IQ scores differed across the control ($M = 108.41$, $SD = 12.846$), music ($M = 113.8$, $SD = 13.882$), and other training ($M = 114.63$, $SD = 15.287$) groups, but the differences between the groups was not statistically significant, $F(2, 27) = 0.691$, $p = .510$.

Effect of Music Training on Development of Attention

To address the question of whether music training had an effect on the development of attention, I conducted two ANCOVA analyses both utilizing the pre-test scores as the covariate: one for overall mean response time and one for overall accuracy rate. The mean response rate is the mean of all response rates across test conditions (i.e., the presence and location of cues and the presence and location or flanker fish) for both test administrations for each participant. The overall accuracy rate is provided in the test results for each test administration and is represented by the percentage of prompts that the participant answered correctly within the time allowed. Both tests passed the assumptions that require the dependent variable be continuous, the independent variable be categorical with at least two independent groups, the covariate be continuous, and that there is independence of observations. The remaining assumptions will be addressed with each analysis below.

Accuracy Rate

Before analyzing the group differences of Accuracy, I established that there was a linear relationship between pre- and post-training accuracy scores for each of the three training groups, as assessed by visual inspection of a scatterplot as well as a significant correlation coefficient (*p* < .001, see Table 4).

Table 4

Correlation Between Pre- and Post-Training Accuracy Rates

		Accuracy	Accuracy_2
Accuracy	Pearson Correlation	1	.693**
	Sig. (2-tailed)		.000
	Sum of Squares and Cross products	8360.967	5290.033
	Covariance	288.309	182.415
	N	30	30
Accuracy_2	Pearson Correlation	.693**	1
	Sig. (2-tailed)	.000	
	Sum of Squares and Cross-products	5290.033	6960.967
	Covariance	182.415	240.033
	N	30	30

** Correlation is significant at the 0.01 level (2-tailed).

There was homogeneity of regression slopes as evidenced by a non-significant interaction term, *F*(2, 24) = 1.926, *p* = 0.168. Standardized residuals for two of the training groups were normally distributed as measured by Shapiro-Wilk's test: Music (*p* = .975*)* and Control (*p* = .364). However, the Other Training group did not meet this assumption (*p* = .043). However, with this single violation being .007 away from non-significance and because ANCOVA is robust in terms of dealing with violations of normality, the decision was made to accept it. For the overall model, the standardized residuals were found to be normally distributed (*p* = .303). There was homoscedasticity as assessed by visual inspection of scatterplots and homogeneity of variance as evidenced by a non-significant Levene's test (*p* = .114). Lastly, there were no outliers as determined by the absence of cases where the standardized residual was ± 3 standard deviations.

As referenced in Table 5, a preliminary examination of the descriptive statistics indicates the unadjusted means for the post-test accuracy scores were higher for the Music training group as compared to the Other Training group and the Control group. When adjusted for the covariate, pre-test score of Accuracy, the order changed slightly with a higher mean score for the Other Training group as compared to the Music training group and the Control group.

Table 5

Unadjusted and Adjusted Training Group Means and Variability for Post-Training Accuracy Scores with Pre-Training Accuracy Scores as a Covariate

Group		Unadjusted		Adjusted	
	N	*M*	*SD*	*M*	*SE*
Music	5	85.40	11.97	79.34	3.99
Other Training	8	83.38	7.09	85.42	5.16
Control	17	76.76	18.74	77.59	2.73

However, results from an ANCOVA analysis utilizing the pre-training Accuracy score as covariate revealed there was not a statistically significant difference ($p > .05$) between the adjusted means for Accuracy in the three training groups (see Table 6, Group2ID). The effect size for the training groups was $\eta^2 = .093$, which indicates that 9.3% of the variance in the post-test accuracy rates (Accuracy_2) was explained by group participation. The covariate, pre-test score of accuracy rate (Accuracy), had an effect size of $\eta^2 = .499$, indicating that 49.9% of variance in Accuracy_2 was accounted for by Accuracy. In light of the non-significant group differences, I failed to reject the null hypothesis that there is no difference in accuracy scores when controlling for pre-training accuracy scores between the training groups.

Table 6

Tests of Between-Subjects Effects of Post-Training Accuracy Scores with Pre-Training Accuracy Scores as a Covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3,681.457[a]	3	1,227.152	9.729	.000	.529
Intercept	1,309.989	1	1,309.989	10.386	.003	.285
Accuracy	3,266.625	1	3,266.625	25.898	.000	.499
Group2ID	334.422	2	167.211	1.326	.283	.093
Error	3,279.509	26	126.135			
Total	198,801.000	30				
Corrected Total	6,960.967	29				

[a] R Squared = .529 (Adjusted R Squared = .475)

Response Time

Before analyzing group differences on mean response time, I first verified that there was a linear relationship between pre- and post-test mean response rate scores—MeanRT and MeanRT_2, respectively—for each of the three training groups, as assessed by visual inspection of a scatterplot as well as a significant correlation coefficient ($p < .05$, see Table 7).

Table 7

Correlation Between Pre- and Post-Training Response Rate Scores

		MeanRT	MeanRT_2
MeanRT	Pearson Correlation	1	.457*
	Sig. (2-tailed)		.011
	Sum of Squares and Cross-products	435268.785	256956.239
	Covariance	15009.268	8860.560
	N	30	30
MeanRT_2	Pearson Correlation	.457*	1
	Sig. (2-tailed)	.011	
	Sum of Squares and Cross-products	256956.239	727307.148
	Covariance	8860.560	25079.557
	N	30	30

* Correlation is significant at the 0.05 level (2-tailed).

There was homogeneity of regression slopes as evidenced by a non-significant interaction term, *F*(2, 24) = .685, *p* = .514. Standardized residuals for the training groups and for overall model residuals were normally distributed as measured by Shapiro-Wilk's test (Music, *p* = .994, Other Training, *p* = .137, Control, *p* = .356, Overall Model, *p* = .199*)*. There was homoscedasticity as assessed by visual inspection of scatterplots and homogeneity of variance as evidenced by Levene's test, *p* = .435. Lastly, there were no outliers as determined by the absence of cases where the standardized residual was ± 3 standard deviations.

Keeping in mind that a lower post-test score is preferable on this dependent variable, a preliminary examination of the descriptive statistics as referenced in Table 8 indicates that the unadjusted means for the post-test response rates were lower for the Music group as compared to the Other Training group and the Control group. When adjusted for the covariate, pre-test score of Response Time, the order by which the groups rank is the same. The adjusted mean response rates were lower for the Music training group as compared to the Other Training group and the Control group.

Table 8

Unadjusted and Adjusted Training Group Means and Variability for Post-Training Mean Response Rate Scores with Pre-Training Mean Response Rate Scores as a Covariate

Group		Unadjusted		Adjusted	
	N	*M*	*SD*	*M*	*SE*
Music	5	866.964	136.736	902.420	66.808
Other Training	8	952.409	139.820	974.037	51.979
Control	17	1,033.187	157.732	1012.581	36.440

However, results from an ANCOVA analysis utilizing the pre-training Response Rate as covariate suggest there was not a statistically significant difference ($p > .05$) between the adjusted means for the three training groups, see Table 9. The effect size for the training groups was $\eta^2 = .07$, which indicates that 7% of the variance in the post-test mean response rates (MeanRT_2) was explained by group participation. The covariate, pre-test score of mean response rate, had an effect size of $\eta^2 = .122$, indicating that 12% of variance in MeanRT_2 was accounted for by the pre-test score of mean response rate (MeanRT). In light of the non-significant group differences, I failed to reject the null hypothesis that there is no difference in mean response rates when controlling for pre-training mean response rates between the training groups.

Table 9

Tests of Between-Subjects Effects of Post-Training Mean Response Rate (MeanRT_2) Scores with Pre-Training Mean Response Rate (MeanRT) Scores as a Covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	192173.941[a]	3	64057.980	3.112	.044	.264
Intercept	72047.276	1	72047.276	3.500	.073	.119
MeanRT	74573.190	1	74573.190	3.623	.068	.122
Group2ID	40482.593	2	20241.296	.983	.388	.070
Error	535133.207	26	20582.046			
Total	29771587.975	30				
Corrected Total	727307.148	29				

[a] R Squared = .264 (Adjusted R Squared = .179)

Group Comparisons of Gain Scores

Based on small sample sizes, the research literature is inconclusive about the best approach to assessing the change between test and re-test scores—and given the role that this study might play in the compilation of support for future research—I also conducted ANOVA analyses for the gain scores of accuracy and response time. This approach allows for a simple model with no covariate. Gain scores were calculated utilizing the standard formula $\Delta X_i = X_{2i} - X_{1i}$ wherein X_{2i} represents the continuous post-test score for a participant and X_{1i} represents the continuous pre-test score for the same participant.

First, a one-way ANOVA was conducted to determine if the change in accuracy rate (ΔAccuracy) was different for groups with different types of training. Participants were classified into the same three groups: music ($n = 5$), other training ($n = 8$), and control ($n = 17$). There were two outliers, as assessed by boxplot, in the control group; data were normally distributed for each group, as assessed by Shapiro-Wilk test ($p > .05$); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances ($p = .124$). As illustrated in Table 10, accuracy gain score increased from the music group to control to other training group, in that order. The conspicuously large difference between the mean gain score of the Other Training group compared to the other two is to be noted.

Table 10

Descriptive Statistics of Accuracy Gain Scores (ΔAccuracy) By Training Group

Training Group	N	Mean	Std. Deviation
Music	5	1.00	3.39
Other Training	8	11.50	13.77
Control	17	3.00	13.42
Total	30	4.93	12.79

However, as shown in Table 11, the differences between these training groups were not statistically significant ($p > .05$). The effect size, partial eta-squared, indicates that training group participation accounts for 10.2% of the variance in accuracy rate gain scores. While the effect of small sample sizes cannot be discounted and taking into consideration the non-significance of the group differences, the disparity in mean gain scores between the Other Training group and the Music and Control group and the small standard deviation for the music group is notable.

Table 11

Tests of Between-Subjects Effects of Accuracy Gain Scores (ΔAccuracy)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	485.867[a]	2	242.933	1.541	.232	.102
Intercept	625.939	1	625.939	3.971	.056	.128
Group2ID	485.867	2	242.933	1.541	.232	.102
Error	4256.000	27	157.630			
Total	5472.000	30				
Corrected Total	4741.867	29				

[a] R Squared = .102 (Adjusted R Squared = .036)

Similarly, a one-way ANOVA was conducted to determine if the change in response time (ΔRT) was different for groups with different types of training. There were two outliers, as assessed by boxplot, in the music group; data were normally distributed for each group, as assessed by Shapiro-Wilk test ($p > .05$); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances ($p = .230$). As illustrated in Table 12, response rate change score increased in order from the Other Training to Control to Music training groups.

Table 12

Descriptive Statistics of Mean Response Time Gain Scores (ΔRT) By Training Group

Training Group	N	Mean	Std. Deviation
Music	5	-122.78	82.60
Other Training	8	-67.44	118.29
Control	17	-78.62	179.10
Total	30	-83.00	149.56

As displayed in Table 13, the results indicate the differences between these training groups were not statistically significant (*p* > .05). The effect size, partial eta squared, of training group indicates that gender accounts for 1.6% of the variability in mean response time gain scores.

Table 13

Tests of Between-Subjects Effects of Mean Response Time Gain Scores (ΔRT)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10175.169[a]	2	5087.585	.215	.808	.016
Intercept	188309.994	1	188309.994	7.963	.009	.228
Group2ID	10175.169	2	5087.585	.215	.808	.016
Error	638488.286	27	23647.714			
Total	855333.455	30				
Corrected Total	648663.455	29				

[a] R Squared = .016 (Adjusted R Squared = -.057)

Again, taking into consideration the small sample sizes and the non-significant overall differences, the observation that the Music group experienced the largest decrease in mean response time from pre- to post-test with a smaller standard deviation is noted.

Influences of Age and Gender on the Development of Attention

As a result of the small sample sizes of the two training groups, in particular, the addition of age, gender, IQ, or household income as additional covariates in the previous ANCOVA models was not ideal. In addition, repeated efforts to analyze effect of these covariates by way of regression analysis resulted in violations of the assumption of homoscedasticity.

With regard to age, prior analysis included above with descriptive statistics, revealed that the training groups did not differ in terms of age at pre-test. So, I conducted correlation analyses (two-tailed Pearson product-moment correlation) between Age and the gain scores for Accuracy and mean Response Time across the total study population (*n* = 30). Gain scores, sometimes also referred to as change scores, are the difference between post-test and pre-test scores: the measure of change for a variable over time. The gain scores allow for the explanation of association between age and the changes in accuracy rates and response times over the three-month training period. In correlational analyses, Accuracy gain score and mean Response Rate gain score passed the assumption of normality as assessed by the Shapiro-Wilks ($p > .05$), but Age measured in months as a continuous variable did not. Therefore, a non-parametric, Spearman's rank-order correlation was conducted for both analyses.

To do so, the variable Age was transformed into a new, ordinal variable: Age_Ordinal. The new variable was calculated by assigning values in half-years to participants according to their age in number of months at pre-test in the following manner:

4 = 48 – 53.99 months (*n* = 6)
4.5 = 54 – 59.99 months (*n* = 8)
5 = 60 – 65.99 months (*n* = 9)
5.5 = 66 – 71.99 months (*n* =3)
6 = 72-77.99 months (*n* = 2)
6.5 = 78 – 83.99 months (*n* = 2)

Preliminary analysis showed the relationship to be monotonic between the ordinal Age variable and the variables, Accuracy gain score and mean Response Rate gain score, as assessed by visual inspection of two scatterplots. As displayed in Tables 14 and 15, the results of the two Spearman non-parametric correlation analyses indicate a negative relationship between Age_Ordinal and both Accuracy gain scores ($r_s(28) = -.139$), which was unexpected, and mean Response Time gain scores ($r_s(28) = -.256$), which was expected. Neither of these relationships was significant, so I conclude that I fail to reject my null hypothesis and fail to accept the alternative hypothesis that there is a significant effect of age on the development of attention.

Table 14

Correlation Between Age and Accuracy Gain Score

			Age_Ordinal	ΔAccuracy
Spearman's rho	Age_Ordinal	Correlation Coefficient	1.000	-.139
		Sig. (2-tailed)	.	.464
		N	30	30
	ΔAccuracy	Correlation Coefficient	-.139	1.000
		Sig. (2-tailed)	.464	.
		N	30	30

Table 15

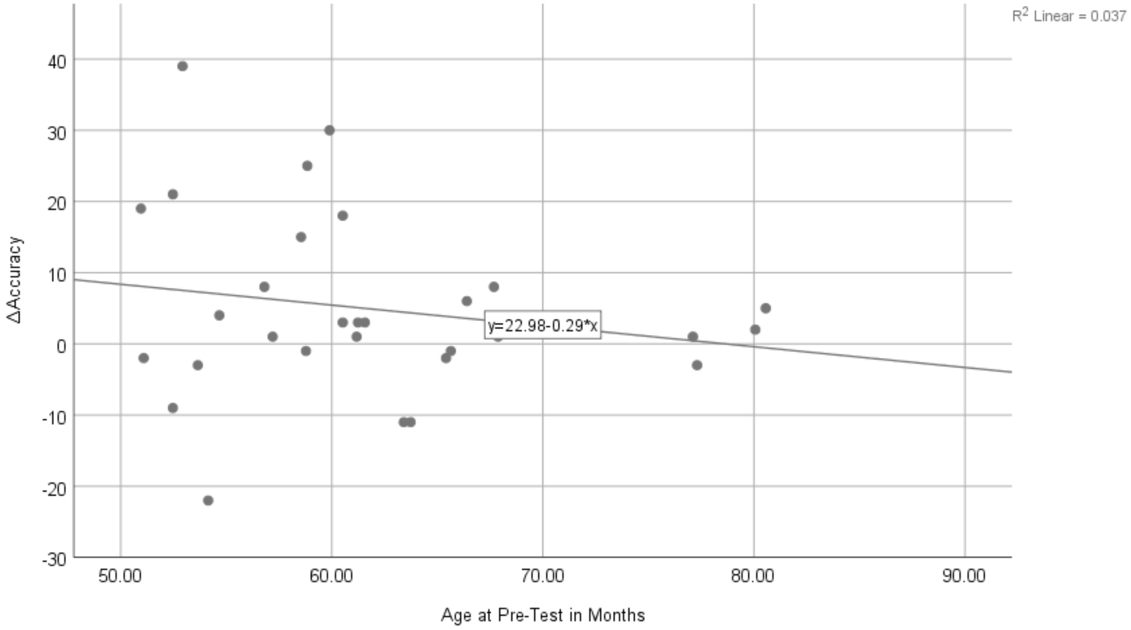
Correlation Between Age and Mean Response Time Gain Score

			Age_Ordinal	ΔRT
Spearman's rho	Age_Ordinal	Correlation Coefficient	1.000	-.256
		Sig. (2-tailed)	.	.171
		N	30	30
	ΔRT	Correlation Coefficient	-.256	1.000
		Sig. (2-tailed)	.171	.
		N	30	30

Significance aside, the decrease in accuracy gain scores by age is curious and to better illustrate the association, a scatterplot (Figure 2) displays the amount and direction of change with age as the continuous variable to ensure each observation is represented and provide a clearer illustration of the distribution. This result could shed light on why regression analyses with Age as a covariate repeatedly failed the assumption of homoscedasticity: the variation in accuracy gain score grows markedly small as participants' age at pre-test increases.

Figure 2

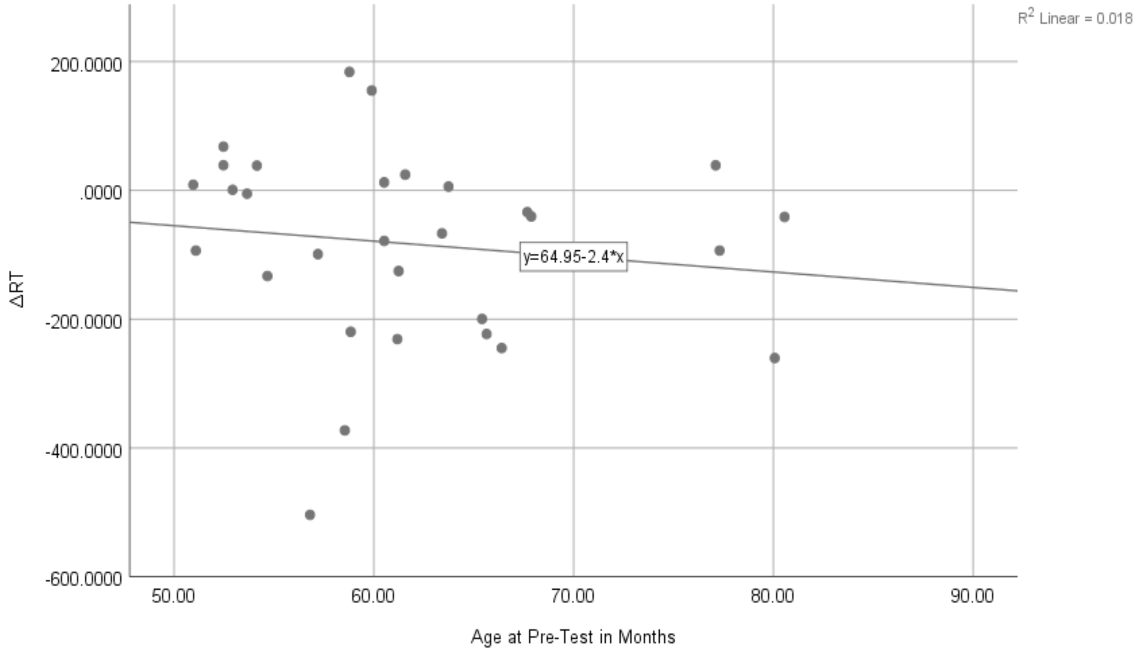
Scatterplot of the Gain Score of Accuracy (ΔAccuracy) by Age at Pre-Test (in Months)



A similar scatterplot for the gain scores in mean Response Time by Age (Figure 3) provides the contrast of a more normal scatter across age. For mean Response Time gain scores, a negative correlation is intuitive since a reduction in processing time, or a quicker response, is expected as a child ages.

Figure 3

Scatterplot of the Gain Score of Mean Response Time (ΔRT) by Age at Pre-Test (in Months)



To address the effect of gender on attention development—and because gender did not differ much between training groups—two separate ANOVA analyses were employed to compare the differences between gender groups in terms of gain scores of Accuracy and mean Response Time. The first one-way ANOVA was conducted to determine if the change in accuracy between pre- and post-test administrations (gain score) was different for the two gender groups: male (*n* = 17) and female (*n* = 13). There was homogeneity of variances, as assessed by Levene's test for equality of variances (*p* = .847). The mean gain score for Accuracy rate was higher for female participants (*M* = 5.46, *SD* = 12.34) than male participants (*M* = 4.53, *SD* = 13.48), but the difference between them was not statistically significant, *F*(1, 28) = .038, *p* = .847. The effect size, partial eta-squared was calculated to be $\eta^2 = .001$ indicating that gender accounts for only 1% of the variance in accuracy rate gain scores.

The second one-way ANOVA was conducted to determine if the change in mean Response Time between pre- and post-test administrations (gain score) was different for the two gender groups: male ($n = 17$) and female ($n = 13$). There was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = .843$). The mean gain score for mean Response Time was larger for male participants ($M = -105.87$, $SD = 149.19$) than for female participants ($M = -53.09$, $SD = 150.56$), but the difference between them was not significant, $F(1, 28) = .915$, $p = .347$. The effect size of gender was calculated to be $\eta^2 = .032$, which indicates that gender accounts for 3.2% of the variability in mean response time gain scores.

Influences of Intelligence and SES on the Development of Attention

Because IQ was also found to not differ between training groups, I conducted a correlation analysis (two-tailed Pearson product-moment correlation) to test the association between IQ and the gain scores of Accuracy and mean Response Time across the total study population. All assumptions were met and all variables: IQ and gain scores for Accuracy and mean Response Time were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). As shown in Tables 16 and 17, the results indicate the positive direction of a small-medium association for IQ and Accuracy gain score and the positive direction of a very weak association with mean Response Rate gain score. However, in light of these non-significant results, I conclude that I fail to reject my null hypothesis and fail to accept the alternative hypothesis that there is a significant effect of IQ on the development of attention.

Table 16

Correlation Between IQ and Accuracy Gain Score (ΔAccuracy)

		IQ	ΔAccuracy
IQ	Pearson Correlation	1	.233
	Sig. (2-tailed)		.216
	Sum of Squares and Cross-products	5304.967	1166.933
	Covariance	182.930	40.239
	N	30	30
ΔAccuracy	Pearson Correlation	.233	1
	Sig. (2-tailed)	.216	
	Sum of Squares and Cross-products	1166.933	4741.867
	Covariance	40.239	163.513
	N	30	30

Table 17

Correlation Between IQ and Response Time Gain Score (ΔRT)

		IQ	ΔRT
IQ	Pearson Correlation	1	.059
	Sig. (2-tailed)		.759
	Sum of Squares and Cross-products	5304.967	3433.273
	Covariance	182.930	118.389
	N	30	30
ΔRT	Pearson Correlation	.059	1
	Sig. (2-tailed)	.759	
	Sum of Squares and Cross-products	3433.273	648663.455
	Covariance	118.389	22367.705
	N	30	30

Next, two separate ANOVA analyses were conducted to compare the differences between household income groups in terms of gain scores of Accuracy and mean Response Time. The first one-way ANOVA was conducted to determine if the change in Accuracy between pre- and post-test administrations (gain score) was different for the three income groups: less than \$20,000 - \$59,999 (*n* = 10), \$60,000-\$99,999 (*n* = 6), and

\$100,000+ (*n* = 14). There was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = .387$). As is displayed in Tables 18 and 19, the mean gain score for Accuracy rate was higher for participants in the middle income group than for participants in the lower income group and the highest income group, but the differences between them were not statistically significant ($p > .05$). The partial eta squared effect size was calculated for household income group effects ($\eta^2 = .133$), which indicates that household income accounts for 13.3% of the variance in accuracy gain scores.

Table 18

Descriptive Statistics of Income Group and Mean Accuracy Rate Gain Scores (ΔAccuracy)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean
					Lower Bound
\$40,000-\$59,999, \$20,000-\$39,999, or less than \$20,000	10	3.50	10.427	3.297	-3.96
\$60,000-\$79,999 or \$80,000-\$99,999	6	14.00	15.336	6.261	-2.09
\$100,000+	14	2.07	12.275	3.281	-5.02
Total	30	4.93	12.787	2.335	.16

Table 19

ANOVA Table of Group Differences for Income Groups and Accuracy Gain Scores (ΔAccuracy)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	628.438	2	314.219	2.062	.147
Within Groups	4113.429	27	152.349		
Total	4741.867	29			

The second one-way ANOVA was conducted to determine if the change in mean Response Time between pre- and post-test administrations (gain score) was different for the three income groups: less than \$20,000 - \$59,999 (n = 10), \$60,000-\$99,999 (n = 6), and \$100,000+ (n = 14). There was homogeneity of variances, as assessed by Levene's test for equality of variances (p = .537). All groups experienced a negative mean gain score indicating a reduction in response time between pre-test and post-test. As shown in Tables 20 and 21, the mean gain score for mean Response Time was larger for participants in the highest income group than for participants in the lowest income group and the middle income group, but the difference between them was not significant (p = > .05). The partial eta squared effect size was calculated for household income group effects (η^2 = .027), which indicates that household income accounts for only 2.7% of the variance in mean response time gain scores.

Table 20

Descriptive Statistics of Income Group and Mean Response Time Gain Scores (ΔRT)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean
					Lower Bound
\$40,000-\$59,999, \$20,000-\$39,999, or less than \$20,000	10	-82.318	136.963	43.312	-180.296
\$60,000-\$79,999 or \$80,000-\$99,999	6	-38.470	103.899	42.417	-147.505
\$100,000+	14	-102.571	177.286	47.382	-204.933
Total	30	-83.000	149.558	27.306	-138.846

Table 21

ANOVA Table of Group Differences for Income Groups and Mean Response Time Gain Scores (ΔRT)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	17264.908	2	8632.454	.369	.695
Within Groups	631398.547	27	23385.131		
Total	648663.455	29			

CHAPTER 5

Discussion

The purpose of this study was to examine the effects of early childhood training on the development of attention skills. Utilizing a theoretical framework from research on the development of attention, experiential canalization, and early childhood music education, this study employed a quasi-experimental design to explain the differences between music training, sports training, and a control group with no training activities. Four to six year-old participants were recruited from local elementary and pre-k schools as well as music teaching studios. This chapter includes an overview of the study results as applicable to literature on attention, cognitive development, and music education. The chapter will conclude with a discussion of study limitations and areas for future research. The overview of results is organized by the research questions:

1. Does music training affect the development of attention?
2. Is there an influence of age or gender on the changes in attention?
3. Is there an influence of intelligence on changes in attention?
4. Is there an influence of SES on changes in attention?

To address the first research question, and using the results of the pilot study on the reliability of the ANT-Child, I utilized two ANCOVA analyses to explain the difference between post-test accuracy rates and post-test mean response rates for the three training groups while controlling for the pre-test scores for accuracy and mean response rates, respectively. By allowing for the inclusion of pre-test scores as a covariate, this type of analysis allowed me to control for the pre-test scores of accuracy and mean response time, respectively, for the three training groups. There was no significant difference between the three groups in terms of accuracy rates although the unadjusted and adjusted means (before and after controlling for the pre-test scores) were both higher for the two training groups than the control. The same held true for the analysis of the differences in mean response rates between the groups. There was no significant difference between the training groups' mean response times though the two training groups reported faster response times than the control before and after controlling for the pre-test scores.

To investigate further, I conducted ANOVA analyses to explain any training group differences in gain scores of Accuracy and mean Response Time. Gain scores are a commonly used alternative to covariance-adjusted scores and there has yet to be a consensus as to which is the better option. Like the ANCOVA results above, there was no significant difference between the groups, but Music Training and Other Training exhibited larger gains in mean response time and accuracy, respectively, and Other Training experienced a much larger gain score in accuracy. Though these results were not significant, the differences revealed between the means of the three groups suggest an agreement with similar findings in previous literature of trends toward, or significance in, greater attention skills and development in participants who had engaged in training. (Pasiali et al., 2014; Rodrigues et al., 2013; Scott, 1991; Strait et al., 2015)

To address the second research question, because age and gender did not differ significantly between training groups and sample sizes for the training groups were small, adding these variables to the previous ANCOVA model as additional covariates was not the best course of action. When the age variable, as continuously measured in months, violated the assumption of normality for a Pearson's *r* correlation analysis, I chose to conduct two non-parametric Spearman's rank-order correlation analyses to explain the relationship between age and the gain scores of accuracy and mean response rate. Two ANOVA analyses on gender and the gain scores of accuracy rates and mean response times for the total participant population examined the differences between gender groups in terms of the development of the two measures of attention.

Surprisingly, there was a negative correlation coefficient for age and accuracy gain scores and not surprisingly, a negative correlation coefficient for age and mean response time gain scores. The unexpected negative correlation coefficient for age and accuracy gain scores indicates a decrease in gain scores from pre-test to post-test accuracy rates for older participants. This observation suggests a waning effect of age on the change or improvement in accuracy rates. This could be a product of an early surge in the development of attention skills that support participants' accuracy within the earlier years of this age group. Subsequent research to examine this observation further should focus on the neurological development that may take place during the fourth and fifth year of age, specifically, and the effects of pre-kindergarten engagement on the development of attention. Notably, during the 4th and 5th year, children from the geographic area in which the sample was drawn typically begin state lottery-funded pre-Kindergarten programs, the structure and curriculum of which may provide a concentrated development period for accuracy skills that begins to level off afterward. Further, the association between age and mean response rate gain scores should be considered to be a medium-sized effect. So, the trend herein is that older children experience less of a change in accuracy as they do in response time.

These findings seem to support research that pinpoints the 4.5 to 6 year age range as a prominent developmental period, particularly for executive attention skills (Breckenridge et al., 2013; Manly et al., 2001). These results are both contradictory, in terms of attention gains, and in agreement with, in terms of response rate gains, to similar research. Mezzacappa (2004) found accuracy rates increased with age while overall response times decreased on similar attention measures and with similarly aged participants. Overall, the hypothesis for this research question was that the age of participants would be negatively correlated with overall mean response time, which was observed although non-significant.

The ANOVA analysis for gender differences on the gain scores of mean response time and accuracy rate were both non-significant, indicating no statistical difference between gender groups on the change in score from pre-test to post-test administrations. However, the results revealed a larger gain score for accuracy for female participants than male participants and a larger improvement in response times from pre- to post-test for male participants than female, though the possibility that this is due to error cannot be discounted. These results are similar to Mezzacappa (2004), who also found that male participants exhibited significantly faster overall response times. The absence of significant gender differences in overall accuracy rates or mean response times suggests no effect of gender on the development of attention skills for this age group.

Similarly, the analyses for the effects of intelligence and socioeconomic status on the development of attention were 1) Pearson correlation tests of association between IQ and the gain scores of accuracy rate and mean response time; and 2) two ANOVA tests for group differences between household income and the gain scores of accuracy rate and mean response time for the entire participant population. The correlation analyses results indicated a positive direction of association for IQ and both attention measures as well as a small-medium sized association for IQ and Accuracy gain scores that was stronger than the association between IQ and mean Response Time gain score, though neither was significant. While the research literature may be divided, this result may be combined with those of Weyandt et al. (2002) and Tourva et al. (2016) who also found non-significant associations between IQ and attention.

The two ANOVA tests for household income groups and gain scores of accuracy rate and mean response time revealed a non-significant difference for both. However, the middle income group experienced a larger change in accuracy scores and the highest income group experienced the largest change in reduction of response time. With such a small sample size, it's likely that transforming the household income variable into a dichotomous variable could have been a better choice, but these results suggest an association between SES and attention development. This proposed association could be attributed to the additional positive experiences that affluence could provide (e.g., increased quality or more stimulating preschool or daycare environment, travel, activities).

In sum, this study revealed no significant difference between training groups and no significant effect of age, gender, IQ or SES on the development of attention across the three-month training period. This is a similar result to prior research of this type with this age group (Rueda et al., 2012). While sample size certainly had an effect on training group differences and forced a change in how associations between variables were assessed—influencing variability and contributing to non- significance across the analyses—there are some findings that should be noted (see Appendix D for summary table of significance and effect sizes across analyses).

In particular, the smaller gain scores in accuracy rate amongst older and more affluent children could indicate a shorter period of rich development than previously thought, leveling out as children reach the sixth year. It may also be influenced by the effects of prior development due to the start of educational experiences in pre-kindergarten and kindergarten (e.g., learning routines, social expectations, working in teams, and staying focused on tasks) and the additional developmental experiences that affluence may make possible. Younger, less-affluent children would not have had much access to either of those resources at the time of testing. Further, the medium effect size of IQ on the gain score of Accuracy, while not significant, should be noted as a contribution to the divided nature of the research literature on intelligence and attention.

Limitations

Key limitations to this study are similar to those found in the current literature and mentioned herein. They include limitations to scope of analysis due to reliability results from the pilot study, small sample size, non-randomized assignment to training groups, insufficient training duration, and limitations in the reliability of the attention measure for this age group. Further, the small sample sizes for this study were primarily the result of challenges in participant recruitment. Recruitment for this study was particularly difficult for many reasons: small potential recruitment pool, school administration and/or teacher buy-in, potential participants' involvement in more than one type of training, parental engagement, and further, participants' ability to stay engaged during the pre-test attention measure administration.

The results of the pilot study of the reliability of the ANT-Child instrument restricted analysis to the two, overall indices of accuracy and response time. While a useful addition to the literature on attention, this result prohibited the examination of the individual networks of attention for the present study. Measuring attention by overall accuracy and response time is sufficient to answer the research questions but, a more nuanced look into the development of the individual components was desired. Anecdotal evidence of children's ability to maintain their gaze on the screen is posited as a contributing factor and is discussed in further detail in subsequent discussion of the reliability of the instrument, in general.

The issues related to the recruitment of participants began with the limited potential recruitment pool. The age range of four and six years is young for music education and not the most popular for starting instrumental music lessons, though there are many Suzuki methods teachers and area associations. I knew during the study design that this may be an issue, but I assumed that there would be enough students in the greater metropolitan area from which I could draw my participants. Outside of the university community music school, the process of getting music teacher buy-in was exceedingly difficult. Many area, region, and state-wide music education teachers and teaching associations were pursued, some with initial positive response, some with no response despite multiple attempts. The few that were interested often did not teach children in the age range, but excitedly passed on the information to those they knew who did or provided contact information in a snowball sampling type of recruitment. Time and again, this resulted in no response despite my best efforts to contact the suggested teachers. Essentially acting as gatekeepers, I had no way of contacting the parents of these young music students without obtaining contact information from the music teacher. Most recently, efforts to collect data from a group of music and dance participants was obstructed by the COVID-19 global pandemic. Children who had completed the pre-test assessment had their lessons or classes halted for the duration of the semester.

Throughout the study duration, it was relayed to me that many children who are involved in a sport or music lessons are involved in more than one and therefore, not eligible to participate in this study. At this young age, I did not foresee this being a major issue, but such anecdotal evidence points to this being one cause for lackluster music participation. It could be that at this younger age, parents are taking a strategy of exposing their children to many different interests. In addition, many music, dance, and sports programs tend to be short in duration, making it challenging to both assess the impact of sustained development in the activity and increasing the variability of children's engagement in many different types of activities. There were also children whose parents could not be contacted to complete the household questionnaire. Multiple attempts to contact via phone numbers and/or email addresses on the parental consent form went unanswered. Even though the participants had completed the pre- and post-test administrations, without data from the questionnaire, the child's assessment scores were not usable.

Further, there were many recruited participants who were not able to complete the pre-test administration of either the attention measure, IQ test, or both. This resulted in their exclusion from the study. The ANT-Child is long, repetitive and not terribly engaging, especially for young participants. Even for some of the older participants, this presented a challenge. But for those older participants, self-regulation skills may have enabled a greater ability to concentrate throughout the long test. Related, the varying levels of student engagement during the attention measure poses a threat to the measurement of accuracy and response rate and also to the measurement of the effect of cues and flankers.

In both the pilot study and the main study, many children were repeatedly observed disengaging their eye contact with the computer screen during the ANT-Child often only re-engaging when the stimulus fish were presented. Their gaze not being on the screen when the cues were presented, precluded the cue effect on alerting and orienting sub-score and effected the overall accuracy and response rate. I found as I gained experience in administering the assessment that I frequently offered praise or encouragement to participants that I noticed were becoming unnecessarily distracted. Reminding them that they were almost finished or praising their efforts often was enough to re-engage their attention enough to finish the test. I posit that this issue may explain the non-significance of the pilot test-retest reliability coefficients for the subscores of alerting effect, orienting effect, and conflict effect in this young age group. The limitations of the reliability of component scores of the ANT-Child attention measure for this age group precluded more nuanced examination of the development of attention. Specific analysis of the effects and development of alerting, orienting, and executive attention skills were not possible because the instrument was not found to be reliable at that level of detail. The difficulty of this test for four to six year-olds is addressed in the implications for future research.

The quasi-experimental design that relied on participants who had already chosen a training group or none at all, presents a great limitation on the strength of this study. Inevitably, there are differences between the participants in the three training groups that are not able to be controlled for. As was evident in the results, the pre-test scores of accuracy and mean response time were higher for the music and other training group. With the study inclusion criteria allowing for some level of prior experience (< 1 year), it is possible that the difference in pre-test scores are due to prior training. However, it is also possible that children who demonstrate greater attention abilities may be lead to participate in music or other training by their parents. This limitation was observed in the literature, but without the funding to pay for the training groups, this simply was not feasible for this study.

A final limitation to this study is the short training duration. Originally planned and proposed to be a six-month training period, I experienced great difficulty finding comparable sports training that lasted six months for this age group. Further, difficult participant recruitment led to a need for a rolling data collection approach instead of a cohort model making a longer training period even less probable. Often, by the time I was able to recruit a participant and schedule a pre-test, there was less than six-months left of their training season. There has been no consensus in the research literature as to an ideal training duration or amount with regard to types of executive function (Bowmer et al., 2018), to which attention is inextricably associated. However, similar to what was observed in prior research (Rueda et al., 2012), I believe that the 3 month training period proved to be insufficient—perhaps specifically for this age group—to establish a clear difference in training effects.

Implications for Future Research

Results of this study may be beneficial for the support of future research in the areas of cognitive psychology, educational psychology, and music education. Suggestions for future research include an updated attention measure and more granular examination of associations between variables in this study and individual permutations of cue presence, location, and flanker effect; further examination of the development within this four to six year age range, particularly addressing the effect of pre-kindergarten and kindergarten on component attention skills; and the utilization of random assignment to treatment groups and more appropriate training duration. Though the generalizability and conclusions from the results are limited, the observed trends herein might be helpful when combined with other, similar study results.

With regard to the reliability of the ANT-Child instrument, I posit that difficulties with participant engagement in the instrument itself played a large part in the non-significance of the reliability of component scores of alerting, orienting, and conflict effect in the pilot study and explains some of the variability in scores for the main study's younger age group. The difficulty that I observed in young children being able to maintain attention and eye-gaze on the screen is not only likely to explain the issues with reliability, but also a threat to the validity of the subset scores of alerting, orienting, and conflict (executive) effect. I frequently observed participants looking away from the screen until they noticed the target stimulus appear (fish). The effects of cue presence and location could not possibly be measured if the participants were not looking at the screen during that time. I did find that as I gained experience in administering the test, I was better able to help participants keep their attention by reminding them that there was a break in the test coming soon, offering stickers during the breaks, encouraging them to keep going, and ensuring them that they were doing a good job.

The data provided from the ANT-Child includes sub-scores for all possible test conditions (i.e., permutations of cue presence, location, and flanker arrangement) that provide a detailed closer look at specific conditions. While the synthesized effect scores (i.e., alerting, orienting, and conflict) did not prove to be reliable in the pilot study herein, a more granular look at the individual conditions or permutations may shed some light on the developmental trends of these specific skills and a replication study with a larger sample size might prove to be beneficial. Because the four- to six-year age range is such a rich developmental period for attention, an instrument to measure attention that is more appropriate for young children is needed. I suggest the creation of an instrument that is less repetitive in nature and one that doesn't have a stimulus-break-stimulus-break pattern throughout. Keeping young participants engaged is difficult, but if the goal is to assess the effect of cues, an instrument should be continuously engaging to encourage children to keep their eyes on the screen. Further, utilizing technology that children of this age are more accustomed to is suggested. Many children were not accustomed to using a laptop or buttons on a trackpad. Consulting research and literature from information, and educational, technology will be beneficial.

The narrowing of variability in older children could be an illustration of the dynamic period of attention development particularly with regard to the development of executive attention skills as found in Breckenridge et al. (2013). As children develop through this period of attention development, the networks that underlie accuracy on this attention measure might experience greater growth in the fourth and fifth year followed by a more protracted developmental trajectory afterward as early studies have suggested (Levy, 1980). Further, the trend toward greater reduction in mean response time for those participants from more affluent household suggests that the 4- to 6-year developmental period of attention might be moderated by affluence and/or participation in pre-kindergarten.

The negative association between age and accuracy gain scores appears counterintuitive to the assumption that accuracy would improve with age. This finding in conjunction with the medium-sized effect of age on improvement in mean response time warrants additional studies that may provide some explanation. Given that research has highlighted this period of development and brain maturation to be quite dynamic—shifting from a two-factor model of attention to a three-factor model—the trends here of a waning effect of age on accuracy and positive effect of age on response time might provide some additional support to future research that investigates the development during this age range in greater detail. Further, changes in the development of accuracy might be affected by a surge in development due to experiences in the fourth and fifth year such as pre-kindergarten and other early educational experiences that affluence provides. It is also possible that if such a surge in development exists, that it levels off after the first year and assumes a more protracted developmental trajectory.

More appropriate duration of training period and random assignment are the two most influential limitations of this study and represent crucial next steps for this area of research. A research design similar to the present study that utilizes research funding to pay for training might be able to randomly assign participants to groups, control and extend training duration, and increase incentive for participation that results in more appropriate sample sizes. Larger sample sizes could provide additional power necessary to better assess reliability in the component scores within the ANT-Child for this age group. This is a necessary next step for this area of research as studies are pointing toward a vigorous development of attention skills within a narrower time-frame than originally thought, seeming to weigh more heavily on the fourth and fifth year. The ability to examine the individual networks with a measure such as the ANT-Child will be crucial toward increasing our understanding of the nature of this development.

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Appendix A

Parent/Guardian Questionnaire

Thank you so much for your participation in this important research. This questionnaire is built to collect information about your child and about your household environment that the research literature shows may contribute to differences in children's development. I am collecting this information to be able to statistically control for each of these areas when the data collection is complete. Your individual information will not be shared with anyone or in any public display of data. Your data and your child's data will be combined with other children and parental data and only displayed as group level results.

Child’s name (in order to link to your child’s study ID”

Child’s birthdate (mm/dd/yyyy) [to allow researchers to calculate age in months]

Child’s gender

- ○ Male
- ○ Female
- ○ Other
- ○ Prefer to not disclose

Parent/Guardian 1: Completed Education

- ○ Less than high school
- ○ High school graduate

- ○ Some college but less than Associate’s degree
- ○ Associate’s degree
- ○ Bachelor’s degree
- ○ Professional degree
- ○ Doctorate
- ○ Unknown
- ○ N/A

Parent/Guardian 2: Completed Education

- ○ Less than high school
- ○ High school graduate
- ○ Some college but less than Associate’s degree
- ○ Associate’s degree
- ○ Bachelor’s degree
- ○ Professional degree
- ○ Doctorate
- ○ Unknown
- ○ N/A

Combined/Total Household Income

- ○ Less than $20,000
- ○ $20,000 - $39,999
- ○ $40,000 - $59,999
- ○ $60,000 - $79,999

- ○ $80,000 - $99,999
- ○ $100,00+

Combined Parent/Guardian Experience

	0-1	1-2	2-3	3-4	4+
Years of Music training	○	○	○	○	○
Years of Sports training	○	○	○	○	○

Combined Experience of Child's Siblings (if applicable)

	0-1	1-2	2-3	4+
Years of Music training	○	○	○	○
Years of Sports training	○	○	○	○

Appendix B

Pilot: Test Re-test Reliability Correlation Table

Correlations for Pilot Variables: ANT-Child

Variable	1	2	3	4	5	6	7	8	9	10
1. Alerting Effect 1	–									
2. Alerting Effect 2	-.09	–								
3. Orienting Effect 1	.05	-.07	–							
4. Orienting Effect 2	.18	.38	.37	–						
5. Conflict Effect 1	.28	-.13	.17	.02	–					
6. Conflict Effect 2	.08	.03	-.27	-.21	.32	–				
7. Grand Mean 1	-.06	.02	-.67**	-.50*	.01	.404	–			
8. Grand Mean 2	.39	-.09	-.34	-.39	.26	.51*	.66**	–		
9. Accuracy 1	.12	.50*	-.12	.26	-.39	-.35	-.27	-.32	–	
10. Accuracy 2	.06	.33	-.14	.34	-.38	-.37	-.46*	-.47*	.83**	–

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Appendix C

Parent and Sibling Music and Sports Training

While not used in the testing of hypotheses, the nature of support at home for children in training groups was of interest during the study design. To measure this, questions were included on the household demographic questionnaire that parents completed as a part of the study. Parents were asked to disclose the combined amount of time, in years, that they had completed in music training and in sports training. Similarly, parents were asked to disclose the combined amount of time, in years, that the participant's siblings had completed in music training and in sports training, if applicable. The following are crosstabulations to illustrate the distribution across the study population, by training group.

Training Group (Group2ID) YrsParentMusicTraining Crosstabulation*

		YrsParentMusicTraining					
		0-1	1-2	2-3	3-4	4+	Total
Group2ID	Music	3	0	0	0	2	5
	Other Training	2	1	3	0	2	8
	Control	6	1	0	1	9	17
Total		11	2	3	1	13	30

Training Group (Group2ID) YrsSiblingMusicTraining Crosstabulation*

		YrsSiblingMusicTraining					
		0	0-1	1-2	2-3	4+	Total
Group2ID	Music	1	3	0	0	1	5
	Other Training	3	3	0	0	2	8
	Control	0	13	1	1	2	17
Total		4	19	1	1	5	30

Training Group (Group2ID) YrsParentSportTraining Crosstabulation*

		YrsParentSportTraining					
		0-1	1-2	2-3	3-4	4+	Total
Group2ID	Music	2	1	0	0	2	5
	Other Training	1	0	1	1	5	8
	Control	7	1	1	1	7	17
Total		10	2	2	2	14	30

Training Group (Group2ID) YrsSiblingSportTraining Crosstabulation*

		YrsSiblingSportTraining					
		0	0-1	1-2	2-3	4+	Total
Group2ID	Music	1	3	0	0	1	5
	Other Training	2	2	2	0	2	8
	Control	1	12	1	2	1	17
Total		4	17	3	2	4	30

Appendix D

Table of Significance and Effect Sizes

Analysis	Sig.	Effect Size
ANCOVA: Accuracy	.283	$\eta^2 = .093$
ANCOVA: Mean Response Time	.388	$\eta^2 = .070$
ANOVA: Accuracy Gain Score	.232	$\eta^2 = .102$
ANOVA: Mean Response Time Gain Score	.808	$\eta^2 = .016$
Correlation: Age*Accuracy Gain Score	.464	$\rho = -.139$
Correlation: Age*Mean Response Time Gain Score	.171	$\rho = -.256$
ANOVA: Gender*Accuracy Gain Score	.847	$\eta^2 = .001$
ANOVA: Gender*Mean Response Time Gain Score	.347	$\eta^2 = .032$
Correlation: IQ*Accuracy Gain Score	.216	$r = .233$
Correlation: IQ*Mean Response Time Gain Score	.759	$r = .059$
ANOVA: Household Income*Accuracy Gain Score	.147	$\eta^2 = .133$
ANOVA: Household Income*Mean Response Rate Gain Score	.695	$\eta^2 = .027$