THE RELATIONSHIP BETWEEN MELODY AND PROSODY: PERCEPTION AND PRODUCTION CAPABILITIES OF MUSICIANS AND NON-MUSICIANS

BY

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DISSERTATION

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Music Education in the Graduate College of the University of Illinois at Urbana-Champaign, 2010

Urbana, Illinois

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ABSTRACT

Music and language are two interconnected acoustic and cognitive phenomena shared by human beings. Among their similarities are their variety of intonations and inflections resulting in melody and prosody, respectively. Previous research has demonstrated that musicians are more successful than non-musicians at detecting pitch errors in speech and melody. These results are often due to extensive musical training beginning at an early age. In examining melodic and prosodic abilities of twenty-nine university undergraduates, this study attempts to better understand the connectedness between these cognitive functions, and the affects various musical experiences may have. To assess these abilities, three production stimuli were developed and Gordon’s Advanced Measures of Music Audiation was used. Statistical analysis demonstrated significantly strong correlations between total length of musical experience as well as the age formal instruction first began. In recognizing the potential transferred effects of beginning and continuing musical training, this study may help to support pedagogical and curricular decisions regarding when and for how long to offer music instruction, in addition to contributing to current research on music education and cognitive psychology.
To my ever patient and supportive family. To Ben, James, Josie, Sammy, and Ginger who have taught me how to appreciate the space between.
ACKNOWLEDGEMENTS

I would like to extend my sincerest gratitude to the members of my doctoral committee for their continuous support throughout my education and professional career. This mentorship has been invaluable. Thank you to Dr. Duane Watson and Dr. Scott Jackson for their collaborative nature and willingness to extend beyond all our comfort zones. Additional thanks to all members of the Communication and Language Lab in the psychology department at the University of Illinois for their patience and feedback throughout the design and data collection of this study.

Thank you to my cohort in Music Education for your ceaseless camaraderie, encouragement, and inspiration (with a few laughs in between). A heartfelt thank you to Allen R. Legutki and Channing A. Paluck for their exquisite eye for detail in editing and audio/visual set-up. Finally, a sincere thank you to my family and friends for their patience and understanding throughout this work.
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Chapter 1: INTRODUCTION

For centuries, the brain has mystified philosophers, scholars, and scientists. The oldest written record of brain mapping dates back 5,000 years to Ancient Egypt, and is from the Edwin Smith Surgical Papyrus (Breasted, 1980). More recently, towards the latter half of the 20th century, the belief of hemispheric specialization dominated the beliefs of human cognition with right-brained individuals characterized as holistic thinkers and left-brained individuals thought to be more logical (Gandour, et al., 2004; Hines, 1987). Beyond mapping the anatomical particularities of the brain, theories of learning, teaching, and the mind-brain relationship have made their way into cognitive and educational research as well (Bransford, Brown, & Cocking, 2000; Pally, 2000).

Until recently, assumptions on cognition were drawn from neuropathology in surgery to address cognitive impairments presumably from physiological particularities, or postmortem dissection (Byrnes & Fox, 1998; Geake & Cooper, 2003). Currently, advances in neuroimaging that measure electrical and magnetic signals such as electroencephalogram (EEG) and magnetoencephalogram (MEG), and those used in assessing metabolic/hemodynamic signals such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) have enabled researchers to more accurately understand how the brain operates in vivo in addition to its physiological structure (Savoy, 2001). These methods measure the temporal and spatial aspects of brain function, which allow for more precisely mapped structural (brain) and functional (mind) elements. Additional modes of testing such as transcranial magnetic stimulation (TMS) which uses magnetic pulses to temporarily inhibit areas of the brain (Bossomaier & Snyder, 2004) and diffusion tensor imaging (DTI) which uses water and MRI to create
images of brain tissue (Luoi & Schlaug, 2009) are being utilized for neuroscientific and cognitive studies as well.

As previously mentioned, data of this type had formerly been obtained using patients with lesions caused either by disease or trauma and often posthumously. The current neuroimaging techniques described above however, have recently allowed for studies involving healthy individuals ranging from infants to geriatrics. These newly developing techniques allow researchers to expand resources from studying the atypical to studying the typical. This growing trend and use of neuroimaging is demonstrated in the search completed by Bandettini (2007) on publications from the database, Medline, for papers with “fMRI” or “functional MRI” in the title, abstract, or keyword from 1992-2006 (see Figure 1.1).

![FMRI Papers Published per Year](image)

*Figure 1.1* Number of papers with keyword, title, or abstract containing "fMRI" or "functional MRI" published per year. Note. From “Functional MRI Today,” by P. Bandettini, 2007, Journal of Psychophysiology, 63, p. 2. Copyright 2007 by the American Psychological Association. Reprinted with permission of the author.

Further indication of the increased use of neuroimaging from exclusively clinical to cognitive research can be found at several universities that maintain MRI machines for
research purposes only. For example, Northwestern University’s School of Communication’s Aphasia and Neurolinguistics Research Laboratory in Evanston, IL uses imaging in an effort to “[build] theories of both normal and disordered language processing” (Northwestern, 2009) using both healthy and aphasic subjects in their studies.

Carving Out a New Trail: A Path Between Neuroscience and Education

“A bridge too far” (Bruer, 1997, p. 1) was a common sentiment amongst neuroscientists and educators in the mid-nineties regarding the notion of building any successful partnership. Current researchers in both cognitive psychology and music education however, are recognizing the importance of such collaborations, and are beginning to build upon each other’s work. Articles in educational research, music education, and several behavioral science journals are slowly initiating publications on this topic. Despite these advances, it is still rare to find collaborations between practitioners and researchers in a shared domain, let alone across disciplines (Hodges, 2008).

The predominant scientific concerns of a collaborative study between science and education are the methods used, and the data obtained (Varma, McCandliss, & Schwartz, 2008). It may seem apparent that any two bodies of research can learn from each other, but if they do not use a common vernacular, nor seek answers to relevant questions, it may become too difficult to communicate. Innovative research paradigms can enable researchers to exchange results, helping to find a common voice, and to corroborate their interests under a variety of contexts.
The interpretation of results is also a matter of concern when collaborating research efforts (Catterall & Rauscher, 2006). Learning is a broad cognitive process involving many physical and emotional motivators that can rarely be attributed to one localized area of the brain. This has resulted in a well-established and expansive research base in education. On the contrary, scientific data such as mapping from neuroimaging, is relatively young, and aims to provide specific results (Varma et al., 2008). How to adapt this breadth of educational research knowledge with the specialized work of neuroimaging is the large impasse Bruer described in his well-cited 1997 article. Cognitive psychologists are attempting to bridge this divide from their scientific perspective. It is now upon educational researchers to approach it from their standpoint.

Neuromusical Research

A new branch of research known as neuromusical research (Fondazioni, 2009) has designated itself as the facilitator between neuroscience, cognitive psychology, music research, and educational research. To date, this facet of research has included psychologists, physicians, geneticists, engineers, and is slowly making its way into educational research (W. Gruhn, personal communication, July 21, 2009). Neuromusical research has made massive advances in understanding music and its effects on the brain and mind as is evidenced by recent publications (Avanzini, Lopez, Koelsch, Majno, 2005; Dalla Bella et al., 2008; Edwards & Hodges, 2006; see Gruhn & Rauscher, 2007). Figure 1.2 depicts the increase in publications in two research databases: RILM Abstracts of Musical Literature and the National Library for Medicine (PubMed) for “music and brain” in the keyword query (Edwards & Hodges, 2006).
Despite the growth of studies in this field, implications of these results on music education are still lacking, as indicated in Figure 1.2 by the decrease of publications in musical literature. Neuromusical researchers such as Donald Hodges at the Music and Research Institute at the University of North Carolina at Greensboro, are actively pursuing these collaborative studies in order to appropriately delineate and apply their findings to education. Aware of the limiting research methods and resultant data he currently has access to as a music educator, Hodges has joined forces with geneticists, neuroscientists, anthropologists, and psychologists, applying their expertise to research in multisensory musical perception; brain mapping with PET, MRI, and fMRI of pianists, conductors, and singers; the evolutionary and human basis of musicality; and the connection between music psychology and music education (MRI, 2008). By utilizing their specialized knowledge and his broad music education experience, Hodges and his colleagues have been able to contribute to cognitive and educational research in a
Cooperative learning between research and teaching is not a novel concept. In 1896, roughly 80 years prior to the invention of the MRI, John Dewey proposed a laboratory school that would combine educational research and practice including assessment and evaluation (Tanner, 1997). A modern example of Dewey’s laboratory school is a teaching hospital. These facilities provide opportunity for direct application of research into practice for medical practitioners and scientists alike. Another application from research to practice is the model of major industries that develop products based on scientific findings prior to introducing them to the public such as crash tests for automobiles (Fischer, 2009).

Fischer and Daniel (2009) argue that both educators and scientists are wanting for a cooperative relationship between research and pedagogy. They suggest this would provide educators with effective assessments of their practice while also engaging scientists to explore the various applications of their findings. Part of the present study’s methodological intentions is to initiate such a collaboration and to demonstrate the benefits of this effort.

Music and Language

The voice is a universal instrument that is utilized in the conveyance of human emotion and communication in forms of music and language. One medium of this auditory expression is through the culmination of music and speech in song (Patel & Peretz, 1997). These are two interconnected acoustic and cognitive phenomena; melody, the musical form, can be defined as the succession of pitched sounds within a given duration (Randel, 2003) while the spoken correlate, prosody, is the intonation and
melodic contour of speech (Wennerstrom, 2001). Both are involved in organized acoustic processing and engage in complex cognitive and motor processes (Altenmüller & Gruhn, 2002). Fundamentally, each is reliant upon frequency, amplitude, and duration while manipulations of such variables provides the variety and means of emotional expression.

The cognition of music and language is not as easily defined, however. Individual variables affect the where, when, and how these seemingly similar soundwaves are processed. Figure 1.3 provides a gross illustration of the basic multilayered processes involved in the cognition and reproduction of an auditory stimulus. When a soundwave hits the ear, the vibrations are translated by the cochlea then converted into electrical impulses in the auditory cortex (Gazzaniga, Ivry, & Mangun, 2002). Words are recognized by phonemes and melodies are identified by their intervallic relationships (see Patel, 2008). Both are subject to interpretation based on their context, semantic, and syntactic information. After the auditory stimulus is received and processed by the brain, it is then reproduced through the vocal tract and the necessary articulators (Appleman, 1986). Finally, the reproduced stimulus is then evaluated by means of auditory feedback, and in the case of reproducing a specific target, evaluation and self-regulation may be involved (Mürbe, Pabst, Hofmann, & Sundberg, 2002; Pintrich, 2000).
Figure 1.3 A simplified depiction of the multilayered processes involved in the cognition and reproduction of an auditory stimulus.

These seemingly similar cognitive progressions are quite complicated in their intricacies and specific characteristics. In Chapter Two Part II, an expansion of the scientific backgrounds of music and language are offered, comparing these cognitive aspects in studies of education, cognitive psychology, and neuroscience.

This study attempts to examine music and language and its relation to music education. It addresses the cognition of music and language stimuli through a behavioral design, which purports that with early and prolonged musical training, individuals will have stronger performances on various melodic and prosodic production and perception tasks. Since there are commonalities between fundamental frequencies of speech and the pitches or tones of music, it is suggested that this ability would pertain to both music and language.
Purpose of the Study

This study aims to understand the behavioral relationship between the perception and production of melodic and prosodic tasks. In examining the potential variables affecting these cognitive functions, this study will explore how the amount of formal and informal music education, and the age in which it was first presented might affect these behaviors.

Prior studies have compared speech and music using subjects with deficiencies in either ability (Cuddy, Balkwill, & Peretz, 2005; Patel, Wong, Foxton, Lochy, & Peretz, 2008). This study however, will compare speech and melody perception and production in ways that seek to better understand human potential rather than deficit. By comparing results from music majors and non-music majors, this research will:

1. determine the relationship of when and how musical experiences are first introduced to the production and perception of melody and prosody;
2. examine any transfer of ability from musical exposure to another cognitive area, prosody;
3. initiate a collaborative atmosphere between cognitive psychologists and music educators implementing innovative research designs for pertinent question that would:
   a. create a mutual vocabulary for both disciplines to foster stronger communication;
   b. cultivate new knowledge that would enrich both professions;
   c. strengthen the results of this partnership; and
4. expand upon current neuromusical and behavioral literature.
Significance of the Study

By addressing the relationship between language and music based on musical experiences, this study will contribute to current research on music, music education, and cognitive psychology by broadening our knowledge of the effects of varying musical exposure. It will provide a stronger basis underlying effective teaching approaches for success in the presented tasks. As a result, it may potentially aid in the diagnosing, designing, and implementing of several curricula including performance and perception methods in both music and language. Understanding more of the behavioral affects of cognition may also help facilitate learning for individual students (Fischer, 2009). This will be accomplished by using the same healthy individuals in both music and language tasks. By correlating how an individual performs on the music tasks with the language tasks, this study will offer new information on how these two cognitive processes may be related, and how success and experience in one may transfer to another.

Using musicians and non-musicians as the subjects, the results will help to develop and inform teaching practice in music education. Correlating the musical experiences of the subjects to how well they perform on the tasks will provide new resources for understanding the significance of music education, the effects of when it is first introduced, the length of practice, and the form in which it comes.

In recognizing the potential affects of music on human cognition, music educators may now hold additional tools to aid in our students’ growth and development. A successful teaching environment where learning is achieved can be defined as a “natural cognition” as described by Strauss (2003, p. 383) in which a demonstration of understanding and a transfer of knowledge exhibit this success. Stewart and Williamson
(2008) remarked, “neuroscientific study of musical learning and performance is ripe for development” (p. 177). This is a complicated feat when most music educators do not have access, or the training to engage in neuroscientific research. While the present study is purely of behavioral design, it meets the profession’s need for expansive research questions and methodologies. It aims to provide results that will connect to, and inform music teaching based on illustrating the proposed relationship between musical practice and tonal performance in speech and music, and thus provide an improved understanding of music education, cognitive psychology, and learning practice as a whole.

Summary

With a vast array of new research methods and intriguing new questions, the potential for growth in both science and education is promising. In order to profit from research in both disciplines, partnerships must be created. Neuromusical research is an intriguing new field with the potential to expand upon our current understanding of learning and cognition through innovative research questions and methodological designs.

Although seemingly ideal, a fusion of research paradigms is sparse in current literature, which therefore necessitates a new vision in design (Stewart & Williamon, 2008). The appropriate timeliness of this work is also evident in the culmination of current scientific knowledge and research abilities that have enabled new questions to be asked that only a study of this collaborative nature could attempt to answer. The substantial increase of studies connecting neuroscience and education demonstrates the intrigue researchers are developing to find new methods at understanding and addressing various research paradigms. How these may lead to more accurate results and even more
comprehensive future inquiries first requires an initial examination of the behavioral data.

This study meets the needs of both cognitive psychology and music education research to initiate an examination of the cognitive connectedness between music and language, and the potential this knowledge has for understanding and benefiting student learning.
Chapter 2: REVIEW OF THE LITERATURE

Part I: Education and Science: Potential for a Bidirectional Exchange

A scientific understanding of learning includes understanding about learning processes, learning environments, teaching, sociocultural processes, and the many other factors that contribute to learning. Research on all of these topics, both in the field and in laboratories, provides the fundamental knowledge base for understanding and implementing changes in education.

-Bransford, Brown, & Cocking (2000, p. 233)

Memory, emotion, and learning are examples of human cognition that are fundamental aspects to education (Geake & Cooper, 2003). To better understand these elements of human behavior, it becomes necessary to understand the physical aspects that may promote or constrain them. An analogy stemming from the 1960s comparing psychologist to software designers aptly illustrates the dichotomous relationship between science and education. The sentiment suggests that it would be impossible to make advances in software development (cognition) without considering the format of the hardware (the brain) (Byrnes & Fox, 1998).

Educational researchers seek to assess current practices in order to improve student learning (AERA, 2008; Byrnes & Fox, 1998). This requires a broad understanding of pedagogy and appropriate evaluative measures. Behavioral research has dominated this field until recent efforts in the sciences have helped to corroborate results from both methodologies. Research of a domain as opposed to the discipline will likely solicit the most comprehensive results (Varma et al., 2008). Something to consider however, is the difficulty involved in isolating many of these disciplines within their domains. For example, reading involves many specific disciplines such as letter
recognition. It may be useful to examine human cognition as it relates to letter recognition, but this becomes a difficult task when acknowledging the many forms letter recognition comes in (i.e. English, math, and music). Education is a fusion of multiple disciplines, and understanding student learning must take a combinatory approach as well. This inherently means relying upon a variety of approaches when pursuing educational research that would not replace current methods, but would enhance those already in place (Goswami, 2004).

From Cells to Schoolhouse

As current technology develops, scientific research grows along with it. It is for this reason that the predominant research comparing music and language has been accomplished through neuroscientific inquiries. Although this work is most often not directly applied to educational practice, their results are still vital to initiating an alternative understanding of learning. To illustrate how neuroscientific knowledge may be beneficial to learning theories, a brief understanding is necessary to explain what the connection is from the cells to the classrooms.

The Brain’s Potential

Humans have relatively small brains at birth compared to our primate relatives (DeSilva & Lesnik, 2008; Mithen, 2006). Between the ages of 4 and 12 months, the brain grows to a maximum density of 150% of an adult only to reduce to an adult level between the ages of 10- and 20-years-old (Goswami, 2006). This growth and reduction is due to neuronal connections called synapses that are utilized and created with repetition, or are trimmed down in a process of efficiency termed pruning (Hodges, 2002). Synapses relay chemical information from one neuron, or axon, to the next creating designated
pathways for specific tasks. From repetition, these pathways become more effective with the help of myelin tissue that forms around these axons like conduit. This makes the electric transfer across the neuron from terminal to terminal that much more efficient. This process is known as myelination (Kandel, Schwartz, & Jessell, 2000).

Certain synaptic connections are genetically predetermined for specific tasks while others are formed from environmental experiences. For example, the visual cortex is a complex system in the brain that involves both the right and left hemispheres (Willingham & Lloyd, 2007). Although infants are born without this system fully functioning, with the proper exposure from the first 2-3 months of life, their visual cortex begins to mature as the synapses are put into practice (Johnson, 1990). Studies such as this demonstrate how when the appropriate stimulus is available, the brain will make modifications, and improved cognition may occur. In understanding this capacity, educational researchers can apply this to various teaching methods in the classroom in the hopes of improving student learning.

Despite the prearranged pathways of these neurons, if they are not utilized, pruning may occur, possibly resulting in the loss of a cognitive ability or, result in a redistribution of function called, plasticity (Stiles, 2000). The Japanese language can be used to illustrate the loss of a synaptic potential. In the spoken language, the consonant “la” does not exist. While all humans posses the capacity for language (Mehler & Christophe, 1995), the exclusion of this sound from the Japanese language inhibits the potential production of it later in life (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). In considering these affects of human plasticity, language students, for example,
might be better prepared to understand and tackle several of the challenges associated
with learning a new language.

The redistribution of functional specificity in the blind and deaf demonstrates how
the brain’s plastic potential may appropriately utilize what is needed. Neville et al. (1998)
found the area in the brain used for speaking a language was employed for sign language
by the deaf and Röder and Neville (2003) discovered that the visual areas of the brain
were enlisted for reading Braille in the blind. Examples of young children regaining
language abilities after left hemispherectomies also demonstrate the brain’s plasticity in
its redistribution of language function (Liégeois, Connelly, Baldeweg, & Vargha-
Khadem, 2008; Schwartz & Begley, 2002).

Environmental exposure has varying affects on human cognition. The former
elements illustrate how the loss of ability may occur when environmental experiences are
absent. However, when in a stimulating environment, the opposite effect may occur. A
study placing rats in a continuously varying setting verses a stagnant one revealed a
structural change in the rats’ cerebral cortex (Rosenzweig & Bennett, 1978). These rats
also performed better on problem-solving tasks than controls. A human analog of this
dynamic environment might be akin to driving in the streets of London. Maguire et al.
(2000) examined the brains of licensed London taxi drivers through structural MRI and
found they had an enlarged posterior hippocampal region compared to controls. These
results correspond with the current theory that this area of the brain stores spatial
representations and that with added stimulation, can develop beyond that of controls.
Another example of repeated experiences transforming the brain is the early and
continuous exposure to music (Goswami, 2006). Greater detail on this change can be
found in this chapter under *Music Cognition* and *Musicians and Non-Musicians.*

*Educational Connectedness*

The question exists then of how this knowledge of pruning, plasticity,
myelination, and cognition relate to learning. Education should examine work in
neuroimaging to better understand the neurological basis of its own practice more
comprehensively. In Goswami’s review of neuroscience and education, she briefly
indicates the connection between what is observed and what can only be speculated of
learning through imaging.

Although it is frequently assumed that specific [educational] experiences have an
effect on children, neuroimaging offers ways of investigating this assumption
directly. The obvious prediction is that specific experiences will have specific
effects, increasing neural representations in areas directly relevant to the skills
involved. (2006, p. 9)

This relationship is illustrated by Ansari and Coch (2006) in their representation of the
progression from individual genetics to test scores, as illustrated in Figure 2.1.
Figure 2.1 Illustration of the multileveled progression connecting genetics to academic ability. Note. From “Bridges Over Troubled Waters: Education and Cognitive Neuroscience,” by D. Ansari and D. Coch, 2006, TRENDS in Cognitive Sciences, 10(4), p. 147. Copyright 2006 by the American Psychological Association. Reprinted with permission of the author.

Education has already inadvertently incorporated scientific data into their practice. For example, data on nutrition and education (Behrman, 1996) has informed the federal government to take initiatives and establish programs such as the National School Lunch Program (USDA, 2009). Scientific research measuring physiological factors has also influenced decisions regarding education. Valdez, Reilly, and Waterhouse (2008) recently studied the effects on attentiveness and effectiveness throughout the day under a variety of settings. Their suggestions for implementation of results included everything from the lighting in a room, the length of time on a task, and the time of day for a task. This has guided educators and administrators to consider these physical factors when scheduling daily classes, standardized testing, physical education, and electives (Queen, 1997; Reilly, Atkinson, & Waterhouse, 1997).
The permeation of scientific research into educational practice has been influential to teaching and administrative decisions. Despite the success of any current associations, the following section reviews the relationship science and education historically held, and the progression of its severance.

The Longstanding Relationship Between Scientific and Educational Research

Historically, the presentation of science and education were ideologically uniform (Samuels, 2009). This can be dated back to Ancient Greece with the likes of Socrates, Plato, and Aristotle and their interest in developing the human character with examination of the arts, the sciences, and the human psyche (Palmer, 2001). The fusion of science and education continued until the 18th century’s Age of Reason (Kuhn, 1970). This movement was a reaction to the mysticism and superstition that greatly influenced the Middle Ages, and continued to exert its influence during the Enlightenment. It was during this latter time where advances and scientific discoveries were explored, moving its way into a distinct discipline (Spary, 1999). This divide continued, and took on additional descriptors baring adjectives such as theoretical or abstract knowledge (education) and technical or practical knowledge (science) (Samuels, 2009). More recently, Degler (1991) stated that in the latter half of the 20th century, socio-cultural accounts took priority over the natural sciences. The growth of literature in this field since that time is consistent with Degler’s position (Eisner, 1991; Geertz, 1973; Patton, 2002; Vygotsky, 1986).

This historic divide has made current attempts at reconnecting the two disciplines challenging. It has even surfaced in academia taking on the designation of qualitative and quantitative in terms of research methodologies. Educational researcher Jennifer Greene
said, “different inquiry traditions embrace different value commitments” (2007, p. 26). Although referring to methodologies, this quote aptly describes the same paradigmatic and pragmatic qualms often met with merging science and educational research.

In the past several decades, many researchers and educators alike have been encouraging a more united front under the distinction of multidisciplinary, interdisciplinary, or transdisciplinary research (Geake & Cooper, 2003; Hodges, 2008; Samuels, 2009; Max-Neef, 2005). Beginning in 1999, the Center for Educational Research and Innovation (CERI) has been providing resources for parents, teachers, researchers, and policy makers on current findings on the brain and learning. Their text, *Understanding the Brain: Towards a New Learning Science*, published by the Organization for Economic Cooperation and Development (OECD), provides a culmination of this information to encourage its readers to better understand the sciences in regards to education and learning practices (OECD, 2009). Projects such as the CERI’s mission, special journal issues on cognition and education, and professional organizations and small interest groups have created a momentum in research with which many educational researchers may be struggling to catch up with (AERA, 2009).

*Aspects of a Collaborative Relationship*

Brynes and Fox (1998) speculate that a shared dialogue between the sciences and education would be extremely beneficial to understanding educational psychology, student learning, and pedagogy. They suggest it would be an evolution synonymous with the growth educational psychology experienced when theories transitioned from the behaviorist model to the cognitive. Any progress however, would require commitment from both science and education to create bidirectional dialogue regarding questions,
results, and applications of new theories (Ansari & Coch, 2006; Berninger & Corina, 1998; della Chiesa, Christoph, & Hinton, 2009).

This communication would help strengthen and confirm results in both fields. For example, Rivera, Reiss, Eckert, and Menon (2005) examined children solving simple arithmetic problems through behavioral assessment and neuroimaging. While behavioral data found that the time it took for the children to solve problems decreased with age, no conclusion could be suggested to explain this effect. The imaging data revealed that younger children processed the arithmetic tasks in different areas of the brain than the older children resulting in a lengthier solve time. The behavioral research first recognized a cognitive difference in these children, and the neuroimaging enabled researchers to extrapolate the results, discovering the physical origins.

Rivera et al.’s study (2005) study depicts a scenario where both disciplines contributed to the concluding results. Although not always as symbiotic, there are notable benefits to education and science if each other’s expertise is taken under consideration (Albin, 2008; Geake, 2004; Harvard, 2009). The demand for additional studies incorporating behavioral designs based on scientific knowledge is the necessary next step that would benefit both disciplines.

Benefits to Educators

Overall curriculum design. Adding another element to understanding human behavior and learning will promote and empower educators in curricular design and pedagogical decisions (Johnson & Hallgarten, 2002). The localized identification of various aspects of cognition, although seemingly too specific for education, have already begun to inform education and best practices. For example, through fMRI it was found
that while doing numerical tasks, multiplication engaged networks of the brain involved in verbal processing while subtraction recruited areas involved in visual-spatial processing (Dehaene, Piazza, Pinel, & Cohen, 2003). Additional imaging has demonstrated how the presentation of teaching materials may affect where these areas are processed in the brain. Tang et al. (2006) imaged Chinese and English students while practicing mathematics with Arabic numbers. The Chinese children who had learned arithmetic via an abacus engaged more of the motor areas of the brain while the English children who were taught the subject verbally showed greater activation in the language areas.

Results from both of these aforementioned studies can facilitate educators to address why these differences exist more specifically for example, whether these findings are due to teaching theories or teaching practice. This knowledge might then inform the development of more valuable curriculum development and teaching decisions. Additionally, simply understanding the typical progression of a student’s cognitive development could also aid in the planning and implementing of well-designed lessons (Ansari & Coch, 2006). The adolescent brain, for example, has not yet reached its mature and stable state and is undergoing transformation, especially in the prefrontal and limbic regions (Braun & Bock, 2006). More specifically, the amygdala, the area within the brain known as the emotional center, is more dominant than the frontal lobe, the region responsible for executive function and planning (Baird, et al., 1999). As children grow into adulthood, this activity shifts, allowing for more thoughtful, reasoned responses (National Institute of Mental Health, 2009). This might lend an explanation for what is often observed objectively by most middle school educators; unlike adults who are more
likely to respond to a given situation thoughtfully and methodically, adolescents often respond more impulsively, acting on their emotions (Irving, 1997; Roeser, Eccles, & Sameroff, 2000). Having an understanding of this dynamic state in human cognition through cognitive science would foster even greater recognition and attention to adolescents’ developmental needs in education.

In order for any study of this nature to find their way into educational research, assistance in how to appropriately interpret the results may be necessary. An opportunity to develop a common language and open a dialogue between education and science would provide this guidance and enable educators to make well-informed curricular decisions and hopefully propel input into future research agenda (Geake & Cooper, 2003; Willis, 2008). This has been aptly applied by current research facilities that are attempting such collaborations to inform educational decisions such as the aforementioned Music Research Institute at the University of North Carolina, Greensboro and the Institute for Music and Brain Research out of Harvard.

Motivation. Motivation plays a strong role in goal orienting and learning (O’Neill & McPherson, 2002; see Schunk, Pintrich, & Meece, 2007). Most educational theories discuss the socio-cultural aspects of intrinsic and extrinsic motivation, however Csikszentmihályi’s (1990) introduction of the psychological state flow has permeated into multiple disciplines including education. Scientific data has addressed motivation from a chemical stance. Dopamine is a neurotransmitter often associated with the rewards system in the brain. Several studies have demonstrated that there is greater activation in this system when students were given cognitive feedback from their teacher such as whether or not they provided the correct answer (Aron et al., 2004; Tricomi,
The increase in dopamine in the brain subsequently provides a molecular incentive for students to stay attentive and participate in the hopes of receiving that same cognitive feedback and neuronal reward. In terms of education, this data supports the importance of feedback in the classroom from teacher to student; a common form of extrinsic motivation already in practice (Reeve, 2006).

Rilling, Sanfey, Aronson, Nystrom, and Cohen (2004) studied this same rewards system comparing two different motivational approaches. Participants played two games for a monetary incentive: one cooperatively with others and the other competitively against each other. Researchers found the cooperative environment solicited greater activation in the reward system in the brain. Implications of this in the classroom may be the form an activity takes for a particular lesson. Understanding the science and physical responses involved may encourage a teacher to appropriately design a lesson with human cognition in mind, thus leading to potentially improved learning.

Teaching methodologies. Judy Willis makes the argument that unbeknownst to many educators, they are already implementing neurological teaching strategies in the classroom. Her philosophy of reticular activating system, amygdala and dopamine, known as RAD, emphasizes the neurological foundations behind student behaviors and learning (RAD, 2009). For example, Willis has remarked on the effectiveness of a student-centered, constructivist, or interest-based teaching model. She claims the construction of knowledge by students based around a given topic promotes a long-term memory change instead of the “drill and kill” method, which implies students often regurgitate memorized responses (Hughes, 2005). With long-term instruction, lasting neurological changes are facilitated that may lead to a more thorough understanding of
context in addition to a potential transference of knowledge to other contents (Steiner, 1963).

**Special education.** Learning disabilities are often researched through behavioral assessment. This can be accomplished by comparing these students to their peers in the classroom context. For decades, the behavioral work on dyslexia was inconclusive with a variety of hypothesis that resulted in a variety of remediation programs (Willingham, 2008). Imaging data has since revealed that some dyslexics had a decrease in activation in the areas of the brain responsible for orthography and phonology (Temple et al., 2003). From this information, specific programs were designed by educational researchers to address these deficits in an attempt to increase activation to these areas (Eden et al., 2004). Brain imaging completed following the remediation revealed a successful increase in activation to those areas, resembling normal readers. The success of this partnership between science and education demonstrates how with the contributions from each discipline, a greater understanding of learning and effective teaching strategies may be implemented to address specific needs.

Delayed language learning has also been researched using neuroimaging. Deficits in auditory processing have been demonstrated with a signature EEG pattern. Guttorm and his colleagues in a 2005 study found that infants less than a year old who produced this pattern exhibited delayed language learning later in life. The possibility of predicting a potential learning disability prior to its onset may allow educators to provide appropriate and timely interventions (Willingham & Lloyd, 2007). Either with the shared information between disciplines eliciting and confirming results on special education, or
from remediation initiated before their onset, there is potential for special education to benefit from neuroscientific data.

*Giftedness.* Just as cognitive deficiencies are being measured with neuroscientific imaging, so too can cognitive strengths be outlined. O’Boyle and Benbow (1990) used behavioral data to address hemispheric specialization and dominance between students who scored in the top one-half of 1% on the Scholastic Aptitude Test (SAT) and matched controls. The dichotic listening tasks demonstrated that those subjects termed *gifted* based on their SAT scores showed equal ability in both ears, or both hemispheres, while the controls demonstrated a right ear, left hemisphere, dominance. This data possibly implies a different functional organization for the gifted students involving both halves of the brain for more efficient processing (O’Boyle & Gill, 1998). With this information, educators might be able to differentiate their curriculum to address individual student abilities, building upon their strengths and stretching their abilities even further.

*Benefits to Scientists*

Cognitive performance is dependent upon its context (Vygotsky, 1978). The diverse use of letter recognition across various disciplines, as mentioned at the beginning of this chapter, illustrates this argument. Neuroscience examines the very minute and specific metabolic cause of an action. Although this can be very precise and localized, it may be an inaccurate demonstration based on the context. For example, the type of responses solicited while lying in a laboratory may be extremely isolated from those experienced in a classroom. The research would then look to the behavioral data to corroborate or extend on a hypothesis. The localized specifications and monitoring utilized in neuroscience, for example, could be elaborated upon and put into the complex
and ecologically valid context of learning through educational, behavioral research (Ansari & Doch, 2006; Byrnes & Fox, 1998).

In addition to a lack of contextual representation, many scientists have not studied pedagogy, have not worked in educational settings, and are therefore unqualified to make proper suggestions for any implementation of results (Ansari & Doch, 2006; RAD, 2009). With a collaborative atmosphere, these decisions would become the responsibility of educators, where results could be interpreted and utilized appropriately.

The applied experience of educators and educational research is far greater than the sum of scientific inquiries (Varma et al., 2008). Cognitive researchers can reference the current literature on learning and build upon what has already been studied, only from an alternate perspective. This may lead to the establishment of new research questions, methods, and paradigms based on educational research’s present demands. Knowing what questions are relevant to ask may be just as significant as knowing how to answer them.

*The Other Side of the Coin*

The benefits of a transdisciplinary research approach does not come without its constraints or concerns. One of the largest trepidations is the misuse and misinterpretation of scientific research applied to education (Catterall & Rauscher, 2007; Goswami, 2006; Varma et al., 2008). Several brain-based curricula have been developed in the last 20 years attempting to use what neuroscience has discovered about the brain (Jenson, 1995; McCarthy, 1987). The mishandling of results in music studies for example, has lead to media driven notions such as the, “Mozart Effect” and even found its way into an American presidential campaign when one candidate made the blanket
statement that students who participate in music perform better in other subjects such as math (Catterall & Rauscher, 2007; Geake & Cooper, 2003; Obama, 2008; Rauscher, 1993).

The term, *neuromyths*, first introduced by the OECD, has been used to describe any hasty conclusion or misapplication of neuroscientific results (OECD, 2007). For example curricula, assessment methods, and brain “training” have been developed based upon the right-brain left-brain mentality (McCarthy, 1987). These have overwhelmed much of the literature and media today due to public interest in empirical work with an inability to appropriately apply and interpret these findings (Levine, 2002; OECD, 2007; Pinker 2002). This has caused hesitation in both fields of any future collaboration for fear of additional misuse of results (Goswami, 2006). Before any stronghold relationship can be built between science and education, these myths must first be dispelled (Geake & Cooper, 2003).

**Conclusion**

Education can vary in methodologies, pedagogical presentations, and assessment measures. The philosophies behind scientific perspectives and educational research are similarly just as varied. The former can approach learning as a chemical process between the circuitry of the brain and its ability to translate and retrieve stored information while the latter interprets learning as an observable modification of an individual’s understanding (Chiesa, 2009). These two interpretations define how each discipline approaches and interprets empirical questions and results. The body of work in both camps is substantial, yet when considered together, a stronger concept of learning and cognition may result (Geake & Cooper, 2003).
Effective teaching can be interpreted as effective changes to the brain, and continued scientific inquiry has and will continue to hopefully confirm and reaffirm what educators have been practicing. This portion of the review of the literature illustrated how continuing and initiating a bidirectional communication between science and education may be challenging at times, but a beneficial and seemingly obvious progression in research. This effort will create stronger educators, researchers, learners, and will hopefully reinterpret the use and definitions of basic and applied research.
Part II: The Science Behind Music and Language

Humans are unparalleled in their ability to make sense out of sound…This provides a special opportunity for cognitive science. Specifically, exploring both the similarities and the differences between music and language can deepen our understanding of the mechanisms that underlie our species’ uniquely powerful communicative abilities.

- Aniruddh D. Patel (1998, p. 3)

As reviewed in the Part I, much of educational research regarding behavioral data has dealt with confirming and reaffirming data from the physical sciences. Part II presents a similar overview of the behavioral and scientific data, but narrows the focus to music and language. It begins with a separate discussion of music and language, then the shared and dissimilar facilities involved in the cognition of both. Also included in this section is a discussion of two disorders that have enabled researchers to understand music and language comprehension: aphasia and amusia. This comparison of music and language is continued in Part III, specifically as it applies to musicians and non-musicians, discussing the noted physical changes in the brain and the possibility of cognitive transfer.

Music Cognition

Growing Curiosity

Due to the intrigue in music learning, performance, and its psychological and physiological affects on the brain’s plasticity (Altenmüller & McPherson, 2006; Hodges, 2006; Schellenberg, 2006; Stewart & Williamson, 2008), cognitive psychologists and music education researchers have begun to look to each other’s disciplines to better understand music cognition. Campus units are flourishing in order to meet the demands of a new breed of interdisciplinary researchers. Examples of these units include: the
University of Montréal and McGill’s International Laboratory for Brain, Music and Sound Research (BRAMS); University of North Carolina’s Music and Research Institute (MRI); Harvard’s Institute for Music and Brain Science; and the Centre for Music and Science at the University of Cambridge. Similar professional organizations include: the Society for Music Perception and Cognition (SMPC); the Brain, Neurosciences, and Education special interest group from the American Educational Research Association; and the Society for Education, Music, and Psychology Research (SEMPRE). New journals, such as the *Journal of Cognitive Neuroscience, Music Perception, Neuromusic News*, are also attempting to meet the needs of all parties by providing publication outlets.

This growing demand of resources in music cognition has broadened the curiosity, and reinforced the need for additional research on music’s cognitive affects. Advances in therapeutic uses of music for cases, such as dyslexia, physical therapy, speech therapy, and a variety of mental illnesses, have also emerged (Altenmüller, Schneider, & Münte, 2008; Overy, 2000; Schlaug, Marchina, & Norton, 2008; Schneider, Schönle, Altenmüller, & Münte, 2007; Silverman, 2003). Moreover, music researchers are gradually recognizing the potential of integrating cognitive psychology and neuroscience into collaborative studies of cognition and music’s impact on learning, memory, visual-spatial skills, and verbal memory (Amen, 1998; Brandler & Rammsayer, 2008; Ho, Chan, Ho, & Cheung, 1998; Cheung, & Chan, 2003). With early and prolonged engagement in music, studies have demonstrated that significant physical changes in the brain may occur due to *plasticity*, the elasticity of the brain, and *myelination*, a strengthening of the myelin sheath around the structure of a neuron. Both of these changes affect the brain’s physical
mapping and neuronal synapses (i.e., connections), resulting in faster and more accurate transfer of information (Gazzaniga et al., 2002; Hodges, 2006). What was once attributed solely to musical experience and expertise can now partially be linked to the physiological modification of neural synapses, the enlargement of structures such as the area posterior to the auditory cortex within Wernicke’s area called the planum temporale, and the corpus callosum, the connective tissue between the right and left hemispheres (Schlaug, Jancke, Huang, Staiger, & Steinmetz, 1995).

Ecological Evolution: From Anthropology to Neurology

Philosophers, ethnomusicologists, archeologists, anthropologists, and linguists have historically documented associations between, and the universality of, music and language. Structurally, each can be defined by their phonology, syntax and semantics (Bernstein, 1976; Slaboda, 1985). Ethnomusicologist John Blacking wrote in his 1973 book, How Musical is Man, of the human specific physiological and cognitive processes required for the two, while archeologist Steven Mithen hypothesized the root of music and language as primordially splitting from the same source. Mithen wrote, “Music and language are known to exist in all extant human societies and all those that have been historically documented...archeologists are confident that both were present in all prehistoric societies of Homo sapiens” (2006, p. 12). Currently, scientists have expanded on this assertion, developing a niche in cognitive research comparing these two cognitive functions (Patel, Wong, Foxton, Lochy, & Peretz, 2008; Peretz et al., 2002).

Charles Darwin wrote in his The Descent of Man and Selection in Relation to Sex, “I conclude that musical notes and rhythm were first acquired by the male or female progenitors of mankind for the sake of charming the opposite sex” (1909, p. 585). More
specifically, archeologist Steven Mithen traced the development of music dating back to our pre-linguistic ancestors and, in *The Singing Neanderthals* (2006), describes how music shares the same roots as language. He suggested the use of music as a survival compulsion along the lines of food and mating that developed as the needs presented themselves. He began with the tribal needs of *Australopithecus* over 3 millions years ago to be expressive with grunts; the evolution of bipedalism with *Homo erectus* over 1 million years ago with the descent of the larynx and erection of the spine which allowed for stronger breath and muscle control leading to enhanced musical expression and mother/infant bonding (Hodges, 1989); the necessary replication of animal sounds for big game hunting; and the most multifaceted use, for cooperation and group bonding. This final development of individualized and identifiable musical tendencies is what has been attributed to distinguishing one culture from another, making music a defining element of a civilization (Langer, 1966). More empirically, it has been suggested that a specific language’s prosody may leave a mark on the rhythm and melodies of that culture’s music (Patel & Daniele, 2003).

A similar progression in musical ability preceding that of language occurs in infants. Plantinga and Trainor (2005) found that six month-olds are relative pitch processors. After being familiarized and preferring the same melody for seven days, they favored a novel melody on the eighth day. They were able to recognize this melody regardless of transposition or starting pitch. This innate ability parallels studies on infants’ abilities to encode and recognize particular phonetic units again regardless of pitch changes (Plantinga & Trainor, 2005). Physiologically, Saccuman et al. (2008)
imaged infants using fMRI and found a neural predisposition for music processing in as young as 3-day-olds.

Mothers from around the world instinctively understand the importance of maternal singing for infant arousal and bonding (Milligan, Atkinson, Trehub, Benoit, & Poulton, 2003). As an example of the transition from anthropological discussion into the realm of empirical research, the biological effect of infant-directed speech from mothers to their children has been studied. In their 2003 study, Shenfield, Trehub, and Nakata found infant cortisol levels were on average lower after twenty minutes of maternal speaking or singing as compared to baseline measurements. What was philosophized and speculative as to the effects of music, has now been validated and further understood with the aid of systematic, interdisciplinary research. Infants’ innate attraction to music from any source is exemplified by their prosodic inclinations as well (Bransford et al., 2000). After running twelve experiments, Jusczyk and his colleagues (1992) concluded that by the age of 9-months-old, infants possessed the ability to parse speech based on their prosodic properties. Data from this and the aforementioned study address the biological predisposition humans may possess to respond to a musical sample whether in the form of musical melodies or the contours of speech.

**Physiology Behind the Function**

The traditional theory of right-brained or left-brained dominance may not necessarily hold true for music and language. Although there may be a dominance of one hemisphere over another (e.g., spatial skills on the right and abstract reasoning on the left), human cognition is not as clearly divided and involves both hemispheres (Rauschecker, 2005). Elements of music such as rhythm, melody, and timbre, have
typically been processed in different parts of the brain (Fox, Parsons, & Hodges, 1998; Peretz, 1990; Zatorre & Belin, 2001). In a PET study of conductors and untrained musicians, Fox, Parsons, and Hodges (1998) mapped the brain’s processing of melody, rhythm, and harmony. They found the bilateral inferior lateral frontal cortex to be involved in all three scenarios, with harmony and rhythm being processed more in the left than the right hemisphere, while melody showed activity in both. Other areas, such as the premotor cortex, were also activated for all three stimuli. Melodic activity was also found in the bilateral inferior parietal region but stronger in the right hemisphere; bilateral superior temporal area where the auditory cortex and the planum temporale lie, also stronger on the right; and in foci in the bilateral subgyral medial frontal areas, possibly needed for attention processing. Other areas activated in musical engagement were white matter tracts in the right inferior frontal gyrus for melodic key-violation and memory, and again, the right auditory cortex for aspects of pitch processing, sequencing, and melodic discrimination (Hyde, Zatorre, Griffiths, Lerch, & Peretz, 2006). Although it was traditionally thought that music was processed solely in the right hemisphere, these results illustrate the bilateral tendencies of certain musical affects.

Despite this anatomical mapping of music cognition, there seems to be more than just the physical involvement in perceiving and producing music. Meyer’s 1956 *Emotion and Meaning in Music* describes the interconnectedness between performer and listener in the conveyance of the meaning of music. He suggests that it is beyond the physical, and that behavior and cultural experiences of individuals also contribute to musical cognition. More recently, neuromusical researchers Eckart Altenmüller and Wilfried Gruhn reiterate Meyer’s stance, which addresses musical experiences as more than an
interpretation of “acoustic structures in time but also as patterns, associations, emotions, expectations, and so on” (Altenmüller & Gruhn, 2002, p. 67). McPherson and Gabrielsson (2002) have also suggested a more gestalt perceptual interpretation of music.

Donald Hodges, from the University of North Carolina in Greensboro, has spent his career developing the field of neuromusical research, which addresses the biological nature of music cognition. In his 2000 article in *Music Educators Journal*, Hodges lists five premises which had been studied and derived from neuromusical research: (a) the human brain has the ability to respond to and participate in music; (b) the musical brain operates at birth and persists throughout life; (c) early and ongoing musical training affects the organization of the musical brain; (d) the musical brain consists of extensive neural systems involving widely distributed but locally specialized regions of the brain: cognitive, affective components, and motor components; and (e) the musical brain is highly resilient (Hodges, 2000). These statements cover what has been successfully studied and analyzed over the past twenty years; and from these, current inquiries are being scrutinized to compile a more sophisticated understanding of musical cognitive functions.

When learning about the brain, it is often easiest to look at deficits and disorders by utilizing dissociation studies. For example, Loui and Schlaug (2009) recently used participants with pitch discrimination difficulties to find a weak connectivity in the white matter bundle. This area of the brain is thought to be involved in the cognition of language, and its relation to musical function is yet unknown. Through examining subjects with deficits in one domain, such as music, it may be possible to illustrate a connectivity to another domain, such as language, or vice versa.
Absolute pitch. Absolute pitch, also known as perfect pitch, has recently peaked the interest of neurological and genetic researchers. It can be defined as a cognitive ability most likely dependent on a genetic predisposition and various experiences to identify or sing pitches without external references (Chin, 2003; Costa-Giomi, Gilmour, Siddell, & Lefebvre, 2001; Plantinga & Trainor, 2005). This ability has been found in less than 1 out of every 10,000 people (Bossomaier & Snyder, 2002; Plantinga & Trainor, 2005). The age in which the experience begins seems to be a large factor in developing this skill. Of the 2,707 music students from music conservatories and university and college music programs in the United States with absolute pitch surveyed in 1999, the mean age in which they began their musical activities was 5.4 years whereas those without absolute pitch was 7.9 years (Gregerson, Kowalsky, Kohn, & Marvin, 1999). This study suggests that early music exposure aided in the acquisition of absolute pitch. However, it has also been suggested that musical experience is not necessary for some to develop absolute pitch (Chin, 2003).

The age in which the musical experiences commence has been linked to specific stages in cognitive development. It has been noted that younger children are more likely to develop absolute pitch if introduced to music prior to a critical cognitive development transition: from what Piaget (1950) termed preoperational thought to concrete operations, or as others have called unidimensional to multidimensional thinking (Siegler, 1996). These categories both represent a developmental period of understanding only first-order relations such as the ability to name individual pitches, as opposed to second-order relations such as naming intervals that involves associating the relationship
between two pitches. This is a clear demonstration of the implications that musical experience and exposure can have on one’s cognition and overall musical ability.

*Tonal languages.* Gregerson, Kowalsky, Kohn, and Marvin (2000), in a follow-up to their 1999 study, reported that of 100 music students in the United States with absolute pitch abilities, 48% were of Asian descent while only 9% were Caucasian. This overwhelming amount of absolute pitch possessors of Asian descent is most likely related to those who speak a tonal language such as Mandarin or Vietnamese (Deutsch, 2002). It also suggests that this ability may occur as early as in the first year of life when other native language features develop. In these languages, the tone in which a word is spoken can change the meaning. For example, the Mandarin word, *ma*, when spoken on one tone means “mother” and when spoken on another, means “hemp” (Wong, 2008). The pitches serve as additional verb features, distinguishing words from each other. Since tonal languages rely on this exactness of pitch production, it stands to reason that this may impact the acquisition of absolute pitch in terms of musical ability.

*Physiology.* With improved neuroimaging, the physiology of those with and without absolute pitch has been under close scrutiny. It has been measured with magnetic resonance imaging that the planum temporale, an area in both temporal lobes in the auditory cortex, is larger in the left lobe in those with absolute pitch (Schlaug, Jancke, Huang, & Steinmetz, 1995b). This asymmetry may be due to a smaller planum temporale in the right hemisphere of these individuals (Keenan, Thangaraj, Halpern, & Schlaugh, 2001), although it is not yet known if this asymmetry is a result of early exposure or if it was present prior to any stimulation (O’Boyle & Gill, 1998).
Through behavioral measurements, Zatorre Perry, Beckett, Westbury, and Evans (1998) found additional differences in those with and without absolute pitch. First, although measuring similar patterns of increased cerebral blood flow (CBF) to the auditory cortex area in positron emission tomography when subjects listened to musical tones, absolute pitch possessors also had a greater activation of the left posterior dorsolateral frontal cortex. This area of the brain is suspected to be associated with learning conditional associations. When subjects were given interval-judgment tasks, CBF activity in the right inferior frontal cortex, an area linked with working memory, increased for those without absolute pitch. These results suggest that those with absolute pitch may not be using their working memory in such tasks. Through this data, magnetic resonance imaging, and electrophysiological data, Zatorre and colleagues (1998) hypothesize that, due to the asymmetry of the planum temporale in the left hemisphere and its potential relation to language processing, absolute pitch may then involve a network in the brain whose function is for verbal-tonal associations. Understanding individual use of short- and long-term memory can in return, illustrate an aspect to individual learning.

Bossemaier and Snyder (2004) have proposed that absolute pitch ability is within everyone, but that it is inhibited by our conscious awareness. This hypothesis is based on the work of Snyder and his colleagues (2004), who demonstrated that by applying transcranial magnetic stimulation for 15 minutes to the left frontotemporal lobe induced temporary savant-like trait including absolute pitch. By stimulating the brain with magnetic pulses, the researchers rewired the brain, at least temporarily.
Amusia

Amusia is the all-encompassing term for any disorder that inhibits the ability to recognize and produce musical tones or rhythms. Its root, a-musia or “lack of music”. It may be congenital as in tone deafness, or acquired later in life from brain trauma, disease, or endogenous listening with an estimated four percent of the population effected (Kalmus & Fry, 1980). It is defined as a loss of basic musical abilities including pitch-processing deficits and the inability to discriminate and/or recognize despite other cognitive health. Olsho, Schoon, Sakai, Turpin, and Sperduto (1982) studied the fine-grained discrimination abilities of infants and adults, revealing normal discrimination abilities averaging around 1/4 tone in ascending and descending pitch projections while examples of amusic sufferers have yielded discrimination results limited to a semitone, or 1/12 of an octave (Peretz et al., 2002).

Although these musical deficits may be comparable to language difficulties due to deficiencies in auditory temporal resolution, separate impediments do occur. It is suspected that composer Maurice Ravel suffered from amusia due to early degeneration of the frontotemporal lobe (Burnett, 1987). His composition, Bolero, exemplifies some limitations that could have resulted of his amusia. While finding it frustrating and nearly impossible to reproduce melodies or rhythms, Ravel’s sense of timbre remained intact. Bolero is an exploration of instrumental timbres where the melody and rhythm of the piece are a repetitive theme and ostinato. Although unable to expand on melodic and rhythmic themes, Ravel was able to continue his composing by delving into timbres instead.
In 1932, Ravel suffered from a head trauma, which perhaps resulted in further neurological deterioration and difficulties with composing. When hired to work on the music for the movie, *Adventures of Don Quixote*, he was unable to complete the work and the job was given to another composer (Burnett, 1987). In speaking with his doctor about the frustrating circumstances of amusia, Ravel said, “I’ve still got so much to say, so many ideas in my head” (Johnson, 2004, p. 159), yet he was unable to reproduce them in a composition. Due to his loss of melodic abilities, coupled with the retention of timbral and rhythmic parameters, doctors posthumously suggested that the injuries he sustained were in the posterior left cerebral hemisphere in the superior temporal gyrus and inferior parietal lobe. Ravel was able to hear the music in its totality in his brain, but was unable to separate it into its melodic components in a composition.

Sixty-four-year-old amateur musician, subject K.B., suffered a right-hemisphere stroke. While he retained a normal ability for most verbal skills, his pitch and rhythmic processing were severely impaired. Steinke, Cuddy, and Jakobson (2001) examined K.B.’s capacity to recognize and identify familiar melodies and songs learned prior to and post-stroke compared to twenty controls. In recognizing novel melodies, K.B. scored extremely low compared to the controls, obtaining a score of 0%. He scored slightly higher, 18%, for recognizing and identifying instrumental melodies, although it was reported that K.B. had attached comical lyrics to several of the instrumental pieces he was able to identify from his youth. The most striking data from this study was K.B.’s score in the recognition and identification of melodies with lyrics that nearly matched the controls. This demonstrated a connectedness between the actual lyrics of the songs to the
songs themselves, suggesting K.B. might have subconsciously employed a specific cognitive process for the task.

*Language Processing*

Language has been understood as a predominantly left hemisphere function from the discovery of Broca’s area (Broadmann area 44 and 45) in the left frontal lobe near the primary motor cortex by Paul Broca in 1861, and Wernicke’s area (Broadmann area 22) in the left temporal lobe near the primary auditory cortex by Karl Wernicke in 1874 (Gazzaniga et al., 2002). However, assessments of the brain post-trauma have demonstrated language capabilities and redistributions of function in other areas of the brain (Sacks, 2007; Taylor & Regard, 2003; Voets, et al., 2006). This reorganization has also included other areas of the brain necessary for language recall such as the temporal lobe for recalling animals, people, or tools, and the motor and premotor areas for speech production. (Gazzaniga et al., 2002).

*Prosody*

Apart from the physiological elements of language, a more impactful element is the resultant speech and how it is presented. The intonation, rhythm, and inflections we put into our speech aids in the communication of ideas and emotion behind our thoughts. Semantics seem to be so much reliant on prosody that meaning is often still conveyed when sentence stimuli use meaningless words, pseudowords, delexicalized sentences, hummed intonations, computer muffled tones, and pitches only (Pannekamp, Toepel, Alter, Hahne, & Friederici, 2005; Thompson, 2008). It is the intonational phrasing that provides the cues for syntactic translation.

Pell (2006) examined the cerebral organization of prosody through a double
dissociation study of right and left hemisphere damaged patients. His findings revealed that both hemispheres were involved in the understanding of prosody: the right hemisphere for the emotional interpretation of phrases, and the left hemisphere for more of the linguistic understanding. Functional magnetic resonance imaging has demonstrated this collaboration between hemispheres with healthy subjects (Mitchell & Ross, 2008).

The line between such contours and melodies is arguably a fine one. Charles Darwin wrote, “musical tones became firmly associated with some of the strongest passions an animal is capable of feeling, and are consequently used instinctively, or through association when strong emotions are expressed in speech” (1872, p. 737). Such a strong correlation between music and prosody exists, that many researchers have dedicated their work to understanding this connection (Hebert, Racette, Gagnon, & Peretz, 2003; Patel, Wong, Foxton, Lochy, & Peretz, 2008). Through both behavioral and functional data from the studies mentioned here, it is evident there is more to understanding a spoken language than merely being familiar with the vernacular.

**Aphasia**

Aphasia is a language disorder that, depending on the area of brain damage, may result in expressive or receptive deficits in producing or understanding language including speaking, reading, writing, and object identification (Adler, 2007; Gazzaniga et al., 2002; Schlaug, Marchina, & Norton, 2008). Individuals suffering from damage to Broca’s area found in the left frontal lobe, maintain the ability to understand language, yet have difficulty with speaking. On the contrary, those who suffer from damage to Wernicke’s area within the left temporal lobe are typically able to speak, but are unable to understand what is spoken to them (Byrnes & Fox, 1998). The extent of disability is
dependent on the range of injury and age of trauma, with an average of 20% of new stroke victims in the United States incurring some form of aphasia (Schwartz & Begley, 2002). Due to the variance of disability and the relatively unknown neural processing involved in post-stroke language recovery, no unanimous treatment of aphasia has been identified. Partial or complete recovery may be spontaneous although most remediation includes some form of speech-language therapy (Schlaug, Marchina, & Norton, 2008).

The research literature in disassociation studies of language and music has largely been with expressive or nonfluent aphasics, characterized by those who understand language but have difficulty producing or acquiring new language (Schlaug, Marchina, & Norton, 2008). In Sacks’ *Musicophilia* (2007), patient Samuel S., despite two years of post-stroke, speech therapy, still suffered from extreme expressive aphasia. It was not until the hospital’s music therapist began singing and accompanying Samuel S. on the accordion that he began reacquiring basic language skills. Recent case studies, such as Samuel S., have enabled researchers to offer several theories behind language acquisition and its connection music. Schön et al. (2008) has suggested three such hypotheses: a) the emotional elements of a song may enhance the arousal and attention levels of the learner; b) the change in pitch contours that so often accompany syllable changes in music may aid in phonological discrimination; and c) learning and cognition may actually be improved from the consistent priming of musical and linguistic information. Isabelle Peretz and colleagues (2004) offer an additional proposal for lyrical memory attributing it to an aspect of temporal sequencing called, *frontal anchoring*. Their theory is based on a study with healthy individuals who, after testing memory recall of familiar and novel
songs found a priming effect based on the speed of recognition and recall for the latter half of lyrics. Results were not as strong for backwards priming in memory.

*Melodic Intonation Therapy*

In 1973, neurologists Sparks, Helm, and Albert developed an alternative method of speech therapy called Melodic Intonation Therapy (MIT) at the Veterans Administration Hospital in New Orleans. It was based on the observations of several patients with nonfluent aphasia being able to sing lyrics as opposed to speaking the same words (Sparks, 1975). Since then, this therapy has been shown to be successful for use with many adults suffering from Broca’s aphasia (Schlaug, Marchina, & Norton, 2008). The patterns used in the therapy maintain the prosodic elements of normal speech including inflections and rhythm. The prosodic contours are then transposed into melodic phrases (Sparks, 1975). Figure 2.2 depicts the development of stimuli with the corresponding melodic pattern.

*Figure 2.2 Illustration of a Melodic Intonation Therapy sample contour. Note. H = high and L = low in reference to pitch height and direction.*

Using MIT, many aphasics have regained aspects of language and communication that with regular speech therapy seemed unattainable (Racette, Bard, & Peretz, 2006). Again, due to scant knowledge about neuronal recovery post-trauma, several theories on the effectiveness of MIT have evolved. A theory relying on the engagement of the right hemisphere during MIT suggests a circuitous route back to the left hemisphere and the
language networks (Marshall & Holtzapple, 1976). This theory is based on the reconditioning of cortical regions in the right hemisphere in order to reengage them in their primary function in the left hemisphere. This may be accomplished by re-experiencing language in a new format, through music (Sacks, 2007).

A second theory on the brain’s adaptive ability suggests it is the plastic potential of the brain that contributes to reacquiring language skills in parts of the brain other than the left hemisphere as briefly mentioned above. In 2004, Van Lancher-Sidtis worked with subject B.L. who suffered from cyanosis and hemiparesis in his first months of life, had right-sided seizures, and underwent a left hemispherectomy at age 5. A battery of twelve protocols examining the hemispheric reassignment revealed that nearly 50 years after the procedure, and despite deficits in the production of phonemically challenging words and challenges in the comprehension of linguistic contrasts in prosody and syntax, his pronunciation, grammar, semantics, and usage appeared grossly normal (Van Lancker-Sidtis, 2004). B.L went on to graduate from college, hold regular employment, and is measured as having above normal intelligence. The surgical procedure occurred at an early enough age in his young developing brain, allowing for the redistribution of brain functions as is so often the case for children who undergo hemispherectomies prior to age six (Liégeois, Cross, Polkey, Harkness, & Vargha-Khadem, 2008; Schwartz & Begley, 2002).

In a recent multiple-case study examining individual hemispheres and language functions of hemispherectomy patients, Liégeois, Connelly, Baldeweg, and Vargha-Khadem (2008) hypothesized an additional theory. Bilateral activation in the brain of the control group under verbal response stimuli during fMRI suggested a preexisting network
for language in both hemispheres: Broadmann areas 44 and 45, Broca’s area, and the right hemisphere homolog. These results suggest the availability and neural capabilities for language in either hemisphere, although with varying functional outcomes.

Regardless if the reacquisition of language abilities through MIT is from re-stimulating the left hemisphere by means of an alternate route, the plasticity of the brain, or the preexisting neuronal potential of the hemispheres, it can now be attested that language may not solely be allocated to the left hemisphere. Without prescribing complete localized networks and lateral function, it is presently even more vital to expand on current research and attempt to address the intermingling between language and other cognitive realms such as music.
Part III: Comparing Music and Language

The central role of music and language in human existence and the fact that both involve complex and meaningful sound sequences naturally invite comparison between the two domains.

- Aniruddh D. Patel (2008, p. 3)

Shared Systems

A follow-up study with the subject, K.B. mentioned in Part II under Amusia, was conducted teaching new melodies including instrumental, those with lyrics, and those sung on the syllable, “la” (Steinke, Cuddy, & Jakobson, 2001). Similar to the familiar melodies, K.B. obtained a score of 0% in recognition and identifying the instrumental melody. Steinke et al.’s study suggests a possible difference between the storage and/or retrieval of melodies learned with lyrics as opposed to instrumental only. The researchers propose that two separate systems are engaged, however they are significantly connected. It has also been suggested that when both lexica are activated during song learning, links between these two networks are created (Peretz, Radeau, & Arguin, 2004; Steinke, et al., 2001).

When first comparing the two systems of music and language, there are several noted similarities. First, both are universal acoustic forms of communication to humans stylistically, geographically, and culturally with expectant sequences of notes and patterns (Tramo, 2001). They are also rule-bound systems with three modes of expression: vocal, gestural, and written. There are an unlimited number of sequences allowing for meaningful exchanges with experienced users, receptive skills precede productive skills, greater acquisition creates increased competence, and there is a
hierarchical structuring of phonology, syntax, and semantics (Bernstein, 1976; Mithen, 2006; Schön, Magne, & Besson, 2004; Sloboda, 1985;).

More specifically, both fields have a general shape or phrasing combining smaller elements into larger units. In speech, this is prosody, and the innumerable contours shaped by trajectories of fundamental frequencies. In music, the phrases are made from pitches grouped together to create intervals and melodies (Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004). Rhythm also plays an important role in both language and melody. Syntactic analysis, or parsing, illustrates the boundaries between spoken phrases and preboundary lengthening at the end of a phrase. Meter represents the musical incorporation of rhythm as the temporal structure of musical phrases (Patel, Peretz, Tramo, & Labreque, 1998).

The biological characteristics are not as easily listed as the structural components. The planum temporale, a region in the auditory cortex has been noted to take part in aspects of both language and music (Tramo, 2001). As mentioned throughout this chapter, other areas of the brain’s suspected involvement in both tasks have been illustrated most often with subjects who have deficits in one cognitive area or another. In a comparison of two subjects with similar cortical damage, Patel, Peretz, Tramo, and Labreque (1998) found that both prosodic and musical abilities were preserved in one subject, and impaired in another. This also suggests some sort of shared neurological system based on the similarities of their behavioral results. Based on the location of the subjects’ injuries, the researchers propose that the left primary auditory cortex and the right prefrontal cortex may be involved in discrimination tasks necessary for both prosody and music, more specifically pitch and temporal patterns. This hypothesis is
consistent with the work of Zatorre and his colleagues (1994). Using PET for metabolic neuroimaging with healthy subjects, the right frontal lobe showed the greatest activity during pitch discrimination tasks.

Using both behavioral and imaging results, Gaab et al. (2005) discovered a change in the performance and anatomy of rapid spectrotemporal processing in musicians and non-musicians. This area is involved in language processing. The authors suggest that it is with musical training that this area is expanded over to traditional language areas such as Broca’s region. While this study addresses a connection between music and language after musical exposure, it still illustrates how when this stimulus is present, it may recruit and/or extend to areas of the brain used for language.

Additional behavioral and electrophysiological measurements have enabled researchers to isolate electrical signals down to the millisecond that are similar in the processing of both music and language. When final notes or final words’ fundamental frequencies were manipulated, both musician and non-musicians showed similar positive amplitude variations (Schön, Magne, & Besson, 2004). Moreover, results of this study demonstrated that the larger the manipulation was in the stimuli for both music and language, the larger the amplitude of centro-parietally distributed components.

Different Networks

While the studies above present a strong case for a language and music connection, the medical history of composer Vissarion Ykovlevich Shebalin illustrates that although his speech parameters were impaired due to expressive aphasia from two left temporal strokes resulting in a left temporal-parietal lesion, he maintained his expressive and receptive capabilities in music and completed his fifth symphony nearly
four years after the diagnosis. In a conversation with one of his physicians he said, “The words…do I really hear them? But I am sure…not so clear…I can’t grasp them” (Blonstein, 2009, p. 11).

In several studies, Isabelle Peretz has demonstrated similar scenarios in which subjects reported an impairment in melodic but not prosodic abilities (Ayotte, Peretz, & Hyde, 2002; Peretz et al., 2002). Musicians have also shown dominance in their left hemisphere under melodic recognition tasks whereas non-musicians demonstrated a dominance in their right. It should also be noted that in music, a finer discrimination of pitches is used such as 1/12 or 1/6 of an octave whereas in speech, contours can use variations of intervals often larger than a half an octave (Patel et al., 2002). In this same study, Patel et al. (2002) examined the abilities of an amusic woman whose deficits seemed isolated to music. She scored significantly lower than the controls on musical tasks and scored comparably to the controls on non-musical items such as nonverbal environmental sounds.

Future behavioral and functional studies must be completed in order to draw any more conclusions on the relationship between music and language. Either in using dissociation studies, or working with healthy subjects, researchers have only scratched the surface in this field. Truly understanding the complete specifics of both processes is still unknown.

Musicians and Non-Musicians

The effects of experience in, and exposure to music are an aspect of cognitive development and brain stimulation that is currently recognized as significant (BRAMS, 2009; Hodges, 2008; Patel, 2008). Behavioral and physiological testing has demonstrated
that musicians have demonstrated a transfer of abilities to other areas of cognition such as general intelligence, verbal memory, spatial ability, and selective attention (Catterall & Rauscher, 2006). Even learning to read music has demonstrated activation in a variety of regions in the brain including the motor areas (Stewart et al., 2003). It may be argued, however that the exhibition of these advanced cognitive abilities and musical experience may merely be a demonstration of overall aptitude. Kenny and Gellrich (2002) purport that deliberate practice in music will lead to a strong internal knowledge base and eventual expertise. This form of educational practice takes discipline and focus amongst a variety of potential motivators (O’Neill & McPherson, 2002). Thus, it may be questioned whether or not these students, who are driven and willing to dedicate their time and mental capacity to practice, would apply the same discipline to other subject areas resulting in a demonstration of greater abilities despite musical background. Moreover, it may be that these students maintain a higher general intelligence overall.

Addressing cognitive transfer through physiological measurements may strengthen the case for music’s impact. Several studies have found musicians to be more accurate in detecting pitch violations in spoken and melodic stimuli than non-musicians, with numerous results reflecting a stronger correlation in the age musical study commenced (Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004; Pantev & Hoke, 1989). Event related potential measurements from EEGs have also demonstrated a faster response time with larger amplitude for musicians and experienced listeners as compared to non-musicians and naïve listeners in other violation studies (Pantev & Hoke, 1998; Petsche, Linder, Rappelsberger, & Gruber, 1988; Shahin, Bosnyak, Trainor, & Roberts, 2003). However, Schön, Magne, and Besson (2004) demonstrated larger amplitudes of
centro-parietally distribution in late positive components for both musicians and non-musicians when a stronger incongruity was tested in both language and music. Due to the similar results and the similar scalp distribution, this study suggests shared neural resources across both domains for cognitive processing between such variables despite musical experience. While these and other similar studies offer what can be varying electrical data based on an individual’s musical background, there has yet to be direct implications for how these results may relate to one’s general cognition and production of music and language based on this experience.

**Physiology**

Again, due to recent improvements in the quality of neuroimaging in recent decades, researchers are now able to more accurately map the structures of the brain. In 1995, Gottfried Schlaug and his colleagues published two reports on the structural differences between musicians and non-musicians. This data fueled additional examinations into the effects of music on the brain. They found the corpus callosum and the planum temporale to be larger in musicians. The cerebellums of musicians were also reported as being 5% larger than those of non-musicians (Schlaug, Lee, Thangaraj, Edelman, & Warach, 1998). Other areas showing increased representations were the asymmetry of the motor and somatosensory cortex in violinists (Amunts et al., 1997; Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Schwenkreis et al., 2007) and the left planum temporales for those with absolute pitch as formerly mentioned.

**Overall Cognition**

Current studies have demonstrated music’s impact on learning: improved coordination and lowered physiological states were found after ten adolescent boys with
emotional and/or behavioral disorders listened in ten consecutive science lessons to excerpts of Mozart’s orchestral music (Savan, 1999); in current research on dyslexia, theories have suggested the abnormal neurological timing of the disorder may be treated with rhythmic activities found in music such as clapping and singing (Overy, 2000); and results of improved attention and diminished impulsivity for 19 children ages 7-17 have been observed through brainwave biofeedback after listening to Classical music three times a week (Amen, 1998). These studies relied upon the strengths of both music education researchers and cognitive psychologists, allowing them to maintain musically relevant questions in the pursuit of empirical results.

It has been mentioned throughout this review that the brain is malleable, and under certain circumstances will redistribute function as needed. This may be resultant of trauma, degeneration with age, or due to repetition of behavior such as musical training. The following is a brief review of how the latter connects to overall cognition in terms of verbal memory, visual-spatial skills, and logic.

**Verbal memory.** An increase in verbal memory abilities for adults has been revealed as reliably higher for musicians than non-musicians (Brandler & Rammsayer, 2003). This was also the case for children with musical training after a 10-minute and 30-minute retention test ($p < .001$) (Ho, Cheung, & Chan, 2003). The age in which subjects began their musical experience, and whether or not they have continued also affected their memory, with those who had continued their musical involvement being most significant.

**Visual-spatial skills.** Rauscher, Shaw, and Ky (1993) demonstrated an increase in temporary visual-spatial skills in a study of 36 undergraduates. Subjects were asked to
listen to three different stimuli: Mozart’s *Sonata for Two Pianos*, a relaxation tape, and silence. Immediately following the listening, they were tested using the Stanford-Binet intelligence scale. An ANOVA of the listening stimuli revealed that subjects who listened to Mozart performed better than the relaxation tape or silence ($p = 0.002$). In a follow-up study, 78 preschool students participated in a longitudinal study of music training and visual-spatial skills. Thirty-four were provided with private piano keyboard lessons and group singing sessions while the remaining students were given either singing sessions, computer lessons, or no lessons at all. The students in the keyboard lessons and group singing revealed the largest increase in their spatial-temporal abilities. A One-Way ANOVA on the pre- and post-test scores for all training groups produced extremely significant results ($p < 0.0001$) (Raushcer, et al., 1997).

*Logic.* It has been suggested that intuition plays a larger part in musical ability than logical thinking (Brandler & Rammsayer, 2003). This was illustrated using the Cattell’s Culture Free Intelligence Test. T-test revealed non-musicians performed better than musicians on series, classification, matrices, and topology exercises, each exhibiting significance ($p < 0.001$).

*Conclusion*

This literature review has addressed the current demands of educational research to broaden their methodological approach by means of collaborations with other disciplines. It has also attended to the significance of any empirical results that may ensue from a combined research effort. Moreover, examining cross-disciplinary domains, such as comparing the melodies of music and the prosody of speech, will provide insight into understanding aspects of learning and human cognition.
Mark Tramo, director of The Institute for Music and Brain Research, said, “understanding music as a universal form of human expression will provide insights into the neurobiology of perception, performance, emotion, learning, development, and plasticity—with a few hints about aesthetics, talent, and creativity thrown in” (Tramo, 2001, p. 56). Music education must find its place amongst cognitive psychologists and researchers to provide new direction, new input, and apply these new results to teaching and learning theories in order to reap the benefits of such empirical work.
Chapter 3: METHODOLOGY

Introduction

The present study attempts to build a bridge between cognitive psychology, music, and educational research. An additional facet to this study is the use of authentic musical stimuli, which perhaps expands this bridge even wider. This chapter describes how the present study has considered the data from the literature review in Chapter Two, and incorporated them into the design of this study.

Contextual Significance of the Study

Current studies in neuromusical research have been restricted by three factors: the researchers, the subjects, and the setting (Varma et al., 2008). First, most studies have been completed by neuroscientists and cognitive psychologists without the collaboration and insight of an educator, despite the studies’ focus on learning and cognition (Byrnes & Fox, 1998). The scenario is even more complicated when studies involve musical stimuli but do not involve a music education researcher involved. This has restricted the expanse of stimuli and musical resources limiting the potential application of any results. Second, most results specifically comparing language to music have been with subjects who have cognitive impairments either from trauma or illness (Hyde, Zatorre, Griffiths, Lerch, & Peretz, 2006; Loui & Schlaug, 2009). While this has allowed researchers to begin understanding and possibly identifying shared and/or localized cognitive networks, studies of this type have limited the application of any results, especially to education and learning.

The present study responds to the limitations of previous research by first, combining the experience of both music educators and cognitive psychologists. As Mark
Tramo, director of The Institute for Brain and Music Science at Harvard University encourages, “If we wish to explore the neurobiological foundations of music, we must design experiments that cross the traditional divide between science and the arts” (Tramo, 2001, p. 54). The design of this study enabled the researchers to negotiate stimuli that would hopefully yield relevant results to each field.

Using musicians and non-musicians with normal cognitive abilities, the current study addresses the second limitation of previous research. The plasticity and myelination of post-injury can redistribute functional areas and specific duties of the brain making appropriate assumptions of normal human cognition difficult. Using healthy subjects offers opportunities to gather and examine data a healthy brain as opposed to deductive researching through the atypical as most studies have presented.

Finally, the tasks in this study may not have an authentic context for which to be presented. However, attempts were made to recreate stimuli that would not be too abstract or out of the norm from what the subjects might hear on a daily basis. The circumstances of the testing environment were also made as relaxing as possible for the participants by: (a) offering breaks throughout and in between tasks, (b) providing clear instructions and practice trials to diffuse any confusion, (c) and running the two portions of the tests in two separate rooms within the lab for privacy. While a genuine context for tasks such as those in this study may not exist, these considerations provided a testing environment that created as relaxing a setting and experience as possible in the hopes of generating as natural results as possible.
Interdisciplinary Inception and Design

This study involved a collaborative interdisciplinary design between two cognitive psychologists and myself, a music educator. Together, we developed pertinent research questions to both our fields that attempt to advance the understanding of any music and language connection meeting the needs of both our professions for interdisciplinary research. In collaboration with Duane Watson and Scott Jackson in the Communication and Language Lab in the psychology department at the University of Illinois, I developed four tasks to measure the production and perception of spoken and musical stimuli to evaluate the relationship between prosody and melody between musicians and non-musicians.

Subjects participated in two forms of tasks: production and perception. For production tasks, subjects were asked to repeat prerecorded stimuli to the best of their ability. These stimuli were developed to assess an individual’s ability to reproduce samples representing three depictions of frequency or pitch. In the perception task, subjects responded to musical pairs answering questions about their likeness. The aim of this task was to determine a subject’s musical aptitude by eliminating the performance element and relying on perceptual abilities. The overall research design is illustrated in Figure 3.1. Specifics about each structural aspect to the design are explained in detail under Development of Tasks and Testing Materials and Data Collection Procedures.
Figure 3.1 Research design intending to compare subjects’ production and perception tasks on musical and speech tasks.

Note. AMMA = Advanced Measures of Music Audiation (Gordon, 1990).

Development of Tasks

*Development of Production Stimuli*

In the production portion of the study, participants were asked to repeat three sets of stimuli: speech utterances, musicalized speech, and melodies with the latter two being based upon the frequencies of the speech utterances. A summary of this development is illustrated in Figure 3.2. The production portion of the study began with eight simple sentences to assess the subject’s ability to reproduce the prosody, or contour and intervals of speech. These sentences were developed with particular articulators in mind for easy frequency translation and interpretation on the phonetic software program, Praat (Boersma & Weenink, 2009). For ease of phonetic analysis, unvoiced consonants were
avoided. The same person recorded each sentence so that the tempo, range, and pronunciation remained relatively constant. The eight sentences are:

- Alan married Annie.
- Marianna made the marmalade.
- Dan drives every morning.
- My dog mangled the mailman.
- Ernie really loves melon.
- Neville argues loudly.
- Your mother’s bringing lemon bars.
- Wooden logs burn easily.

**Figure 3.2** Progression and development of stimuli.

In order to evaluate the subjects’ ability to produce a variety of contours, each sentence was recorded using eight different prosodic models: bored, subject focused, verb focused, inflections of ascending-ascending-ascending, inflections of ascending-descending-ascending, declarative, incredulous, and singsong. This resulted in the 64
speech utterances. Using Praat, it was possible to then isolate the fundamental frequency in the target pitch of each syllable and form 64 tone phrases that were termed *musicalized speech* (see Figure 3.3).

![Text grid and soundwaves for the sentence “Alan married Annie” from Praat.](image)

In order to create stimuli that sounded more like recognizable pitches and less like computer simulations, harmonics were added to each. This formula was used in Praat to determine sound pressure at every sample, and to add a specified fundamental to each:

\[
\frac{1}{2} \sin(2\pi \cdot \text{pitch value} \cdot x).
\]

*Sine* was used since it initializes from zero, *pi* is a constant, *pitch value* is the value we extracted from each of the speech measurements providing the frequency of the wave, *x* is the time point of the sample, and \( \frac{1}{2} \) specifies the peak air pressure amplitude in Pascals. In order to add harmonics, we added more sine tones on top at integer multiples. The formulas for the added harmonics are:

\[
\frac{1}{8} \sin(2\pi \cdot \text{pitch value} \cdot x \cdot 2)
\]

\[
\frac{1}{32} \sin(2\pi \cdot \text{pitch value} \cdot x \cdot 3)
\]
The changes are the multiplication by two or three in the inside of the formula, which
doubles or triples, respectively, the frequency of the sine tone. The change to 1/8 or 1/32
indicates that these harmonics have smaller amplitudes than the fundamental. Dr. Jackson
chose these ratios after qualitative analysis. Because they were integer multiples of the
fundamental, it provided samples that sounded more like natural harmonics.

To develop the melodic stimuli, a representative sentence from each contour was
selected for a total of eight models. The syllable’s frequencies from each model were
then translated into their corresponding musical pitches using the chart in Figure 3.4.

![Figure 3.4 Pitch to frequency mapping including scalar degrees (obtained from the
Peabody Conservatory of Music, 2009).](image)

Using the notation software, Sibelius, seven melodic variations for each contour
were then composed to create 64 melodies. A tonality closest to the original speech
utterance was selected to generate a more melodious sample. In order to maintain this
tonality, pitches may have been altered up to a half step. Both major and minor keys were
used. Figure 3.5 illustrates the melodic translation of the original declarative sentence,
“Alan married Annie”.

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The variations were composed by taking the original contour, and modifying each successive pitch but keeping the remaining pitches unaltered. For example, for a third variation of a melody, the second pitch in the series was changed so that difficulties with specific intervallic relationships could perhaps be determined in the subsequent analysis. The sound files were exported and played on the piano instrumentation setting. Because the commonly used syllable, “la,” presents a change in intensity upon release due to airflow during vocal production and would therefore complicate the analysis in Praat, subjects were asked to repeat these samples and the musicalized speech on the syllable, “na.” All musicalized speech and melodies preserved the same tempo and rhythm as the original speech utterances in order to isolate the presentation of the frequencies and pitches as the main variables.

Perception Task

For perceptual measurements, subjects completed Gordon’s (1990) Advanced Measures of Music Audiation (AMMA), a musical aptitude test developed for college students. This multiple-choice evaluation plays 30 musical pairs and asks subjects to identify tonal and rhythmic changes in melodies. This test was chosen because of the reliability it has demonstrated in the testing of tonal and rhythmic aptitude as is explained under, Validity of Testing Elements. The AMMA was standardized in 1989 and provides percentile rank norms for music majors and non-music majors in tone, rhythm, and a
combination of the two. Raw scores and percentile ranks for college music majors or non-music majors are reported.

Post-Test Items

Survey. After finishing both the production and perception tasks, participants were given a post-test survey to complete. These were created to obtain individual background information that might be pertinent to the study such as their major, musical background, languages spoken, and handedness. Post-test Survey A was developed for music majors containing specific detail about musical training (Appendix A) and Post-test Survey B was designed specifically for non-music majors (Appendix B).

Edinburgh Handedness Inventory. As part of the survey, subjects were asked to complete Oldfield’s (1971) Edinburgh Handedness Inventory (Appendix C). This inventory is used to determine an individual’s dominant hand. In answering questions about the preference of one’s left or right hand in the practice of daily activities, handedness can be deduced. To score participant responses, the total of “Left” responses are subtracted from the total of “Right” responses, then divided by a cumulative score of “Left” and “Right” responses. This total is then multiplied by 100. The handedness interpretation is based on the following scoring:

• below -40 = left-handed
• between -40 and +40 = ambidextrous
• above +40 = right-handed

Debriefing form. As a collaborative study with the psychology department, it is their practice to offer a debriefing form to all subjects at the completion of a study (see Appendix D). This form includes a brief summary of the purpose of the study along with
several additional references in the hopes of providing an opportunity for subjects to learn from the experience of participating.

Validity of Testing Elements

Stimuli

The methods for creating the three sets of stimuli have been used in analogous forms in other studies. For example, Patel, Peretz, Tramo, and Labreque (1998) used a similar method to generate the musical stimuli as in the present study. First, the fundamental frequency of each syllable was obtained, the timing was matched to the original sentence waveforms, and finally, two integer harmonics were added. Several of these steps, obtaining the fundamental frequency, maintaining the sentence waveforms for timing, and adding the harmonics are identical to the procedures of this study.

Advanced Measures of Music Audiation

The AMMA was tested in a one-year longitudinal examination for validity of testing measures (Gordon, 1990). It was administered to all members of the Esther Boyer College of Music of Temple University’s orchestra, concert choir, and band including undergraduates and graduates at the beginning of the school year. These results were then correlated to three judges’ scores of the same students playing an etude at the end of the school year. The results illustrated a strong validity for using this examination to assess musical aptitude for college music majors and non-music majors.

Praat

The phonetic software, Praat, has been used in numerous language studies and more recently has made its way into analysis with musical data. In Dalla Bella, Giguere, and Peretz’s (2006) work with sung examples, Praat was largely used in the analysis.
This included determining pitch height, pitch stability, number of pitch interval errors, number of contour errors, and size of interval deviation.

**Subjects**

Studies have illustrated that occasional singers were successful at remembering starting pitches of familiar, popular songs, but had overall poor pitch matching abilities (Dalla Bella, Giguere, & Peretz, 2006). They also found that when asked to reproduce individual pitches, non-musicians deviated by 1.3 semitones on average while musicians only deviated by 0.5 semitones. Furthermore, it was reported that non-musicians seemed to have less control over pitches relative to time in comparison to musicians resulting in a larger number of incorrect intervals for their tasks. The demonstrated difference in ability between musician and non-musicians is encouraging for the selected participants in the present study of music majors and non-music majors.

**Surveys**

A panel of practiced music educators was asked to review both post-test surveys. Every member of this panel had over 5 years of teaching in the classroom and/or privately, and possessed at least 1 year of research experience. From suggestions made by this panel, detailed questions were added to the music major survey addressing instruments played, and inquiries regarding informal ensemble participation were added to the non-music major surveys.

**Participants**

Participants were recruited through two methods. First, an email was sent to the theater department and to university orchestra members. Volunteers from the theater department and the School of Music were reimbursed for their time using funds allocated
to Duane Watson and the Communication and Language Lab. The second recruitment method was through the psychology department’s subject pool website that allows students to participate in studies for course credit. The demographic characteristics and pertinent variables for all participants are listed in Table 3.1.

Table 3.1
*Demographic Characteristics for Participants (N = 29)*

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<th>Characteristics</th>
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<tr>
<td>Male</td>
<td>11</td>
<td>38</td>
</tr>
<tr>
<td>Female</td>
<td>18</td>
<td>62</td>
</tr>
<tr>
<td>College major</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Music</td>
<td>9</td>
<td>31</td>
</tr>
<tr>
<td>Theater</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>Other</td>
<td>15</td>
<td>52</td>
</tr>
<tr>
<td>Any Musical experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>22</td>
<td>76</td>
</tr>
<tr>
<td>No</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>Formal training (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>15</td>
<td>52</td>
</tr>
<tr>
<td>1-5</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>6-10</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>11-15</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>16-20</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Age began formal training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>15</td>
<td>52</td>
</tr>
<tr>
<td>3-6</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>7-10</td>
<td>9</td>
<td>31</td>
</tr>
<tr>
<td>11-14</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>15-18</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Age began informal exposure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NA</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>3-6</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>7-10</td>
<td>13</td>
<td>45</td>
</tr>
<tr>
<td>11-14</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>15-18</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Handedness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Right</td>
<td>25</td>
<td>86</td>
</tr>
<tr>
<td>Tonal language speaker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>No</td>
<td>27</td>
<td>93</td>
</tr>
</tbody>
</table>
For this study’s purpose, musical experience included formal and informal training where formal training was defined as one-on-one lessons with a private instructor while informal training was considered any experience playing an instrument most likely in a larger ensemble setting such as a high school band. The Edinburgh Handedness Inventory determined subject handedness.

Procedure

Sessions were recorded in the Communication and Language Lab. They were recorded in two private rooms: one where the computer with the AMMA CD-ROM was uploaded for the perceptual tasks, and the other with the program MatLab that would run the production tasks. MatLab is an interactive software program that allows researchers to write and run countless scripts (The MathWorks, 2009). A script for running the production tasks and prompting subjects was written for this particular study. Target stimuli were presented followed by a pause for the subject to respond. Participants would then click the mouse to prompt the program to continue. Prior to this preliminary study, the script was piloted to ensure success in playing and recording the stimuli.

Participants were given a random subject number to ensure anonymity. Prior to beginning the production task, instructions were read to them aloud by the researcher. The instructions for each task as read by the researcher can be found under Appendix E. They explain that the quality of a subject’s voice was not the main focus of the study, and briefly introduced what prosody is. The instructions did not go into the specifics of the test and participants were not told the purpose of the study until completion of all tasks as this may have biased their responses.
Each computer was in its own room to ensure subject anonymity and to limit noise interference. The walls of the lab testing room contain sound attenuating material. A participant singing or speaking at a normal volume will most likely not be heard outside of the testing room. If it seemed a particular participant was singing or speaking at a loud enough volume for others to hear, no other participants were run at the same time ensuring there would be limited noise in the recording and that only lab personnel would be present.

After the initial instructions were read, subjects were prompted to proceed with 4 practice trials that were played back for them. This was to help familiarize the participant with the task expectations and to confirm an appropriate recording and playback volume. When both these criterion were met, subjects began the testing. The first tasks were the speech stimuli, followed by musicalized speech, then the melodies. Additional instructions were read to them prior to each set of stimuli (Appendix E).

After completing the production elements on MatLab, participants were escorted to the other private room to complete the AMMA. Again, the subject number assigned to them in the production tasks was the same number used for the AMMA. The researcher entered this number and the category of either “music major” or “non-music major” into the program before beginning. When the subject was ready to begin, they clicked the start button and the CD-ROM advanced automatically; first with aural and written instructions, followed by practice trials, then finally the actual examination.

Following completion of both production and perception tasks, subjects were asked to complete their respective post-test survey and the Edinburgh Handedness Inventory. At the end of the session, they were given the debriefing form and an
opportunity to ask the researcher questions regarding the study. The entire research session took no more than 110 minutes per participant.

Procedural Concerns

With any study involving human subjects, there is often the risk of priming and fatigue. To control for the risk of potential prosodic priming from the speech utterances to the musicalized speech samples, all stimuli were presented in a random order arranged as a function of a database. To address the concerns of participant fatigue, optional breaks were provided during the production tasks after blocks of sixteen stimuli were completed. In addition, another break was offered to participants before moving onto the AMMA.

Ethics Protocol

All Institutional Review Board (IRB) protocols have been followed and approved for this study, case number 09229 (see Appendix F). Participation in this study was voluntary and subjects were made aware of their rights to withdraw at any time. Consent forms approved by the IRB were provided to each subject prior to beginning the study (see Appendix G). All data was collected in person. The experimental data is in the electronic form of audio recordings and is stored as digital files on password protected computers. No personal information is associated with participants’ audio recordings. Additional data from the AMMA, the post-test survey, the Edinburgh Handedness Inventory, and the analysis are also stored as digital files on password protected computers. All names of those involved were coded with a randomly assigned subject number and are made confidential in the report. All staff associated with this study were trained to lock the physical data (surveys and the handedness inventory) in a cabinet.
Staff was also trained to log out of computers containing critical data after use to maintain password protection.

Data Collection Procedure

In order to better understand the domain specificity and cognition, and their relationship to one another, subjects’ ability to cognate and reproduce accurate pitches in prosody and melody were assessed by comparing responses to the target pitches and correlating them with their musical aptitude results on the AMMA. To hopefully demonstrate any correlations of significance between language and music, the musical history of a subject, their accuracy during prosodic and melodic production, and their performance on the AMMA was evaluated.

Quantitative

Data was collected from: a) the AMMA; b) post-test survey; c) Edinburgh Handedness Inventory; d) assessment of starting pitch and final interval accuracy of the production tasks; and e) overall contour to rate subjects’ prosodic ability in the production tasks. The AMMA raw scores were extracted from the CD-ROM after all participants had completed the examination. Subjects’ background information including if and when they began any formal musical training, for how long they continued their study, and whether or not they spoke any languages other than English was collected. Subjects’ handedness was then determined using the Edinburgh Handedness Inventory.

Ratings for speech, musicalized speech, and melodies were collected in the same manner. In preparation, the samples were first organized by stimulus. For example, every subject’s response to speech stimulus 4 was grouped together and every subject’s response to musicalized speech stimulus 63 was grouped together. This strengthened the
reliability of the scoring since all samples were listened to and compared at the same time. Evaluation of starting pitches was selected as a clean measurement of the tonal memory capability of subjects to reproduce heard pitches. Final interval accuracy was chosen as another variable due to its noted significance in phrasing of both music and language (Benward & Saker, 2003; Cohen, Morgan, & Pollack, 1990).

Using a coding script in Praat, the target stimulus was first played followed by a random presentation of a subject’s response. This blinded evaluation was also utilized to strengthen the reliability of the assessment. After a rating was assigned, this process of the target stimulus being played followed by a subject’s response continued until all 8 subjects were rated. There were options to play both the target and the response unlimited times. When the entire group was complete, a post-script was run in order to export the data into a table that included the order of presentation, subject number, target stimulus, and rating.

This assessment process was completed three times for every stimulus for starting pitch accuracy, final interval accuracy, and an overall contour rating. The starting pitch and final intervals were binary yes or no responses with a score of 1 representing no and a score of 7 representing yes. The starting pitch was an objective assessment of a subject’s ability to match the very first pitch of a stimulus. The final interval was a measurement of a subject’s ability to repeat the intervallic relationship between the second to last and the last pitch of each phrase. If a subject had transposed the phrase to a higher or lower pitch, or neglected to repeat several intermittent pitches correctly but still matched this final interval, they were still given a 7. This rating process was the same for speech, musicalized speech, and melodies.
The overall contours were rated on a scale of 1-7. Errors were judged based on intervallic integrity and pitch accuracy. For example, if a subject repeated an entire melody correctly but transposed it to another key, they were marked as having one error and were scored a 6. Another subject would have also been scored a 6 if they sang the melody in the correct key, but missed one of the intervals. Table 3.2 describes the criteria for each score. These scores, along with the AMMA and the survey responses provided the raw data for the statistical analysis.

Table 3.2

*Contour Rating Scores and Criterion*

<table>
<thead>
<tr>
<th>Score</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No semblance whatsoever of target contour.</td>
</tr>
<tr>
<td>2</td>
<td>One intervallic attribute of contour present.</td>
</tr>
<tr>
<td>3</td>
<td>Two intervallic attributes of contour present, or a general semblance to the target contour.</td>
</tr>
<tr>
<td>4</td>
<td>General contour correct from start to finish but with at least 3 intonation or intervallic mistakes.</td>
</tr>
<tr>
<td>5</td>
<td>Almost perfect response but with two intervallic or pitch error.</td>
</tr>
<tr>
<td>6</td>
<td>Almost perfect response but with one intervallic or pitch error.</td>
</tr>
<tr>
<td>7</td>
<td>Perfect response to target contour.</td>
</tr>
</tbody>
</table>

Qualitative

The final two questions on the survey, “Did you notice anything strange about the sentences or melodies in the experiment?” and “What do you think this experiment was about?” were reviewed for qualitative assessment. These provided insight into whether or not observable connections were made between the stimuli, and to determine whether or not these observations were made by musicians and/or non-musicians. How subjects respond to the stimuli while performing the tasks was also observed and considered for qualitative analysis. Potential behaviors could have been laughing at a mistake, repeating a phrase or specific pitch until correct, or verbally self-reflecting on their performance.
Reliability of the Main Data Collector

To ensure as reliable a rating as human subjectivity would allow, several considerations were made. First, as explained in the Data Collection Procedure, all subject responses were anonymous. A randomly assigned subject number was the only identifying factor on each sound file. The AMMA scores and subject biographical information were also not revealed to the main data collector until completion of all ratings as to avoid any potential scoring bias. Furthermore, each sample was grouped together and played for the researcher at random. This blind block of samples made it nearly impossible to distinguish any identifying factors that may have lead to a scoring bias.

Second, the main data collector performed self-reliability tests throughout the ratings. This was accomplished by randomly selecting a sample file to rate for a second time. The results of the first and second rating were compared to ensure consistent scorings. Finally, in comparing the overall scores on the production and perception tasks, it seems apparent the ratings were consistent with how subjects performed on the AMMA again confirming a reliable rating system.

Analysis

Given that this study sought to compare particular variables to subjects’ performance on production and perception tasks, linear regression were employed to determine if any relationships existed. Since the variables were heteroscedastic, and the data ordinal, Spearman Rank-Order Correlations were used to test the significance of variables. Evaluation of means and standard deviations were also used to compare individual performance and subgroup performance against the entire sample. The
significance of relationships, and overall performance as determined by the descriptive statistics were compared to existing research in the field in order to corroborate our results, and to help address the speculations made as to the basis of the relationships found. All statistics were completed with the software program, The R Project for Statistical Computing (R Project, 2009).

The qualitative data was taken into consideration for a discussion of subjects’ perceptiveness of what the intent of the tasks may or may not have been, and how they reacted to their own responses. For example, their personal feedback demonstrated an awareness of their mistakes, and recognition of what the target contour should have been. This suggests that those subjects may have perceived the sample correctly; but for various reasons, may not have been able to produce it correctly. These responses were considered with their biographical information and descriptive statistics as an additional element to the analysis.

Delimitations

The field of neuromusical research is merely decades old, and its acceptance into music education research as a legitimate practice is even younger. The research designs, analysis, and application of any results are still highly debated amongst researchers and practitioners as to the appropriateness of its inclusion in the field (Hodges, 2005). This has made the overall development challenging due to the infantile nature of an interdisciplinary study of this sort including creating appropriate tasks, subject recruitment, method of analysis, and implications of results.

In terms of this study, the first impediment was to create stimuli that generated as natural responses as possible from the participants. The context and presentation of these
stimuli were also of concern to again create as natural a setting as possible for the participants. Seeing as this was an assessment of behaviors, no conclusions can be made about the physiological characteristics that may have influenced the results. A final limitation from this study is the relatively small sample, and the wide range of variables that may or may not have been factored into the analysis, such as musical experiences, languages, hearing abilities, mode of music instruction/education, and form of general education.

What this study did accomplish was the initiation of a successful bidirectional exchange between cognitive psychologists and educational researchers. This helped to establish and validate appropriate development of tasks, data collection, and analysis of said tasks. The results of this study will help in the understanding of what effect musical experiences and music learning have on the perception and production of musical tasks such as those presented in the study. It will also offer a conjecture as to what the transferred cognitive effects from this learning may be on speech and prosody. A possible future study might address the length, form of instruction, and age of introduction of these musical experiences in order to isolate exactly what form of music education would create the strongest effects.

Assumptions

There are two assumptions that are essential for this study: (a) the brain is malleable and with early and repeated exposure to a particular stimulus, will physically alter itself; and (b) music is an example of such a stimulating environment that, with repeat exposure, will elicit these physical changes. By accepting these two statements, it can be postulated that with any physical changes to an area of the brain, cognitive
efficiency might occur, potentially causing intra- and extra-transferred effects; those within the domain of music and those outside to other disciplines.

Summary

This chapter reviewed the method by which we created suitable stimuli in order to compare subjects’ production and perceptual capabilities in specific speech and music tasks. The interdisciplinary nature of the overall design was an attempt to include pertinent research goals from both cognitive psychology and music education in order to collect authentic and naturalistic data from the participants. As is explained in the following chapters, the results of this study are encouraging for demonstrating a relationship between musical experiences and learning, and the potential transferred cognitive effects to other areas such as prosody.
Chapter 4: PILOT STUDY

The overall procedures were piloted in order to replicate the intended study including the presentation of stimuli, all data collection methods, and the analysis. In addition, the participants were drawn from the same sample pool. This chapter presents the results from this preliminary study, plus information relevant to the validity of the procedures, the testing measures, and the data analysis.

Participants

The participants in this pilot were eight volunteer university undergraduates (mean age = 19.5; range = 19-21 years). Of these students, four were music majors and four were non-music majors including 1 theater major; 1 tonal language speaker; and 2 left-handed participants (1 music major, and 1 non-music major). The average amount of formal study for the music majors was 10 years while none of the non-music majors had any formal musical instruction background. The designation, “formal study”, is used to describe any one-on-one private instrumental or vocal training. The demographic for all pilot participants can be found in Table 4.1.

Table 4.1
Pilot Participant Background Information (N = 8)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Major</th>
<th>Tonal Language</th>
<th>Main Instrument</th>
<th>Age Began</th>
<th>Years of Formal Study</th>
<th>Handedness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>MM</td>
<td></td>
<td>piano</td>
<td>7</td>
<td>12</td>
<td>R</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>MM</td>
<td></td>
<td>piano</td>
<td>7</td>
<td>10</td>
<td>R</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>MM</td>
<td></td>
<td>bass</td>
<td>9</td>
<td>11</td>
<td>R</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>MM</td>
<td>Mandarin</td>
<td>viola</td>
<td>10</td>
<td>7</td>
<td>L</td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>NM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>NM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>7</td>
<td>20</td>
<td>NM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>TH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
</tbody>
</table>

Note. Mean age = 19.5 (SD = .7559); MM = music major; NM = non-music major; TH = theater major.
Subject Recruitment

Pilot participants were recruited in the same manner as the main study: via email to orchestra and theater students, and using the psychology department’s subject pool website. Additional detail on these methods can be found in Chapter 3.

Results

Descriptive Statistics

Based on the post-test survey and initial examination of the raw data, 7 subgroups were developed for evaluation: music majors, theater majors, non-music and non-theater majors, tonal language speaker, non-tonal language speaker, right-handed participants and left-handed participants (see Table 4.2). The division of subgroups allowed for a deeper understanding of the independent and dependent variables. Means and standard deviations were calculated for the Advanced Measures of Music Audiation (AMMA) raw scores of all participants and for each subgroup (Table 4.3), and for starting pitches, final intervals, and overall contours for speech, musicalized speech, and melodies (Table 4.4).

Table 4.2

Table Division of Subgroups by Subject Number

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>n</th>
<th>Subject Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music Majors</td>
<td>4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Non-Music and Non-Theater Major</td>
<td>3</td>
<td>5 6 7</td>
</tr>
<tr>
<td>Theater Major</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Tonal Language</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Non-Tonal Language</td>
<td>7</td>
<td>1 2 3 5 6 7 8</td>
</tr>
<tr>
<td>Left-Handed</td>
<td>2</td>
<td>4 5</td>
</tr>
<tr>
<td>Right-Handed</td>
<td>6</td>
<td>1 2 3 6 7 8</td>
</tr>
</tbody>
</table>

An examination of the individual AMMA raw scores (Table 4.5) demonstrates that most subjects scored close to average on the tonal and rhythm portions of the exam. The tonal language speaker scored the lowest of all participants in both categories. Based
on evidence presented in the literature review, it has been noted that tonal language speakers are typically more prone to having absolute pitch related abilities and it would thus be expected that an assessment of tonal matching would reflect this (Bossomaier & Snyder, 2004; Deutsch, 2002). Despite this theory, however, subject 4’s poor result on the AMMA illustrates the converse; although she shared the highest mean score for melodic final intervals and scored the highest on melodic overall contour (see Table 4.4).

The left-handed subgroup did not demonstrate any statistical significance and scored the next lowest on the AMMA. With such a small sample, it cannot be determined if this is attributed to handedness rather than poor individual perceptual abilities in music.

Table 4.3
Means and Standard Deviations of the AMMA for all Subgroups

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>AMMA/T ± SD</th>
<th>AMMA/R ± SD</th>
<th>AMMA/C ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Participants</td>
<td>24.38 ± 4.37</td>
<td>28.00 ± 3.55</td>
<td>52.38 ± 7.39</td>
</tr>
<tr>
<td>Music Majors</td>
<td>24.75 ± 6.13</td>
<td>27.25 ± 5.06</td>
<td>52.00 ± 10.95</td>
</tr>
<tr>
<td>Non-Music and Non-Theater Major</td>
<td>24.33 ± 3.06</td>
<td>29.33 ± 1.15</td>
<td>53.67 ± 2.31</td>
</tr>
<tr>
<td>Theater Major</td>
<td>23.00 ±</td>
<td>27.00 ±</td>
<td>50.00 ±</td>
</tr>
<tr>
<td>Tonal Language</td>
<td>17.00 ±</td>
<td>23.00 ±</td>
<td>40.00 ±</td>
</tr>
<tr>
<td>Non-Tonal Language</td>
<td>25.43 ± 3.46</td>
<td>28.71 ± 3.15</td>
<td>54.14 ± 5.87</td>
</tr>
<tr>
<td>Left Handed</td>
<td>21.00 ± 5.66</td>
<td>26.50 ± 4.95</td>
<td>47.50 ± 10.61</td>
</tr>
<tr>
<td>Right Handed</td>
<td>25.50 ± 3.78</td>
<td>28.50 ± 3.39</td>
<td>54.00 ± 6.42</td>
</tr>
</tbody>
</table>

Note. Values are M ± SD; AMMA/T = Advanced Measures of Music Audiation tonal score; AMMA/R = Advanced Measures of Music Audiation rhythm score; AMMA/C = Advanced Measures of Music Audiation composite score.

Table 4.4
Pilot Individual and Overall Mean Results for Production Tasks

<table>
<thead>
<tr>
<th>Subject</th>
<th>SSP</th>
<th>SFI</th>
<th>SCNTR</th>
<th>MSSP</th>
<th>MSFI</th>
<th>MSCNTR</th>
<th>MLSP</th>
<th>MLFI</th>
<th>MLCNTR</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.91</td>
<td>6.34</td>
<td>6.78</td>
<td>5.97</td>
<td>4.84</td>
<td>5.08</td>
<td>6.41</td>
<td>4.38</td>
<td>5.47</td>
<td>5.80</td>
</tr>
<tr>
<td>2</td>
<td>7.00</td>
<td>6.34</td>
<td>6.84</td>
<td>6.06</td>
<td>4.47</td>
<td>4.72</td>
<td>6.13</td>
<td>2.69</td>
<td>5.11</td>
<td>5.48</td>
</tr>
<tr>
<td>3</td>
<td>6.81</td>
<td>6.63</td>
<td>6.89</td>
<td>6.53</td>
<td>5.03</td>
<td>5.61</td>
<td>6.22</td>
<td>5.31</td>
<td>6.19</td>
<td>6.14</td>
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<tr>
<td>4</td>
<td>5.88</td>
<td>6.63</td>
<td>6.61</td>
<td>4.56</td>
<td>4.84</td>
<td>4.58</td>
<td>6.22</td>
<td>5.31</td>
<td>6.31</td>
<td>5.66</td>
</tr>
<tr>
<td>5</td>
<td>5.69</td>
<td>6.25</td>
<td>6.45</td>
<td>4.94</td>
<td>4.75</td>
<td>4.44</td>
<td>2.20</td>
<td>1.84</td>
<td>3.78</td>
<td>4.48</td>
</tr>
</tbody>
</table>

(continued)
Table 4.4 (cont.)

<table>
<thead>
<tr>
<th></th>
<th>6</th>
<th>6.91</th>
<th>6.63</th>
<th>6.73</th>
<th>5.31</th>
<th>3.16</th>
<th>4.31</th>
<th>4.91</th>
<th>2.31</th>
<th>4.77</th>
<th>5.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>6.53</td>
<td>5.50</td>
<td>5.94</td>
<td>2.97</td>
<td>3.25</td>
<td>2.73</td>
<td>4.92</td>
<td>2.97</td>
<td>4.61</td>
<td>4.38</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>6.81</td>
<td>6.06</td>
<td>6.73</td>
<td>6.06</td>
<td>4.28</td>
<td>4.48</td>
<td>4.72</td>
<td>3.63</td>
<td>5.06</td>
<td>5.32</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>6.57</td>
<td>6.30</td>
<td>6.62</td>
<td>5.30</td>
<td>4.33</td>
<td>4.49</td>
<td>5.21</td>
<td>3.55</td>
<td>5.16</td>
<td>5.28</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>0.51</td>
<td>0.38</td>
<td>0.31</td>
<td>1.15</td>
<td>0.73</td>
<td>0.83</td>
<td>1.40</td>
<td>1.33</td>
<td>0.83</td>
<td>0.62</td>
<td></td>
</tr>
</tbody>
</table>

Note. Shading indicates highest mean score for said variable; SSP = speech starting pitch; SFI = speech final interval; SCNTR = speech contour; MSSP = musicalized speech starting pitch; MSFI = musicalized speech final interval; MSCNTR = musicalized speech contour; MLSP = melody starting pitch; MLFI = melody final interval; MLCNTR = melody contour.

The shaded scores in Table 4.4 represent the highest marks for each category of production tasks. Each of these was achieved by a music major. Further, when comparing the music majors’ scores to the sample’s means, two out of the four never had a mean score below the sample mean. Interestingly though, the music majors scored lower than the tonal language speaker on all final intervals, although higher than non-music majors. All four music majors (non-tonal and tonal language speakers) scored equal to or lower than the non-music and non-theater majors on the AMMA rhythm portion ($M = 27.25$ and $M = 29.33$, respectively).

Table 4.5

<table>
<thead>
<tr>
<th>Individual Pilot Participant Raw Scores for the AMMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Music Majors</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>Non-Music Majors</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
</tbody>
</table>

Note. AMMA/T = Advanced Measures of Music Audiation tonal score; AMMA/R = Advanced Measures of Music Audiation rhythm score; AMMA/C = Advanced Measures of Music Audiation composite score.

The starting pitches for the tonal language speaker (Subject 4) were inconsistent.

For speech and musicalized speech, she scored .69 and .74 below the sample mean,
respectively. For the starting pitch of the melodies however, she scored 1.01 higher than the sample mean. While it is possible that the low score for speech may be due to a potential language difficulty, this does not explain a similarly low score for the musicalized speech, especially since her melodic starting pitch score demonstrates her ability to match starting pitches fairly accurately.

Following the music majors, the theater major had the next highest score. On the contrary, all non-music scores, Subjects five through seven, scored below the sample mean for every melodic variable and musicalized speech contour. Additionally, two out of three of them scored below the sample mean on all remaining variables.

Since the speech ratings were relatively high, 6.57, 6.30, and 6.62 with standard deviations of 0.51, 0.39, and 0.31 respectively, the remaining descriptive analysis will be focused on musicalized speech and melodies. Tables 4.6, 4.7, 4.8, 4.9, 4.10, and 4.11 illustrate the means and standard deviations for said variables’ starting pitch and final interval for all subgroups. Within each table, the shaded figure indicates scores at or higher than the sample mean. Table 4.12 and Figure 4.1 compare the mean scores of music majors to non-music majors.

Table 4.6
*Means and Standard Deviations of Musicalized Speech Starting Pitch for Subgroups*

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Participants</td>
<td>5.30</td>
<td>1.15</td>
</tr>
<tr>
<td>Music Majors</td>
<td>5.78</td>
<td>0.85</td>
</tr>
<tr>
<td>Non-Music and Non-Theater Major</td>
<td>4.41</td>
<td>1.26</td>
</tr>
<tr>
<td>Theater Major</td>
<td>6.06</td>
<td></td>
</tr>
<tr>
<td>Tonal Language</td>
<td>5.30</td>
<td></td>
</tr>
<tr>
<td>Non-Tonal Language</td>
<td>5.41</td>
<td>1.20</td>
</tr>
<tr>
<td>Left-Handed</td>
<td>3.77</td>
<td>1.13</td>
</tr>
<tr>
<td>Right-Handed</td>
<td>5.81</td>
<td>0.58</td>
</tr>
</tbody>
</table>
Table 4.7
*Means and Standard Deviations of Melodies Starting Pitch for Subgroups*

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Participants</td>
<td>5.21</td>
<td>1.40</td>
</tr>
<tr>
<td>Music Majors</td>
<td>6.24</td>
<td>0.12</td>
</tr>
<tr>
<td>Non-Music and Non-Theater Major</td>
<td>4.01</td>
<td>1.57</td>
</tr>
<tr>
<td>Theater Major</td>
<td>4.72</td>
<td></td>
</tr>
<tr>
<td>Tonal Language</td>
<td>5.21</td>
<td></td>
</tr>
<tr>
<td>Non-Tonal Language</td>
<td>5.07</td>
<td>1.45</td>
</tr>
<tr>
<td>Left-Handed</td>
<td>5.57</td>
<td>0.92</td>
</tr>
<tr>
<td>Right-Handed</td>
<td>5.10</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Table 4.8
*Means and Standard Deviations of Musicalized Speech Final Interval for Subgroups*

<table>
<thead>
<tr>
<th>Subgroup</th>
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<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Participants</td>
<td>3.55</td>
<td>1.33</td>
</tr>
<tr>
<td>Music Majors</td>
<td>4.80</td>
<td>0.24</td>
</tr>
<tr>
<td>Non-Music and Non-Theater Major</td>
<td>3.72</td>
<td>0.89</td>
</tr>
<tr>
<td>Theater Major</td>
<td>3.63</td>
<td></td>
</tr>
<tr>
<td>Tonal Language</td>
<td>4.33</td>
<td></td>
</tr>
<tr>
<td>Non-Tonal Language</td>
<td>4.25</td>
<td>0.76</td>
</tr>
<tr>
<td>Left-Handed</td>
<td>4.05</td>
<td>1.13</td>
</tr>
<tr>
<td>Right-Handed</td>
<td>4.42</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Table 4.9
*Means and Standard Deviations of Melodies Final Intervals for Subgroups*

<table>
<thead>
<tr>
<th>Subgroup</th>
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</thead>
<tbody>
<tr>
<td>All Participants</td>
<td>3.55</td>
<td>1.33</td>
</tr>
<tr>
<td>Music Majors</td>
<td>4.80</td>
<td>0.24</td>
</tr>
<tr>
<td>Non-Music and Non-Theater Major</td>
<td>3.72</td>
<td>0.89</td>
</tr>
<tr>
<td>Theater Major</td>
<td>3.63</td>
<td></td>
</tr>
<tr>
<td>Tonal Language</td>
<td>4.33</td>
<td></td>
</tr>
<tr>
<td>Non-Tonal Language</td>
<td>4.25</td>
<td>0.76</td>
</tr>
<tr>
<td>Left-Handed</td>
<td>4.05</td>
<td>1.13</td>
</tr>
<tr>
<td>Right-Handed</td>
<td>4.42</td>
<td>0.68</td>
</tr>
</tbody>
</table>

84
Table 4.10

*Means and Standard Deviations of Musicalized Speech Overall Contour for Subgroups*

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Participants</td>
<td>4.49</td>
<td>0.83</td>
</tr>
<tr>
<td>Music Majors</td>
<td>5.00</td>
<td>0.46</td>
</tr>
<tr>
<td>Non-Music and Non-Theater Major</td>
<td>3.83</td>
<td>0.95</td>
</tr>
<tr>
<td>Theater Major</td>
<td>4.48</td>
<td></td>
</tr>
<tr>
<td>Tonal Language</td>
<td>4.49</td>
<td></td>
</tr>
<tr>
<td>Non-Tonal Language</td>
<td>4.48</td>
<td>0.89</td>
</tr>
<tr>
<td>Left-Handed</td>
<td>3.66</td>
<td>1.30</td>
</tr>
<tr>
<td>Right-Handed</td>
<td>4.77</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Table 4.11

*Means and Standard Deviations of Melodies Overall Contour for Subgroups*

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Participants</td>
<td>5.77</td>
<td>0.58</td>
</tr>
<tr>
<td>Music Majors</td>
<td>4.39</td>
<td>0.53</td>
</tr>
<tr>
<td>Non-Music and Non-Theater Major</td>
<td>5.06</td>
<td></td>
</tr>
<tr>
<td>Theater Major</td>
<td>5.16</td>
<td>0.83</td>
</tr>
<tr>
<td>Tonal Language</td>
<td>5.00</td>
<td>1.21</td>
</tr>
<tr>
<td>Non-Tonal Language</td>
<td>5.46</td>
<td>1.20</td>
</tr>
<tr>
<td>Left-Handed</td>
<td>5.06</td>
<td>0.80</td>
</tr>
<tr>
<td>Right-Handed</td>
<td>5.16</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Table 4.12

*Comparison of Music Majors and Non-Music Majors Means*

<table>
<thead>
<tr>
<th></th>
<th>All Music Majors Means (n = 4)</th>
<th>Music Majors/Non-tonal Language Means (n = 3)</th>
<th>Music Major/Tonal Language Speaker Means (n = 1)</th>
<th>Non-Music/Non-Theater Majors Means (n = 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMMA/T</td>
<td>24.75</td>
<td>27.33</td>
<td>17</td>
<td>24.33</td>
</tr>
<tr>
<td>AMMA/R</td>
<td>27.26</td>
<td>28.67</td>
<td>21</td>
<td>29.33</td>
</tr>
<tr>
<td>AMMA/C</td>
<td>52</td>
<td>56</td>
<td>40</td>
<td>53.67</td>
</tr>
<tr>
<td>SSP</td>
<td>6.70</td>
<td>6.91</td>
<td>5.88</td>
<td>6.38</td>
</tr>
<tr>
<td>SFI</td>
<td>6.46</td>
<td>6.44</td>
<td>6.63</td>
<td>6.13</td>
</tr>
<tr>
<td>SCNTR</td>
<td>5.82</td>
<td>6.84</td>
<td>6.61</td>
<td>6.38</td>
</tr>
<tr>
<td>MSSP</td>
<td>4.81</td>
<td>6.19</td>
<td>4.56</td>
<td>4.41</td>
</tr>
<tr>
<td>MSFI</td>
<td>6.28</td>
<td>4.78</td>
<td>4.84</td>
<td>3.72</td>
</tr>
<tr>
<td>MSCNTR</td>
<td>4.41</td>
<td>5.14</td>
<td>4.58</td>
<td>3.83</td>
</tr>
<tr>
<td>MLSP</td>
<td>6.78</td>
<td>6.25</td>
<td>6.22</td>
<td>4.01</td>
</tr>
<tr>
<td>MLFI</td>
<td>5.01</td>
<td>4.13</td>
<td>5.31</td>
<td>2.38</td>
</tr>
<tr>
<td>MLCNTR</td>
<td>5.71</td>
<td>5.59</td>
<td>6.31</td>
<td>4.39</td>
</tr>
</tbody>
</table>
Figure 4.1 Line graph of variable means for production tasks.

Note. MMNT = music major non-tonal; MMT = music major tonal; NMNT = non-music major and non-tonal; 1 = speech starting pitch; 2 = speech final interval; 3 = speech overall contour; 4 = musicalized speech starting pitch; 5 = musicalized speech final interval; 6 = musicalized speech overall contour; 7 = melody starting pitch; 8 = melody final interval; and 9 = melody overall contour.

Statistical Analysis

Spearman correlations demonstrated no significant results in AMMA scores against musical background, handedness, or tonal language. Several highly significant results however, were found between the production tasks and musical experience (see Table 4.13).

The age participants began their musical study was significantly correlated to musicalized speech final interval \((r_s = .80, p < .05)\) and musicalized speech contour \((r_s = .78, p < .05)\), in addition to melodic starting pitch \((r_s = .82, p < .05)\), melodic final interval \((r_s = .77, p < .05)\), and melodic overall contour \((r_s = .93, p < .001)\). A significant relationship was also found between the length of formal music training and speech contour \((r_s = .74, p < .05)\), musicalized speech final interval \((r_s = .77, p < .05)\),
musicalized speech contour \( (r_s = 0.91, p < .01) \), melodic starting pitch \( (r_s = .89, p < .01) \) and between melodic overall contour \( (r_s = .76, p < .05) \).

Correlations were also demonstrated between production tasks. Overall contour performances between speech and musicalized speech yielded a positive correlation \( (r_s = 0.84, p < .01) \). Melodic contour and musicalized speech contour also exhibited significant results \( (r_s = .77, p < .05) \). This overall trend of high speech contour results, low musicalized speech result, and a moderate melodic contour is illustrated in Figure 4.2. From the significant correlations, the relative range of rating scores is also depicted.

![Overall Contour Results](image)

**Figure 4.2** Boxplot comparison of all overall contour mean scores.
*Note.* SCNTR = speech overall contour; MSCNTR = musicalized speech overall contour; MLCNTR = melody overall contour.
Table 4.13

**Intercorrelations for Musical Background and Production Tasks**

<table>
<thead>
<tr>
<th></th>
<th>Began</th>
<th>Years</th>
<th>Tonal</th>
<th>SSP</th>
<th>SFI</th>
<th>SCNTR</th>
<th>MSSP</th>
<th>MSFI</th>
<th>MSCNTR</th>
<th>MLSP</th>
<th>MLFI</th>
<th>MLCNTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Began</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years</td>
<td>0.79*</td>
<td>0.62</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tonal</td>
<td>0.62</td>
<td>0.94</td>
<td>-0.42</td>
<td></td>
<td></td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSP</td>
<td>0.07</td>
<td>0.46</td>
<td>0.43</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SFI</td>
<td>0.66</td>
<td>0.49</td>
<td>-0.42</td>
<td>0.58</td>
<td>0.27</td>
<td>0.91**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCNTR</td>
<td>0.50</td>
<td>0.74*</td>
<td>-0.25</td>
<td>0.72*</td>
<td>0.52</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSSP</td>
<td>0.24</td>
<td>0.49</td>
<td>-0.42</td>
<td>0.58</td>
<td>0.27</td>
<td>0.91**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSFI</td>
<td>0.80*</td>
<td>0.77*</td>
<td>0.33</td>
<td>-0.19</td>
<td>0.41</td>
<td>0.45</td>
<td>0.34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSCNTR</td>
<td>0.78*</td>
<td>0.91**</td>
<td>0.08</td>
<td>0.35</td>
<td>0.48</td>
<td>0.84**</td>
<td>0.72*</td>
<td>0.84**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLSP</td>
<td>0.82*</td>
<td>0.89**</td>
<td>0.33</td>
<td>0.33</td>
<td>0.48</td>
<td>0.51</td>
<td>0.18</td>
<td>0.63</td>
<td>0.71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLFI</td>
<td>0.77*</td>
<td>0.61</td>
<td>0.50</td>
<td>-0.04</td>
<td>0.36</td>
<td>0.36</td>
<td>0.24</td>
<td>0.67</td>
<td>0.64</td>
<td>0.76*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLCNTR</td>
<td>0.93***</td>
<td>0.76*</td>
<td>0.58</td>
<td>0.22</td>
<td>0.65</td>
<td>0.59</td>
<td>0.37</td>
<td>0.70</td>
<td>0.79*</td>
<td>0.83*</td>
<td>0.87**</td>
<td></td>
</tr>
</tbody>
</table>

Note. Began = age began formal study; Years = total years of formal study; AMMA/T = Advanced Measures of Music Audiation tonal score; AMMA/R = Advanced Measures of Music Audiation rhythm score; AMMA/C = Advanced Measures of Music Audiation composite; SSP = speech starting pitch; SFI = speech final interval; SCNTR = speech contour; MSSP = musicalized speech starting pitch; MSFI = musicalized speech final interval; MSCNTR = musicalized speech contour; MLSP = melody starting pitch; MLFI = melody final interval; MLCNTR = melody contour. *p < .05. **p < .01. ***p < .001.
Discussion

*Qualitative Observations*

From answers on the post-test survey, only one participant was able to recognize the similarities between the speech, musicalized speech, and melodies. Interestingly, this observation was made by a non-music major (Subject 5) who had only one year of high school orchestra and four years of high school choir. A similar observation was made by another non-music major (Subject 6) who commented that the sentences had minor differences but generally remained constant. This was an accurate observation since the stimuli were based off the same eight models with slight modifications.

Subject 7, a non-music major, corrected her final pitch for musicalized speech sample 51. She first sang the interval incorrectly then corrected herself to the appropriate final pitch. This participant had no prolonged formal music training but did have a background in music with two years of piano study starting at age seven, one year with the flute beginning at 18 years of age, and one year of guitar begun at age 9. Overall, her production scores were the second lowest, but her perception scores were above the sample mean. This may infer that she was cognizant of the target contour, but may not have been able to reproduce it and was attempting to do so with this correction.

The tonal language speaker made an incorrect statement about the tasks in her post-test survey. She remarked, “The melodies were very atonal whereas the sentences didn’t range as much in pitches”. The melodies were based on the frequencies of speech, but were created to present themselves more melodically by maintaining a tonality therefore this statement is inaccurate. Another music major, Subject 3, also commented that the melodies were “more abstract” than the speech utterances. This would again be
an inaccurate observation since the melodies could have been arguably more representative of a completed phrase. The presentation of melodies in a given key most likely offered an acoustically complimentary contour. Subject 8, the theater major, made a final incorrect assumption. He remarked that the tempo of the musicalized speech was, “much faster” than the sentences. This is again incorrect due to the attention given to maintaining a consistent tempo for all three production tasks.

Subgroup Speculations

Music major. It has been theorized by many that an individual who dedicates an extended amount of time in a certain field will perform relatively well in that field (Gladwell, 2008). The music majors in this study exemplified this by scoring higher than all other subjects on the musical stimuli. This was the case for both the music majors with and without a tonal language background.

This was also illustrated in the highly significant correlation \((r_s = 0.93)\) between when musical study began and overall musical contour ability, and by significant results in musicalized speech final interval, musicalized speech contour, and melodic starting pitch and final interval. The youngest age musical training began was 7 and the oldest was 10. Again, no other subjects had any other formal musical background. The significant correlations from the years of formal training also concurs with the aforementioned theory of extended exposure to a particular area increasing an individual’s ability in that field. A suggested explanation of this may be the specificity to which musicians can hear pitch variances. Music uses low-level pitch perception, which requires fine-grained discrimination of pitches 1/12 or 1/6 of an octave (Vos & Troost, 1989), as opposed to speech intonation contours that rely upon pitch variations larger
than half an octave to convey relevant information (Patel et al., 1998). Repeated experience in the former may train musicians to attend to pitch discrepancies more precisely than their non-musician counterparts.

The low score on the AMMA rhythm sparks an interesting question of musical training background. With two piano and two string players, a discrepancy might be expected between the percussive background and the string background for the rhythm portion, however this was not the case (AMMA scores = 30, 23, 33, 23, respectively). This study demonstrated that length of study is correlated to other musical factors and perhaps the length of study at the university may have a relationship to the success on the AMMA. This is possibly illustrated by the eldest music major who had the lengthiest amount of study at the university. He scored a 33 on the rhythm, which was the highest of the entire sample. This subject also scored the highest on the tonal portion, which may also be attributed to individual performance suggesting an alternative implication of the university training. Since the remaining music majors were enrolled in the same music program and were in the same year of study, perhaps there was a stronger focus on tonal preparation than rhythmic practice in their studies. Both these hypothesis cannot be adequately addressed in a study of this size, and the question lends itself to a larger sample in possible subsequent studies.

_Tonal language speaker._ As noted above, the tonal language speaker in this study, who was also a music major, scored low on speech starting pitch and speech overall contour, musicalized speech starting pitch, and on the AMMA tonal. While a possible theory for the low score for speech may be due to language difficulties, this does not explain a similarly low score for the musicalized speech starting pitch and her AMMA
score. This is especially baffling, considering her melodic starting pitch was above the sample mean and was the second highest score.

One consideration may be the presentation of the melodies compared to the musicalized speech. To most individuals, a piano is a familiar instrument. This is especially true for music majors who often have extended experience with the piano from their undergraduate studies. It might be speculated that this subject had more experience listening to, and perhaps even responding to piano pitches in several of her aural skills courses. Although, a comparison of her performance and her AMMA scores, which were also presented on a piano, contradicts this suggestion since she scored so poorly.

*Theater major.* Several theories may address why this subject scored well on several variables. The first and most obvious would be the speech starting pitch and overall contour. As a theater major, he most likely has had experience learning about expression through dialogue, in essence, training his prosodic abilities. While part of a music performance education is the study of melody, part of a theater student’s education focuses on prosody. This assumption would most likely then affect this subject’s overall contour in speech. This subject’s training may have also included practice in presenting dialogue in public. This may have positively affected his comfort in the recording sessions and facilitated stronger results.

A final suggestion can be made about two additional scores. While this subject had no instrumental background, he did have small dance experience from high school. Perhaps his former musical experience in this ensemble had a link to his musicalized speech starting pitch and melodic final interval scores.
Non-music major and non-theater major. For the experiential reasons previously mentioned for music majors and theater majors, it is expected that non-music and non-theater majors did not score as well on most of the tasks. Their low performance, especially on the musical factors, illustrates how their lack of exposure to formal musical training may have indeed affected their abilities in the musicalized speech and the melodies.

What is most interesting however, are the entire sample’s overall contour scores. The pitches of the musicalized speech samples were all based entirely on the frequencies of the speech contours. It would then be expected the scores for the speech would be similar to the musicalized speech. This was not reflected in the subject scores, as is illustrated in Table 13 and Figure 6. The common factors between these stimuli are frequency/pitch, rhythm, and tempo; the only variable is the lack of words.

Final intervals and intermittent pitches. The low final interval scores can possibly be attributed to a lack of concentration, or the inability to focus on the final pitch when intermittent pitches were presented between the starting pitch and final interval. Although the final interval of the target would have been the last two pitches the subject heard, there would still be the distraction of them repeating all pitches prior to reaching the final interval again. As Plantinga and Trainor (2008) have found, the greater number of tones played after a target pitch correlated negatively to the ability of remembering that target pitch. This may address why the participants were unable to successfully reproduce the final interval; there were often 4 or 5 interfering pitches that needed to be recalled prior to getting to the final interval. This may have been distraction enough to forget the final interval.
Another issue may be the relatively short mental ability to recall after several seconds. This may be a function of short-term memory (working memory), or more specifically, echoic memory (Gazzaniga et al., 2002). Both retain audible information for limited amounts of time, depending on variables such as mental capacity, focus, and repetition. Echoic memory refers to the mental echo that is repeated after an auditory stimulus has been heard (Williamson, Baddeley, & Hitch, 2010). This effect has been demonstrated to maintain auditory information from 200 ms to several seconds (Cowan, 1984). It may be that for the non-music majors, their capacity to retain tonal information in the short-term memory or echoic memory may not be as developed as music majors. The stimuli in the production tasks ranged from 3 to 4 seconds. This means the length of time from the beginning of the target to the subject’s repetition may be 6 to 8 seconds. This amount of time would explain the loss of tonal information towards the end, leaving the final interval forgotten.

*Modifications for the Expanded Study*

Due to the success of the testing procedures, tasks, and analysis, these remained constant for the main study. Based on the performance of the theater major compared to the music majors, additional variables were addressed in the larger study as to the type of musical background of participants. More specifically, formal musical training was compared to informal musical experience, along with the age of first exposure of each. This examined how the various forms of musical experience or education may affect someone’s performance on the presented tasks. In terms of cognition, the age these musical encounters commenced addresses the appropriate age to introduce such experiences in order to facilitate a cognitive change, as was indicated by subjects’
performances. These two variables offer implications for both music education and cognitive psychology.

Summary

It is with caution that any implications can be offered based on the results of this preliminary study. A small sample size can lead to interpretation and over-generalization errors. Therefore any interpretations based on these results may be misleading. However, several assumptions can be made from these results. Overall, all subjects scored well on the speech utterances despite musical and language background. This was not the case, however, with the musicalized speech or the melodic phrases, with music majors generally scoring better than non-music majors.

Furthermore, from the significant correlations demonstrated between when a subject began their musical training ($r_s \leq .93, p < .001$), and for how long they continued ($r_s \leq .89, p < .01$), it can be suggested that there may be differences in how an individual’s musical background may affect their ability to perceive and produce speech and melodic stimuli. Although no general trends were demonstrated in the differing abilities between the theater major, the tonal language speaker, or left- and right-handed participants, these variables were still considered in the larger study.

The aim of this pilot was to design an interdisciplinary study with proper musical stimuli to obtain empirical results that would apply to both music education and cognitive psychology. This pilot provided validation for the testing techniques, data collection procedures, sample population, and analysis. Given the caveat previously mentioned about sample size, it can be concluded that the pilot did offer encouraging results for
undertaking a larger, more sophisticated study based on the significant results comparing musical background and performance and perception of prosodic and melodic tasks.
Chapter 5: STUDY RESULTS

As predicted, musical experience demonstrated the strongest correlation to subjects’ success on production and perception tasks. Upon further analysis, the particulars of these relationships included the length and form of musical exposure. This chapter presents the data through descriptive and statistical analysis. A discussion of the implications for music education and cognitive psychology are expanded upon in Chapter 6 through a discussion of the results, suggested theories behind these results, and qualitative data collected throughout the study.

Subgroups

From the data obtained in the post-test surveys, additional subgroups were developed for analysis. As well as comparing music majors, non-music majors, theater majors, length and age beginning formal music training, handedness, and tonal language speakers as completed in the pilot (see Chapter 4), further divisions were made to consider overall informal musical exposure and the age that any musical training was first introduced. In this study, formal training is used to describe any one-on-one private lessons and informal exposure to music implies playing an instrument without private lessons such as in a school ensemble. Total years of exposure to music include both formal and informal musical experience. Participants’ musical backgrounds are reported in Table 5.1. The results of individual and subgroup performance can be found under the Descriptive Statistics and Statistical Analysis portions of this chapter.

The Sample

Of the 29 participants, 9 were music majors (2 voice, 4 string, and 3 piano), 5 were theater majors, and 15 were majors outside of the performing arts; 18 were female;
4 were left-handed; 5 were non-native English speakers, with 2 being native speakers of tonal languages; and ranged between 19 and 26 years old at the time of the study ($M = 20.2 \pm 1.63$). Subjects in the sample reported having musical exposure ranging in 0 to 23 years ($M = 8.24$, $SD = 6.26$) beginning anywhere from the age of 3 to 18 ($M = 6.79$, $SD = 4.87$). Formal musical training ranged from 2 to 17 years ($M = 4.90$, $SD = 5.78$) commencing between age 5 and 15 ($M = 4.86$, $SD = 4.93$). Of the 22 participants who played an instrument, 12 reported playing more than one. One subject’s musical background was in dance performance only.

Music Majors

Each music major had at least 7 years of formal experience with the longest being 17 years ($M = 11.7 \pm 3.50$). When they began ranged from 5 to 11 years of age ($M = 7.78 \pm 2.11$).

Theater Majors

All five of the theater majors reported having musical experience ranging from 8 to 10 years: one subject had 2 years of formal training; 2 subjects had 11 years of formal training; and the remaining two had informal exposure only. The ages they began their formal training was 15, 11, and 8, respectively.

Other

Nine of the fifteen participants who were neither music nor theater majors reported having some amount of informal musical experience ($M = 4.20 \pm 5.14$ years), commencing as early as 7 years of age and as late as 18 years of age ($M = 6.53 \pm 6.42$). Three of these subjects also had formal music training with the longest time being for 6
years and the shortest time less than a year \((M = 0.87 \pm 1.88)\) beginning at ages 14, 9, and 7.

### Table 5.1

**Formal and Informal Musical Background \((N = 29)\)**

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<tr>
<th>Subject</th>
<th>Major</th>
<th>Total (years)</th>
<th>Began (age)</th>
<th>Instrument(s)</th>
<th>Total (years)</th>
<th>Began (age)</th>
<th>Instrument(s)</th>
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*Note.* MM = music major; NM = non-music major; TH = theater major.
Descriptive Statistics

Individual Performance

Means and standard deviations for individual and sample performance on the production and perception tasks can be found in Table 5.2 and Table 5.3. The shaded results represent those who scored at or above the sample mean for each task.

Production Tasks’ Means

Overall, performance on musicalized speech final intervals, musicalized speech contours, and melodic final intervals resulted in the lowest means with scores of 4.24, 4.42, and 3.60 respectively. The largest deviations amongst scores were musicalized speech starting pitch, melodies starting pitch, and melodic final interval with scores of 1.42, 1.93, and 1.57 respectively. All speech stimuli held the highest performance mean and the smallest deviations amongst subjects with starting pitch scoring 6.36 ± 0.62, final interval scoring 6.34 ± 0.46, and overall contour scoring 6.59 ± 0.23.

Subjects 8, 25, and 26 scored below the sample mean on all production tasks and Subjects 23 and 27 scored below on all except for speech final interval. Performing above the sample on all tasks were Subjects 2, 4, 10, 11, 12, 28, and 29 while Subjects 3, 5, 22, and 24 scored above the sample on all except for one task each. Subjects 22 and 29 scored a 7.00 on speech starting pitch and Subject 29 scored a 7.00 on melodic starting pitch.
### Table 5.2

*Production Tasks Means and Standard Deviations (N = 29)*

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<td>6.50</td>
<td>6.16</td>
<td>6.34</td>
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</table>

**M** 5.14  6.36  6.34  6.59  5.01  4.24  4.42  4.71  3.60  4.94

**SD** 0.92  0.62  0.46  0.23  1.42  0.84  1.03  1.93  1.57  1.20

*Note.* Shading indicates scores at or above the sample mean; SSP = speech starting pitch; SFI = speech final interval; SCNTR = speech contour; MSSP = musicalized speech starting pitch; MSFI = musicalized speech final interval; MSCNTR = musicalized speech contour; MLSP = melody starting pitch; MLFI = melody final interval; MLCNTR = melody contour.
Table 5.3

*Advanced Measures of Music Audiation (Raw Scores, Means, and Standard Deviations (N = 29)*

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Tonal</th>
<th>Rhythm</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
<td>23</td>
<td>40</td>
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<tr>
<td>2</td>
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<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
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<tbody>
<tr>
<td>Tonal</td>
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<tr>
<td>Rhythm</td>
<td>27.76</td>
<td>3.04</td>
</tr>
<tr>
<td>Composite</td>
<td>52.57</td>
<td>7.04</td>
</tr>
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</table>

*Note.* Shading indicates performing at or above the sample mean; AMMA/T = Advanced Measures of Music Audiation tonal score; AMMA/R = Advanced Measures of Music Audiation rhythm score; AMMA/C = Advanced Measures of Music Audiation composite score.

Individual performances demonstrated overall strengths and/or weakness for specific stimuli. For example, Subject 6 scored above the sample mean on all tasks except for all musicalized speech stimuli scoring 0.26, 0.33, and 0.25 below. Similarly, Subject 9 performed above the sample mean on all tasks except for musicalized speech final
interval and musicalized speech contour. Despite performing above the sample on all musicalized speech and melody tasks, Subject 7 scored slightly below on all speech tasks. Musicalized speech stimuli, however, proved to be the more challenging task with two out of three lowest means from the sample. Subject 14 scored above the sample mean only on musicalized speech final interval and contour; Subjects 23 and 27 scored below the sample on all tasks except for speech final interval; and the remaining subjects, Subjects 8, 13, 25, and 26, performed below the sample mean on all tasks.

Music majors. Of the nine music majors, seven scored above the sample mean scores for all melodic tasks, one scored above except for melodic final interval, and one did not perform above on any of the production tasks. Musicalized speech tasks solicited similar results. Seven of the music majors scored above the sample on all tasks, one subject scored below the sample on musicalized speech final interval and contour, and the final music major scored below the sample on all tasks. The results for speech targets were more varied with five music majors scoring above the sample, one performing below on starting pitch, one performing below on final interval, one scoring below the sample on all speech targets, and one scoring below on all production tasks.

Theater majors. Four of the five theater majors scored above the sample on all speech stimuli and on all melodic stimuli. The remaining theater major scored below the sample on every production task. The musicalized speech samples created the largest variety amongst this subgroup with one scoring above on all targets, one missing starting pitch, one missing final interval, and two scoring below on each stimuli.

Years of musical experience. Subjects 11, 13, 15, 16, 17, and 23 reported having 0 years of musical exposure. Subjects 13 and 15 scored below on all samples; Subject 23
scored below on all samples except for speech final interval; Subject 16 scored above except for speech final interval, speech final contour, and musicalized speech final interval; Subject 17 scored above except for melodic final interval, melodic contour, and musicalized speech final interval; and Subject 11 scored above the sample on all production targets.

There was a discrepancy for subjects reporting the lengthiest amount of musical exposure and those reporting the most formal music training. The six subjects with the longest amount of experience including formal and informal with a mean years of 16.17 (SD = 3.82) were Subjects 7, 9, 20, 27, 28, and 29. Subject 7 scored above on all musicalized speech and melody targets, Subject 9 scored above on all except for musicalized speech final interval and contour; Subject 20 scored below except for speech and musicalized speech starting pitch; Subject 27 only scored above on speech final interval; and Subjects 28 and 29 scored above on all stimuli.

Subjects 7, 9, 28, and 29 were also among the six reporting the longest amount of formal training in addition to Subjects 6 and 21 (M = 13.5, SD = 2.51). The mean starting age for these six was 6.83 with a standard deviation of 1.60. Subjects 6 scored above the sample on speech and melodic tasks but below on each musicalized speech stimuli and Subject 21 scored above on all stimuli except for speech final interval.

Perception Tasks’ Means

Mean scores of the tonal, rhythm, and composite raw scores from the Advanced Measures of Music Audiation (AMMA) were used in the analysis. Of the 29 subjects, 10 scored above the sample mean on all measures of the AMMA; 3 scored above on tonal and composite only; 1 scored above on rhythm and composite only; 1 scored above on
tonal alone; 4 scored above on rhythm alone; and the remaining 10 subjects scored below on all measures. Five of the music majors scored above the sample on all measures of the AMMA and the other four scored below on all measures. For the theater majors, 2 subjects scored above on all AMMA measure; 1 scored above on the tonal and composite only; and the final 2 scored above on rhythm only.

**Overall Means**

Eight were music majors (out of a total of 9 music majors from the sample) and four were theater majors (out of a total of 5 theater majors). For perception tasks, 14 subjects scored above the sample with five of those being music majors and three theater majors. Ten subjects scored above the sample on both production and perception. Four of these subjects were music majors and two were theater majors.

**Comparing Performance and Perception**

*Music majors.* For the five subjects who scored above on the perception tasks, they did similarly well on the production tasks. Subjects 4, 28, and 29 scored above on both production and perception tasks; Subject 21 scored above on all perception and production tasks except for speech final interval; and Subject 7 scored above on perception and all production except for the speech stimuli. The performance of the four who scored below on all factors of the AMMA was not necessarily reflective of how they scored on the production tasks, although Subject 25 scored below the sample on all production and perception tasks. The remaining three (viz., Subjects 1, 9, and 22) scored below the sample on speech starting pitch and musicalized speech starting pitch; musicalized speech final interval and contour; and melodic final interval only, respectively.
Theater majors. From the theater majors who scored above on all elements of the AMMA, Subject 2 also scored above on all production tasks, and contrarily, Subject 8 scored below on all production tasks. Subject 3, who scored above the sample on the tonal and composite elements of the AMMA, and Subjects 5 and 6 who scored above on the AMMA rhythm, all scored above the sample mean on production tasks except for musicalized speech starting pitch, musicalized speech final interval, and all musicalized speech stimuli, respectively.

Years of musical experience. As noted under Production Tasks’ Means, Subjects 11, 13, 15, 16, 17, and 23 reported having zero years of musical exposure. Subject 11 performed above the sample on the AMMA rhythm, AMMA composite, and above on all production elements; Subject 13 scored below the sample on both tasks; Subjects 15 and 23 scored below the sample mean on all tasks except for AMMA tonal and speech final interval (respectively); Subject 17 performed above the sample’s overall mean for production but not perception tasks; and despite scoring below the sample on several individual production tasks and AMMA rhythm, Subject 16’s mean lay above the sample for both production and perception.

Subjects with the longest amount of musical exposure, viz., Subjects 7, 9, 20, 27, 28, and 29, also performed at varying abilities. Subject 7 scored above the sample on all production tasks, except for speech, and above on all AMMA measures; and Subject 9 scored above on all production except for musicalized speech final interval and contour, but below the mean on all perception tasks. Subject 20 and 27 both performed poorly on production tasks only scoring above the sample on speech and melodic starting pitch and speech final interval (respectively), however Subject 20 scored above the sample on
AMMA tonal and AMMA composite while Subject 27 scored below the sample on all perception. Subjects 28 and 29 scored above the sample on all production and perception tasks.

Spearman Rank-Order Correlations

The examination of theater majors and tonal language speakers demonstrated no significant correlations to any results. With *rho* ranging from 0.01 to 0.98 amongst all correlations, it can be strongly suggested that those variables that did demonstrate significance (*p* < .05, *p* < .01, and *p* < .001) were considerably robust. The specifics of the statistical analysis for production tasks and perception tasks are presented first, followed by a comparison of production to perception tasks, then finally individual subgroups’ results are reported.

*Production Tasks*

Each production stimuli demonstrated various strengths of significance to each other (*p* < .05, *p* < .01, and *p* < .001) except for speech starting pitch and speech final interval (see Table 5.4). All musicalized speech and melodic tasks were highly correlated (*p* < .001). Total years of formal music training exhibited significant relationships to all melodic tasks and musicalized speech final interval and overall contour (see Table 5.5). Total years of informal music training shared similar results with an additional correlation to speech overall contour. While the age informal musical exposure first began did not demonstrate any relationship to tasks, when formal music training began was significant for all tasks except speech and musicalized speech starting pitch and musicalized speech overall contour.
### Table 5.4
*Intercorrelations for Production Stimuli (N = 29)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>SSP</th>
<th>SFI</th>
<th>SCNTR</th>
<th>MSSP</th>
<th>MSFI</th>
<th>MSCNTR</th>
<th>MLSP</th>
<th>MLFI</th>
</tr>
</thead>
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<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SFI</td>
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<td>SCNTR</td>
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<td>-</td>
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<tr>
<td>MSSP</td>
<td>0.78***</td>
<td>0.48**</td>
<td>0.69***</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>MSFI</td>
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<td>0.67***</td>
<td>0.62***</td>
<td>0.78***</td>
<td>-</td>
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<td></td>
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</tr>
<tr>
<td>MSCNTR</td>
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<td>0.60***</td>
<td>0.91***</td>
<td>0.85***</td>
<td>-</td>
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<td></td>
</tr>
<tr>
<td>MLSP</td>
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<td>0.45*</td>
<td>0.55**</td>
<td>0.73***</td>
<td>0.68***</td>
<td>0.82***</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>MLFI</td>
<td>0.55**</td>
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<td>0.53**</td>
<td>0.77***</td>
<td>0.75***</td>
<td>0.88***</td>
<td>0.90***</td>
<td>-</td>
</tr>
<tr>
<td>MLCNTR</td>
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<td>0.53**</td>
<td>0.78***</td>
<td>0.75***</td>
<td>0.89***</td>
<td>0.91***</td>
<td>0.98***</td>
</tr>
</tbody>
</table>

*Note.* SSP = speech starting pitch; SFI = speech final interval; SCNTR = speech contour; MSSP = musicalized speech starting pitch; MSFI = musicalized speech final interval; MSCNTR = musicalized speech contour; MLSP = melody starting pitch; MLFI = melody final interval; MLCNTR = melody contour. *p < .05. **p < .01. ***p < .001.

### Table 5.5
*Correlations Between Musical Experience and Production Tasks (N = 29)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Informal exposure to music</th>
<th>Formal training in music</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (years)</td>
<td>Began (age)</td>
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<tr>
<td>SFI</td>
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<td>0.21</td>
</tr>
<tr>
<td>SCNTR</td>
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<td>0.19</td>
</tr>
<tr>
<td>MSSP</td>
<td>0.28</td>
<td>0.10</td>
</tr>
<tr>
<td>MSFI</td>
<td>0.43*</td>
<td>0.30</td>
</tr>
<tr>
<td>MSCNTR</td>
<td>0.37*</td>
<td>0.07</td>
</tr>
<tr>
<td>MLSP</td>
<td>0.65***</td>
<td>0.04</td>
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<tr>
<td>MLFI</td>
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<td>0.03</td>
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<tr>
<td>MLCNTR</td>
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<td>0.06</td>
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</table>

*Note.* SSP = speech starting pitch; SFI = speech final interval; SCNTR = speech contour; MSSP = musicalized speech starting pitch; MSFI = musicalized speech final interval; MSCNTR = musicalized speech contour; MLSP = melody starting pitch; MLFI = melody final interval; MLCNTR = melody contour. *p < .05. **p < .01. ***p < .001.

### Comparing Production and Perception Tasks

Table 5.6 illustrates the correlations between AMMA tonal, AMMA rhythm, and AMMA composite scores to performance tasks. AMMA tonal scores demonstrated significance in all musicalized speech and melodic tasks at the level of .001 for musicalized speech starting pitch and contour, .01 for musicalized speech final interval...
and melodic final interval and contour, and .05 for musicalized speech starting pitch.

AMMA rhythm exhibited extremely strong relationships to musicalized speech starting pitch and contour, all melodic tasks ($p < .001$) and significance to speech starting pitch. AMMA composite scores correlated significantly to all musicalized speech and melodic tasks in addition to speech starting pitch. As is illustrated in Table 5.7, no significant relationships were found between any AMMA measurements and the amount of formal or informal training.

Table 5.6
*Correlations Between Production Tasks and AMMA Measurements (N = 29)*

<table>
<thead>
<tr>
<th>Tasks</th>
<th>SSP</th>
<th>SFI</th>
<th>SCNTR</th>
<th>MSSP</th>
<th>MSFI</th>
<th>MSCNTR</th>
<th>MLSP</th>
<th>MLFI</th>
<th>MLCNTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMMA/T</td>
<td>0.32</td>
<td>0.08</td>
<td>0.13</td>
<td>0.61***</td>
<td>0.47**</td>
<td>0.63***</td>
<td>0.47*</td>
<td>0.50**</td>
<td>0.52**</td>
</tr>
<tr>
<td>AMMA/R</td>
<td>0.44*</td>
<td>0.08</td>
<td>0.19</td>
<td>0.59***</td>
<td>0.36</td>
<td>0.59***</td>
<td>0.58***</td>
<td>0.59***</td>
<td>0.58***</td>
</tr>
<tr>
<td>AMMA/C</td>
<td>0.39*</td>
<td>0.08</td>
<td>0.16</td>
<td>0.65***</td>
<td>0.48**</td>
<td>0.67***</td>
<td>0.55**</td>
<td>0.59***</td>
<td>0.60***</td>
</tr>
</tbody>
</table>

*Note.* AMMA/T = Advanced Measures of Music Audiation tonal score; AMMA/R = Advanced Measures of Music Audiation rhythm score; AMMA/C = Advanced Measures of Music Audiation composite score; SSP = speech starting pitch; SFI = speech final interval; SCNTR = speech contour; MSSP = musicalized speech starting pitch; MSFI = musicalized speech final interval; MSCNTR = musicalized speech contour; MLSP = melody starting pitch; MLFI = melody final interval; MLCNTR = melody contour. *$p < .05$. **$p < .01$. ***$p < .001$. 

Table 5.7
*Correlations Between Musical Experience and AMMA Measurements (N = 29)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Informal exposure to music</th>
<th>Formal training in music</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (years)</td>
<td>Began (age)</td>
</tr>
<tr>
<td>AMMA/T</td>
<td>0.07</td>
<td>0.13</td>
</tr>
<tr>
<td>AMMA/R</td>
<td>0.30</td>
<td>0.04</td>
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<tr>
<td>AMMA/C</td>
<td>0.19</td>
<td>0.12</td>
</tr>
</tbody>
</table>

*Note.* AMMA/T = Advanced Measures of Music Audiation tonal score; AMMA/R = Advanced Measures of Music Audiation rhythm score; AMMA/C = Advanced Measures of Music Audiation composite score.

Subgroup Results

*Music majors.* The nine music majors, viz., Subjects 1, 4, 7, 9, 21, 22, 25, 28, and 29, individually demonstrated varying abilities on production and perception tasks. Their correlation results as a subgroup are illustrated in Table 5.8. While there are slight
discrepancies between categories, amount of formal music training proved to be the more significant factor when correlated to subjects’ performance on production tasks. However, overall amount of informal musical exposure was the stronger factor when correlated to subjects’ performance on perception tasks.

Table 5.8
*Correlation for Music Majors (n = 9) Compared to Sample (N = 29)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Music Majors</th>
<th>Informal Exposure (years)</th>
<th>Formal Training (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMMA/T</td>
<td>-0.08</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>AMMA/R</td>
<td>-0.01</td>
<td>0.30</td>
<td>0.23</td>
</tr>
<tr>
<td>AMMA/C</td>
<td>-0.06</td>
<td>0.19</td>
<td>0.10</td>
</tr>
<tr>
<td>SSP</td>
<td>0.22</td>
<td>0.20</td>
<td>0.24</td>
</tr>
<tr>
<td>SFI</td>
<td>0.12</td>
<td>0.33</td>
<td>0.37</td>
</tr>
<tr>
<td>SCNTR</td>
<td>0.38*</td>
<td>0.29</td>
<td>0.44*</td>
</tr>
<tr>
<td>MSSP</td>
<td>0.29</td>
<td>0.28</td>
<td>0.36</td>
</tr>
<tr>
<td>MSFI</td>
<td>0.40*</td>
<td>0.43*</td>
<td>0.49**</td>
</tr>
<tr>
<td>MSCNTR</td>
<td>0.40*</td>
<td>0.37*</td>
<td>0.49**</td>
</tr>
<tr>
<td>MLSP</td>
<td>0.54**</td>
<td>0.65***</td>
<td>0.68***</td>
</tr>
<tr>
<td>MLFI</td>
<td>0.50**</td>
<td>0.58***</td>
<td>0.60***</td>
</tr>
<tr>
<td>MLCNTR</td>
<td>0.48**</td>
<td>0.59***</td>
<td>0.59***</td>
</tr>
</tbody>
</table>

*Note.* Shading indicates highest mean score for said variable; AMMA/T = Advanced Measures of Music Audiation tonal score; AMMA/R = Advanced Measures of Music Audiation rhythm score; AMMA/C = Advanced Measures of Music Audiation composite score; SSP = speech starting pitch; SFI = speech final interval; SCNTR = speech contour; MSSP = musicalized speech starting pitch; MSFI = musicalized speech final interval; MSCNTR = musicalized speech contour; MLSP = melody starting pitch; MLFI = melody final interval; MLCNTR = melody contour. *p < .05. **p < .01. ***p < .001.

**Tonal language speakers.** Five subjects were non-native English speakers; and of those, two were tonal language speakers. These were Subjects 1, 2, 7, 18, and 20 who spoke Mandarin, Korean, Taiwanese, Chinese, and Korean respectively. None of these subjects’ data were statistically significant for the tonal language subgroup.

**Theater major.** The subgroup of five theater majors (viz., Subjects 2, 3, 5, 6, and 8) did not exhibit statistically significant results.
Summary

The analysis presented in this chapter provides the empirical results supporting the predictions that were the impetus to this study. Musical experience, either in a formal or informal setting, can affect a subject’s performance on melodic and prosodic production tasks and melodic perception tasks. Furthermore, at what age these musical experiences were commenced also correlated to how well individuals performed. While performance on the Advanced Measures of Music Audiation (AMMA) did not correlate with the aforementioned criteria, it did exhibit strong relationships with a majority of the production tasks. As an examination designed to assess musical aptitude or potential ability through the assessment of tone and rhythm, it seems the inclusion of the AMMA was an appropriate assessment of subjects’ perceptual abilities related to melodic and prosodic tasks as well. Building upon the results presented here, Chapter 6 suggests several theories which evolved from the analysis, addresses the particularities of informal and formal musical experiences, and discusses the implications of these results for music education and cognitive psychology.
The previous chapter reported the results for individual performance and subgroups through the use of descriptive statistics and linear regressions. Along with a discussion of these findings from Chapter 5, this chapter offers additional interpretations of the data as a means of contextualizing these findings within music education and cognitive psychology. Upon additional scrutiny of the statistical data and the qualitative data obtained from fieldnotes and post-test surveys, several resultant trends emerged. This information is presented and elaborated upon in four sections within this chapter. The first, Discussion of Descriptive and Statistical Analysis, addresses the results reported from the statistical analysis. Part II, Suggested Trends Based on the Results, further delineates the potential reasons for these results. The qualitative data collected throughout the testing is presented in Part III, Qualitative Analysis, followed by additional suggested explanations in Part IV. The final portion of this chapter, Part IV’s Implications of Results, elaborates upon the implications of these theories and results for music education and cognitive psychology.
Part I: Discussion of Descriptive and Statistical Analysis

**Descriptive Statistics Discussion**

**Complexities of the Tasks**

Based on the mean scores of subjects’ production tasks, a conclusion can be drawn as to their difficulty. Since performance on speech tasks was the least varied, followed by the musicalized speech, then melodies (see Table 6.1), it can be deduced that this would also reflect the general order of difficulty of tasks.

**Table 6.1**

*Production Tasks Means and Standard Deviations (N = 29)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>SSP</th>
<th>SFI</th>
<th>CNTR</th>
<th>MSSP</th>
<th>MSFI</th>
<th>MLSP</th>
<th>MLFI</th>
<th>ML CNTR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>M</strong></td>
<td>6.36</td>
<td>6.34</td>
<td>6.59</td>
<td>5.01</td>
<td>4.24</td>
<td>4.71</td>
<td>3.60</td>
<td>4.94</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>0.62</td>
<td>0.46</td>
<td>0.23</td>
<td>1.42</td>
<td>0.84</td>
<td>1.03</td>
<td>1.93</td>
<td>1.57</td>
</tr>
</tbody>
</table>

*Note.* SSP = speech starting pitch; SFI = speech final interval; SCNTR = speech contour; MSSP = musicalized speech starting pitch; MSFI = musicalized speech final interval; MSCNTR = musicalized speech contour; MLSP = melody starting pitch; MLFI = melody final interval; MLCNTR = melody contour.

Performance of starting pitch and final interval proved increasingly poorer from speech, musicalized speech, to melody. The boxplot in Figure 6.1 depicts this trend for all starting pitch tasks. The range of mean scores for speech starting pitch were 5.03 to 7.00 with an overall mean for subjects of 6.63. The range for musicalized speech starting pitch was larger at 2.2 to 6.81 with an overall mean of 5.01. Melodic starting pitch had the largest range of 1.19 to 7.00 with an even lower average mean score of 4.71. Figure 6.2 illustrates a paralleled pattern for speech final interval, musicalized speech final interval, and melodic final interval, with ranges from 5.41 to 6.91 (m = 6.34), 2.50 to 6.34 (m = 4.24) and 1.28 to 6.34 (m = 3.6), respectively.
Figure 6.1 Boxplot of starting pitch mean scores for the sample (N = 29).

Figure 6.2 Boxplot of final interval mean scores for the sample (N = 29).
Experiential Factors Influencing Performance

Speech stimuli. The overall success of subjects on all speech tasks regardless of musical background implies the ease of this particular stimulus. A possible explanation for this is the familiarity of the targets, and the presumed practice subjects would have with similar phrases in daily speech. The strong results for music majors in musicalized speech, and especially melodic stimuli, also supports the explanation that personal experience affected performance. If this is true, then it is possible that the melodic reinforcement from musical practice may be represented in the performance of these two stimuli.

Presentation of targets. Subject success may also have been attributed to the form in which targets were presented. The familiarity of the human voice in speech is an ordinary occurrence for all subjects therefore making the presentation of these targets a familiar one. The presentation of the melodic tasks using a MIDI piano recording may also have been more familiar for subjects. The piano is a common instrument and most likely would have been recognized as such. The melodic speech samples, on the other hand, were computer generated producing an unfamiliar timbre. The lack of glides between pitches for musicalized speech may have also been jarring for subjects. These stimuli incorporated the frequencies of pitch with the likeness of music so it was neither recognized as speech nor music. This combination of unusual characteristics required subjects to acclimate themselves to the tone color of this foreign sample, thus adding to the complexity of the task.

Syllabic attachments. As noted in the review of the literature, it has been suggested that the combination of words and melodies may aid in cognitive tasks such as
language acquisition. As introduced in Chapter Two, Schön et al. (2008) reported that this may be attributed to: (a) the overall attention solicited by semantics, (b) the phonological boundaries enhanced by pitch changes resulting in a greater ease of discrimination, and/or (c) the simultaneous linguistic and melodic mapping that can foster greater global connectivity. The success of subjects on the speech tasks may have been due to any of the aforementioned explanations. For example, emotionally connecting to the words and their meaning may have provided an additional anchor for subjects to recall or perhaps a supplementary cognitive connection to navigate through in addition to the melodic and prosodic properties. Thus, when these properties were removed (i.e., musicalized speech and melodic targets), the tasks became more difficult as was illustrated in the production task data.

**Subgroups**

Having a limited amount of participants in this study, it is with caution that subgroup theories can be made. With smaller samples, conclusions are made more cautiously. However, by examining overall trends through descriptive statistics and individual performance means along with the regressions calculated in the statistical analysis, more robust explanation can be made based on the characteristics of the subgroup.

*Music majors.* As covered in Chapter Five, the performance of music majors varied, however the majority of them scored above the sample on all tasks with an even greater percentage scoring above on musicalized speech and melodic tasks. The performance on the musicalized speech and melodic tasks can most likely be attributed to
subjects’ experience hearing, reading, and performing musical phrases. This would also explain the similar results music majors had for perception tasks.

While these subjects auditioned to be accepted as music majors for their university, there is more than likely wide variability in their individual abilities. Added training provides opportunity for further musical experiences and as the statistical analysis demonstrates, the amount of formal training was even more significant than those majoring in music. Although the music majors did report having the lengthiest amount of formal training, several other subjects also reported having extended periods of formal musical training. Furthermore, several non-music majors reported having even lengthier amounts of informal musical experiences. These aspects are addressed under Statistical Analysis of this chapter.

Theater Majors. As expected, a large majority of theater majors scored above the sample on all speech tasks. Presuming theater majors may be considered students of prosodic expression from the nature of their field, it would be expected that they would score equally well on musicalized speech and melodic tasks. This subgroup did score equally well on melodic tasks however, musicalized speech elicited the greatest variance of performances. For the aforementioned explanations such as familiarity of targets, experience with tasks, and prior experience with performance, it can be concluded that these impacted this subgroup’s performance on production tasks as well.

Statistical Analysis Discussion

As reported in the intercorrelations presented in Chapter Five, rho ranged from 0.01 to 0.98. Therefore, those variables that did exhibit significance with r, close to 1 can
be acknowledged as strongly related. Significant correlations were found within the variety of tasks themselves, and amongst individual subject variability.

**Correlations Within Tasks**

All performance tasks were significantly correlated, and all but speech starting pitch and speech final interval, at the level of .001. The strength of the correlations ($p < .001$) between all musicalized speech tasks and melodic tasks validate the test design as a reliable demonstration of performance ability since the prosodic and melodic ability of subjects was consistent for each stimulus.

Nearly all production tasks were strongly correlated to the perception tasks as well. The tonal score of the Advanced Measure of Music Audiation (AMMA) demonstrated strong relationships to all musicalized speech and melodies ($0.47 < r_s < 0.63$, $p < .05$, $p < .01$, and $p < .001$) but not to any speech tasks. Although there are tonal elements present in the prosody of the speech targets, the presence of syllables may have affected the cognition of these tasks. Since there were no words associated with the musicalized speech and melodies, subjects may have interpreted the targets as more musical or tonal, thus explaining this correlation.

The AMMA rhythm scores correlated to all starting pitch tasks ($r_s = .44$, $p < .05$; $r_s = .59$, $p < .001$; and $r_s = .58$, $p < .001$) musicalized speech contour ($r_s = .59$, $p < .001$), and all remaining melodic tasks ($r_s = .59$, $p < .001$ and $r_s = .58$, $p < .001$). As detailed later in this chapter under *AMMA Rhythm and Starting Pitch*, there is a possibility that there may be a relationship between rhythmic preciseness and starting pitch performance. This timing may have also aided in the overall accuracy of subjects, as is evident from the overall statistical significance of these tasks. Observations of subjects throughout the
study found that those who paused or hesitated before repeating a target, performed with additional errors. Under Part III: Qualitative Analysis of this chapter, these timing issues are addressed with specific attention to individual subjects.

Correlations Amongst Subject Variables

Significant relationships were demonstrated between the amount of informal musical exposure, formal musical training, and the age formal training began. Since all music majors reported having at least 7 years of formal training beginning anywhere from 5 to 11 years of age, it is logical that there would be strong levels of association between several variables amongst subjects. The most significant correlations as demonstrated by \( \rho \) were between the total years of formal training, followed by the age the subjects began their formal training, and finally the total years of informal musical exposure.

The correlations between the age subjects began their formal music training and all melodic tasks, speech final interval, speech overall contour, and musicalized speech final interval are in accord with the literature indicating a connection between starting age and musical training. As suggested by several studies, the prime time to begin formal music training in order to take advantage of the brain’s plasticity and solicit the greatest amount of cognitive growth is before the age of 7 (Altenmüller & Gruhn, 2002; Costa-Giomi et al., 2001; Pantev et al., 2001; Watanabe, Savion-Lemieux, & Penhune, 2007).

For the participants in this study, the average age of initiating formal study was 4.86, well within the suggested window, corroborating the notion of early introduction to music training fostering later success.
There was no significant correlation between AMMA scores and age, or amount of informal and formal musical experiences. Gordon developed the AMMA to assess musical aptitude, not ability. This would be the genetic predisposition and environmental factors contributing to examinee’s success (Gordon, 1990). As reported in Chapter Five, several subjects who scored well on the AMMA did not necessarily score as well on the production tasks. While they may have possessed the aptitude for tonal and rhythmic discrimination, they may not have been able to reproduce them. Therefore, this supports the notion that perceiving and producing prosodic and melodic tasks may be two separate aspects of cognition.
Part II: Suggested Trends Based on the Results

This section of the chapter offers an explanation of the trends that evolved throughout the study, and considers the basis for these results. These are provided simply as speculative comments concerning these relationships. Each speculation is presented below, along with the subjects and/or subgroups that help substantiate each premise. The connectedness between language and music, and musical background and subject ability in production and perception tasks are also addressed through each explanation.

Experimental Validity

As reported in the Statistical Analysis in Chapter Five, significant correlations were demonstrated between the AMMA tonal portion and all musicalized speech and melody. This would seem to confirm the ability of this particular examination to predict tonal aptitude in musical tasks. The rhythm portion also exhibited significant correlations in these tasks, except for musicalized speech final interval and included speech starting pitch. Although not the focus of this study, it seems that the rhythmic aspects of musical aptitude may have been appropriately assessed in the musicalized speech and melodic tasks. These results confirm the validity of utilizing this particular examination in association with the developed production tasks.

An explanation can be offered that might elucidate how musical aptitude, as measured by the AMMA, would predict success on production tasks. Overall, six of the seven subjects who scored above the sample mean on every production task also scored above the sample on all perception tasks. Looking at the individual elements of the perception tasks, fifteen subjects scored above the sample on the AMMA tonal with 73% of those subjects scoring above the sample in overall mean score, 73% scoring above the
sample on melodic stimuli, and 60% scoring above the sample on musicalized speech stimuli. Sixteen subjects scored above the sample for AMMA rhythm. Seventy-five percent of these subjects scored above the sample in overall mean score and 69% scored above the sample on each starting pitch stimuli. With results better than chance it would seem there is a matter of predictability from performance on the AMMA and production abilities.

**AMMA Rhythm**

**AMMA Rhythm and Speech**

Interestingly, only the AMMA rhythm and composite scores correlated to any speech task. From the sixteen subjects who scored above the sample on AMMA rhythm, nine scored above the sample on all speech stimuli. With success in both the performance and production of similar abilities, the rhythmic elements of music or of speech, it may be suggested that the ability to perceive specific timing elements may be related to the ability to produce them. This notion has been the basis behind several therapeutic practices such as the rehabilitation of motor skills in stroke patients or the returned use of speech in aphasic patients (Norton, Zipse, Marchina, & Schlaug, 2009; Schneider, Schönle, Altenmüller, & Münte, 2007).

**AMMA Rhythm and Starting Pitch**

A strong relationship was found between the AMMA rhythm and all starting pitches. To examine how this was demonstrated amongst individuals, subject mean production and perception scores were compared. Subject 19 performed well above the sample mean on each production’s starting pitch scoring 6.91, 5.36, and 4.94 on speech, musicalized speech, and melodies, respectively. Subject 19 also scored above the sample
on AMMA rhythm. He did not perform as well on any of the musicalized speech stimuli, melodic stimuli, or the AMMA tonal thus exhibiting a strong relationship between rhythmic aptitude and starting pitch performance. Conversely, Subjects 1 and 3 scored below the sample on AMMA rhythm. Subject 1 also performed below on speech and musicalized speech starting pitch and Subject 3 scored below on musicalized speech starting pitch. Both subjects performed above the sample on all remaining production tasks. The difficulty with starting pitch tasks along with their performance on the AMMA rhythm again supports the idea of a relationship between these tasks.

From fieldnotes collected during the analysis of the 5,568 subject sound files, nearly every subject performed his or her response in the tempo in which the target was presented. Responses were therefore completed in the same amount of time as the targets. Errors did occur, however, for those several responses that were delayed and out of the target tempo. Subject 20 was a non-music major reporting no formal music training but 13 years of informal musical experience. She scored below the sample on all production tasks except for speech starting pitch and melodic starting pitch. Her responses most often began after a pause or hesitation and were almost always outside the target tempo. On perception tasks she scored above the mean on AMMA tonal and well above the mean on AMMA rhythm. Although this subject demonstrated difficulty with accurate timing throughout the production tasks, her performance on the AMMA rhythm and starting pitch tasks corroborate the conjecture that there may be a connection between these two elements.
Statistically significant correlations were demonstrated between the AMMA tonal and all musicalized speech and melodic tasks ($0.47 < r_s < 0.63$, $p < 0.01$ and $p < 0.001$). This would suggest that individuals who performed poorly on the tonal portion of the AMMA might perform similarly on musicalized speech and melodic tasks. This was characterized by the majority of subjects who did score above the sample mean on the AMMA tonal and those who performed below on the two elements. Despite the variance amongst individuals, this general performance supported the relationships found in the statistics.

**Consistencies on Production and Perception Performance**

Those subjects who performed above the sample on all or nearly all production tasks also scored above the sample on all perception tasks. Similarly, those who scored below the sample on all or nearly all production tasks also performed below the sample on perception tasks. Forty-eight percent of the sample fell in one of these two categories. More specifically, Subjects 2, 4, 10, 12, 28, and 29 performed above the sample mean on all production and perception tasks; Subject 11 performed above on all except for AMMA rhythm, and Subject 21 performed above on all except for speech final interval, although only 0.09 below the sample mean. For those performing below, Subjects 13, 25, and 26 scored below the sample on both production and perception tasks; Subjects 23 and 27 scored below on all except for speech final interval; and Subject 15 scored below on all except for AMMA tonal. These results suggest a potential predictability between production and perception ability.
Inconsistencies on Production and Perception Performance

An additional conjecture suggests a difference in the production and perception abilities of subjects based on the analysis. For example, Subjects 8, 14, 16 scored above the sample on all AMMA elements but below the sample on all production tasks. Subject 20 performed similarly, but did score above the sample on speech starting pitch and melodic starting pitch. Conversely, Subjects 22 and 24 scored below the sample on perception tasks but above on all or nearly all production tasks.

Interestingly, Subjects 8, 14, 16, and 20 reported having no formal music training and limited informal musical experience. Perhaps this provides an explanation for the inconsistent scores on tasks. Suggestions for this disparity are offered further in Part IV of this chapter under Production practice and Short-term memory.
Part III: Qualitative Analysis

Fieldnotes were gathered from observations of subject behavior throughout the testing. Observations were made of individual subjects during the production tasks with specific regard to reactions to their performance and the repetition of the targets themselves. Again, since the production tasks were presented and subsequently recorded in random order then grouped by target and assessed blindly, the observations were made and notated using the numbered order in which they were presented. These were then cross-referenced to the spreadsheet of results reported by Praat where the order and subject number were included. This process ensured anonymity, allowing for unbiased observations.

Task Difficulty

From qualitative data collected throughout the analysis, it was evident that specific targets, intervals, or alterations to target contours were generally challenging for the entire sample. Large intervallic jumps such as octaves were more challenging for non-musicians although as reported under Individual Subject Performance, one subject negotiated the difficulty of these leaps by transposing and singing the octave within her comfortable range. The first interval of musicalized speech sample 21 was an octave leap. This proved to be a challenge for most subjects resulting in a mean sample score of 4.48 ± 1.43. When the octave was placed as a final interval, such as melodic sample 51, it was also difficult for subjects. In this target, nearly every mistake was in performing a minor third instead of completing the octave.

Increments of half steps were difficult for subjects moreover, where these half steps were in the target contour contributed to the challenge. For example, the final interval of
musicalized speech sample 35 was an ascending half step, and was the first target containing this pattern. Only 4 subjects performed this correctly with most of the errors happening due to subjects performing a descending half step instead of ascending. Another complexity with a half step relationship was when it occurred at the beginning of a phrase such as musicalized speech target 43. From this target, not a single perfect rating was scored.

The smaller intervals equal to or less than a major third fostered more successful responses by all subjects such as melodic sample 44. However, intervals smaller than a half step, although infrequent yet present in musicalized speech target 50, were extremely difficult for most subjects to decipher. It would seem understandable since as explained in Chapter Two, speech incorporates large intervals while music most often utilizes more fine-grained discriminations however; neither commonly contains intervals less than half steps. This would then credibly serve as a challenge to all subjects when presented with this interval.

Discriminations between half steps and whole steps were also particularly challenging for subjects, such as the first interval on melodic target 11. Nearly all subjects performed a half step instead of the target whole step. The aforementioned theories in Part I of personal experience with similar tasks, such as what one might experience from playing an instrument or in an aural skills music class, may have contributed to the performance of subjects who had any musical experience.
Individual Subject Performance

General trends of subgroup performances were exemplified by the qualitative observations of individual subjects. Their responses to the targets and any conduct during the testing help to illustrate these instances.

Music majors. All but one instance of subjects correcting themselves and repeating the target a second time was performed by a music major. Subject 28, who scored above on all production and perception tasks, seemed the most frustrated and disappointed with her performance throughout the production tasks. In melodic sample 2, she was unable to complete her response after singing an incorrect starting pitch that seemed to distract her from finishing. This may have been the result of her self-perpetuated distraction or perhaps from a loss of content due to short-term memory. This subject also forfeited and did not attempt to complete musicalized speech sample 59. She did, however, regulate the registers in which she sang and comfortably transposed to avoid large octave jumps, which, as mentioned previously, proved to be challenging for many others.

Based on her audible responses throughout the production tasks, it was clear Subject 25, another music major, was also cognizant of her errors. In melody sample 3, she was aware of her mistake and tried to repeat the target a second and third time in order to perform the correct contour. As with Subject 28, possible explanations for this may either have been distraction from self-assessment or short-term memory limitations.

Theater majors. From observations during production tasks, Subject 2 and 12 were the only two theater majors who were vocal in their frustrations. Both subjects scored above the sample mean on all production and perception tasks. Subject 2 had 2
years of formal music training beginning at age 15 and 11 years of informal music training beginning at age 10. Subject 12 reported having no formal music training but 2 years of informal music experience beginning at 18. Both subjects were aware of their errors on several samples and made verbal comments of their frustration. Subject 12 exclaimed, “dammit” after being unsuccessful in his attempt at melodic contour sample 18 and said, “ew” after his repetition of melodic sample 38. In melodic sample 25, Subject 2 was not only aware of her mistake in the final interval, but she repeated it a second time, then sang “that’s the last” while singing on the final pitch. If musical experience is connected to production and perception abilities as demonstrated in the statistical analysis, it can be speculated that the ability to self-assess on these tasks might also be connected as illustrated with these theater majors and the previously discussed music majors.

Musical experience. Subject 11 reported having no formal music training and less than 1 year of informal musical exposure on the clarinet. He scored above the sample on all production tasks and above on the AMMA tonal. Despite his limited musical experience, he performed well on his tasks and was aware of his errors as well. For example, for melodic sample 48, he exclaimed, “shoot” when he performed the final interval incorrectly.

Subjects 15 and 23 each scored below the sample on all production tasks. Subject 15 scored below on perception tasks and Subject 23 scored above on the AMMA tonal only. Both these subjects were non-music and non-theater majors and reported having no formal or informal musical experiences. These two subjects answered nearly all musicalized speech and melodic targets with a unique stock response that was incorrect.
in pitch and did not reflect the rhythm of the target either. Two possible explanations may be provided for this behavior. First, from the lack of musical experience, the subjects may have been unable to accurately self-assess and were unaware of their errors. A second explanation, although also potentially related to the lack of musical experience, could have been that these subjects were potentially overwhelmed by the challenge of the tasks and offered their stock response in order to expedite their participation.

Based on the perception tasks scores of Subject 15 and observation notes, it may be suggested that she was attempting to respond to the targets correctly, but was unsuccessful in her efforts for one of the abovementioned theories. It would also be presumed that since Subject 23 scored above the sample mean on the AMMA tonal portion, that she would also perform well on the musicalized speech and melodic samples. However, this may be an example of a subject with the ability to perceive the correct pitches with the inability to perform them accurately as previously suggested in *Inconsistencies on Production and Perception Performance* in Part II of this chapter. Both these explanations are speculative. A definite resolution would have required additional post-study interviews with the subjects, however since subject numbers were randomly assigned and the analysis was blocked and rated blindly, this was not possible.
Part IV: Additional Explanations

_Tonal Mapping_

Through all the variations of the singsong contour, nearly every subject sang the original, more recognized contour illustrated in Figure 6.3. This occurred for both musicalized speech and melodic targets regardless of what or where the alteration to the contour occurred. This also meant that despite these variances, subjects were still able to sing the correct final interval if it was unaltered. This scenario suggests the possibility of tonal memory, or mapping, for this familiar contour. This is an example of a long-term memory result as opposed to short-term effects as discussed later in this section.

_Figure 6.3 Melodic transcription of the original singsong contour._

_Speech Tasks_

Despite the significant relationships demonstrated between the AMMA tonal and musicalized speech and melodies, no statistically significant correlation was found between AMMA tonal and speech tasks. A suggestion, as mentioned under Part I, may be the ease or familiarity all subjects had with the speech stimuli resulting in limited variability of scores and weak correlations.

An additional explanation may be the targets themselves and the perceptions subjects had of these targets. The AMMA was designed to assess musical aptitude by means of tonal and rhythmic examination, but perhaps the subjects did not perceive the speech tasks as musical. If on a lower level of processing these tasks were not approached as musical or tonal phrases, then perhaps on a higher level of cognition, they were not
managed as such. This might explain why a strong correlation at the level of .01 and .001 was found between musicalized speech and melodic tasks, but not speech tasks.

Performance Practice

As mentioned in prior sections of this chapter, former experience played a role in the success of several subjects’ performances. The oral repetition of targets in this study may have hindered several subjects while others may have been better prepared based on their background in music. It may be assumed that both theater and music majors would have prior experience performing publicly to some extent (i.e., in the classroom, in rehearsals or on stage). Furthermore, it can be assumed that theater majors might have specific experience with prosodic repetitions and oral recitations that could have provided an advantage in the performance tasks of this study. Examination into the performance background of all subjects including theatrical experience might illustrate the significance of this experience. The post-test surveys in this study limited the questions to musical background. It is only with a general knowledge of theater and music curricula that this explanation has been offered.

Final Intervals and Intermittent Pitches

For each stimulus, accuracy on final interval mean scores was the lowest. From the qualitative observations, most errors occurred with the final pitch and/or final interval. This may be attributed to a lack of concentration from subject fatigue or frustration throughout the testing, or the inability to focus on the final pitch when the subject had already heard and focused on the starting pitch and the subsequent intermittent pitches. Although the final interval of the target would have been the last two pitches the subject heard, there would still be the distraction of the repetition of all
pitches prior to reaching the final interval. As Plantinga and Trainor (2008) have reported, the greater number of tones played after a target pitch correlated negatively to the ability of remembering that target pitch. This addresses a possible reason why subjects were unable to successfully reproduce the final interval; there were 4 to 5 interfering pitches that were to be recalled prior to reaching the final interval. This may have been distraction enough for subjects to forget the final interval.

*Short-Term Memory*

Another theory addressing the variance of subject performance amongst subgroups and between starting pitch, final interval, and overall contour success may be the relatively limited ability for human recall after several seconds. This may be a result of either short-term memory or echoic memory, as described in Chapter Four. Baddeley’s model of short-term or working memory covers three components of human central executive function including reference to echoic memory: (a) phonological loop, (b) visuospatial sketchpad, and (c) episodic buffer (Baddeley & Hitch, 1974). The first component, the phonological loop, is synonymous to echoic memory. This is the portion that acts as an auditory storage for cognitive transfer or recall.

It may be possible that the non-music majors and their capacity to retain tonal information as a function of either their short-term or echoic memory may not be as developed and practiced as music majors and those with extensive musical experience. The stimuli in the production tasks ranged from 3 to 4 seconds. This means the length of time from the beginning of the target to the subject’s repetition was around 6 to 8 seconds. This amount of time would explain the loss of tonal information towards the end of the repeated phrase, leaving the final interval forgotten. Based on the results from the
present study, it can be suggested that with extended musical training and experience, a potential change to subjects’ mental capacity for retaining and recalling information is lengthened.

An additional complexity for subjects could have been the amount of pitches presented in each target. In 1956, noted psychologist George Miller proposed that the average person can identify seven items plus or minus two (Miller, 1956). He continued to specify the restrictions suggesting that the average person can identify one of five or six pitches before getting confused. Although the tasks of the present study required subjects to repeat pitches and not identify them, Miller’s theories are still relevant especially when considering the varied musical experience of subjects. Miller states that these confines are not fixed and can be expanded upon due to experiential history and individual performance.

An additional way in which subjects could affect their memory for tones is by chunking the information to be recalled, or recoding (Miller 1956). Chunking is the organizational grouping of presented information (Burtis, 1982; Ellis, 1996). Recoding is another term used for the either conscious or subconscious mental classification of information to facilitate memory and recall. Several subjects throughout their repetition of musicalized speech targets demonstrated this process. Of those subjects unable to complete the entire target, their errors were often from only being able to recall the first half or the second half of the target. Although this data was from qualitative observations alone, it would appear these pitches were mentally organized based on either the intervallic relatedness, or the pitches’ relationship to the overall musical phrase.
Formal music training can typically involve aural skills practice and repetitions of melodic phrases. Within these phrases, intervallic relationships are studied for the purpose of achieving precise intonation. This would require intermittent chunking of intervals and potentially larger chunking of musical contours or phrases. Based on these practiced skills, it seems likely that any long-term formal musical training would affect these abilities, which were necessary for all tasks in this study.
Part V: Implications of Results

Due to the limited sample size, caution must be taken in the interpretation of the results. A small sample can lead to multiple statistical errors, and conclusions based on this analysis may be misleading. However, the empirical data from the present study has provided significant results that allow for several suggested implications for music education and cognitive psychology. In addition to these results, this section also offers suggestions for potential future studies.

Significance to Cognitive Psychology

By definition, cognitive psychology aims to address the mental processes and activities of the human mind (Gazzaniga et al., 2002). The production and perception of speech and music are two such mental abilities. This study contributes to the understanding of prosodic and melodic ability by focusing on their unifying elements, their acoustic properties. In utilizing targets both with and without syllables based on the same fundamental frequencies, authentic stimuli were developed including a relatively new form, musicalized speech. This stimulus provided an alternative cognitive perspective that, with further integration into methodological designs may better demonstrate the cognitive relationship between speech and music. As mentioned in Chapter One, current behavioral literature comparing music and language is limited. Therefore, this study has contributed to this body of work by demonstrating an appropriate use of the generated stimulus in addition to the success of study design and significant empirical results.

The demonstrated effect that including words may have on individuals’ cognitive abilities is a second considerable implication from this study. Possible explanations may
have been due to the semantic associations aiding in memorization and/or recall; a priming effect of phrases making recognition of additional prosodic changes easier; or the tasks themselves seeming easier to subjects due to the familiar nature of the stimuli. Understanding the relatedness of various cognitive abilities such as processing or producing prosodic and melodic phrases may provide additional insight into overall human cognition and perhaps even cognitive transfer.

Another area of interest for cognitive psychology that unfolded during the analysis is working memory. The suggested theory of musicians having extended their short-term memory capacity applies directly to the understanding of brain plasticity based on cognitive experiences. In demonstrating the changes resultant of repetition on a given task such as playing music, a possible link between an acquired specific ability and a supplementary cognitive function is suggested. A future examination into the exact limitations of musicians and non-musicians in their prosodic and melodic retention might further explain this process.

The dissimilarity between subjects’ experience in musical training provides clues concerning the variables that may have been involved in cognition. Although the connectedness between music and language has been tested through mostly scientific inquiries (see Patel, 2008), this study illustrates the implications personal experience can have on the production and perception of both functions through behavioral measurements.

*Significance to Music Education*

The review of the literature in Chapter Two presented several scenarios in which the brain’s functional and physiological characteristics were altered based on individual
experience. This is consistent for musical experiences as well, resulting in various performance and perception of musical stimuli (Hannon & Trehub, 2005; Pantev et al., 2001; Schlaug, 2001).

The present work offers several considerations for music education: total length of musical experience, when musical experiences commenced, and in what form it occurred. With the increasing accessibility of music to students (e.g., convenient Internet searches and downloads, videogames, and handheld devices) along with traditional experiences (e.g., family and cultural traditions, school ensembles, and private lessons) the definition of music training is expanding. The initial design of this study was developed to compare music majors and non-music majors. After the initial analysis, the variance of musical experiences revealed itself as more significant. Although there were nine music majors included in the study, upon initial review of the data, it seemed more appropriate to compare musical experiences as opposed to declared majors.

Length of Musical Experience

Total years of informal training demonstrated significance in all musicalized speech and melodic tasks except for musicalized speech starting pitch. Correlations for total years of formal training were closely similar, in addition to speech overall contour as well. Longitudinal behavioral studies are extremely limited on the topic of music training and various cognitive performances however, Ho et al. (2003) did compare subjects who began, continued, and discontinued musical training on verbal retention tasks. They demonstrated significant positive percentage changes in both 10-minute and 30-minute retention tasks for those subjects who had continued their musical training (12.65%, \( p < .05 \) and 12.44%, \( p < .01 \), respectively). Those who had discontinued their
training demonstrated a negative change from the 10-minute retention (-9.97%) and a slight positive change (1.32%) for the 30-minute retention. These results concurs with findings in the present study’s analysis suggesting that any prolonged musical exposure can have a positive effect on various cognitive abilities (verbal memory) and tonal performance (musicalized speech and melodic tasks). Suggested reasons for this relationship could be from a) personal experience with musical tasks, and/or b) physiological changes to the brain reflected in subject performance.

**Personal experience with music tasks.** It can be assumed that formal training, as defined by this study, involves some form of aural training skills. Beyond this specific practice, any musical experience involves listening to and/or performing melodic phrases to some extent. It is perhaps these experiences that better prepared the subjects for the various performance tasks.

**Physiological changes.** From either the repetition of certain behaviors or the absence of those, that potential structures in the brain may be altered and even be transferred to another cognitive ability. This might explain how continued participation in band and orchestra could affect a seemingly unrelated skill such as verbal memory, as mentioned previously.

**Age Began Musical Experience**

In addition to the total years of musical experience relating to a majority of production tasks, the most significant result for music education potentially is the age in which the formal training began. In this study, a significant correlation (0.37 < r² < 0.56, p < .01 and .001) was demonstrated between the age training began and all production tasks except for speech and musicalized speech starting pitch. This means, the younger subjects
began their formal training, the better they performed on these tasks. A possible explanation for the lack of significance between speech and musicalized speech starting pitch is perhaps the relative ease of this task for subjects to match the very first pitch. This could be due to previous tonal memory practice and may have caused a general achievement rate for these subjects.

*Implications for practice.* When to introduce musical instruction can be a parental or a curricular decision. Disregarding the potential physical constraints with early music instruction on various instruments, when to begin a student in order to experience the greatest benefit has been speculated. As mentioned in the literature review, instruction commencing prior to the age of 7 has often been recommended. General education researchers and psychologist have acknowledged the great potential young children have to learn, and the long-term effects of this early exposure to their later development (Simons, 2001). Music education researchers, such as Francine Rauscher, have examined early music learning and its effects on other cognitive functions with relative success (Rauscher et al., 1997). As demonstrated from the results of the present study, the earlier musical training commenced, the more significant the correlations were with the other tasks. Awareness of the supplementary advantages to starting music training at an early age might benefit aspects of students’ long-term learning and success.

For curricular considerations, maintaining music offerings is currently a struggle for school districts having to meet budgetary requirements, balance the schedule, or work towards test scores (Dillon, 2006; Miller & Coen, 1994). Having the information of what age students should first be exposed to various musical experiences, in addition to knowing how the potential benefits of the experience might extend into other cognitive
realms is supportive for maintaining music programs. Currently, many music educators are forced to focus on advocacy efforts (CMW, 2010; Woodford, 2005). While this may be seen as a distraction from the musical and pedagogical aspects of music education, it is a reality. Having empirical behavioral data to illustrate the positive effects music education can have on a student’s overall development is a fundamental argument. Moreover, by focusing on the importance of early introduction to music, educators have additional information necessary to promote music education programs as part of the school curriculum.

**Form of Musical Experience**

This study does not address the particular form of musical experience, but generalizes them into two categories: informal and formal. The main analysis was on the total years of experience and the age subjects began. Thus, the implications made here address only the differences between informal and formal exposure. As was evident with the correlations, formal training was the strongest factor impacting production tasks ($0.44 < r_s < 0.69$ at the level of .05, .01, and .001), with similar results for informal training.

One possibility is that with one-on-one formal training, students spend a majority of their lesson time playing for their instructor. The success of these subjects on production tasks illustrates this practiced skill. Perhaps playing for their instructor during their lessons better prepared subjects in this study for responding aloud and independently to the targets. Those whose musical background was from informal experiences reported either learning and/or playing solely in an ensemble setting or on their own independent of an instructor. This type of exposure, while it might prepare
them for some of the musical tasks, may not have primed these subjects for performing aloud such as was asked of them in the production tasks.

Although the total amount of formal training exhibited the strongest results, length of informal music training demonstrated significant relationships to musicalized speech final interval, musicalized speech overall contour, and all melodic tasks. These are arguably representative of the more tonal tasks and the data demonstrates that with any length of musical experience, these subjects performed better on production tasks. These results provide music educators with empirical data addressing the significance of music education either in private lessons or in the ensemble setting, by demonstrating the effectiveness of instruction.

_Suggestions for Future Work_

From the limited behavioral research on this topic available at the time of this study’s development, its design was carefully considered. The methodology intended to indicate any transfer of cognitive ability from music to prosody and address the specific variables affecting this ability. The present study served as a significant contribution to the field of prosodic and melodic comparative research. Overall questions of plasticity, training, and human cognition are ongoing, and future studies addressing these aspects would continue to benefit music education and cognitive psychology. Continuing with these developments, several potential future methodological considerations and research inquiries are presented in Figure 6.4.
Methodological Considerations

- Strict subject inclusion to allow concentration on specifics of subject variability such as:
  - Examination into the form of formal instruction (i.e., Suzuki, Yamaha, etc…)
  - Examination into the form of informal instruction (i.e., passive versus active music participation)
  - Any prior public performance experience

<table>
<thead>
<tr>
<th>Research Inquiries</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Comparison of short-term memory and chunking ability and the impact of stimuli with and without syllables</td>
</tr>
<tr>
<td>• Addressing the differences between various pitch presentation, such as glides, and other elements of continuous transitions</td>
</tr>
<tr>
<td>• Use same stimuli but present one as speech and one as melody to assess subjects’ perception of tonal phrases.</td>
</tr>
</tbody>
</table>

Figure 6.4 Methodological considerations and research inquiries for potential future work.

Conclusion

It has taken several decades for music education to embrace and apply research questions from the sciences that may impact their own discipline. Scientific inquiry in education and psychology has arguably existed for centuries, but most often independent of each other. It was not until the mid-twentieth century when these two fields of research began to mutually acknowledge their similar research interests. The inception of neuromusical research has evolved in order to facilitate an involvement between the behavioral sciences and the physical sciences. This has resulted in the initiation of collaborative relationships that foster innovative interdisciplinary studies.

This study established a productive dialogue and cross-disciplinary collaboration between music education and cognitive psychology in order to address relevant questions to both fields. The results confirmed the speculated relationships between melody and prosody and the particular variables impacting success with each. Significantly, results also illustrate the effect of prior musical experience on cognitive tasks. The implications
for both cognitive psychology and music education are extensive and encouraging for continuing to address the source of these relationships.

Scientists, philosophers, politicians, and teachers have all endorsed music as an educationally fundamental experience. When it begins, how it is delivered, and for how long it is practiced have also been part of this discourse. In illustrating a behavioral association between melody and prosody, this study has provided information on the significance and connectedness between music and other cognitive tasks. By addressing the variables affecting these abilities, insight into the impact music can have on learning and cognition is supported. The mentality (i.e., that music is educationally essential), has dictated the educational beliefs and actions of many and has crossed several philosophical and methodological barriers. It is the hope that the findings presented in this dissertation has contributed to the understanding of the underlying question concerning why music is essential in the education of all children.


Blonstein, A. (2009). In the end was music: The cases of George Gerswhin and Vissarion Shebalin. *Karger Gazette, 70*, 11.


McPherson (Ed.), *The Child as Musician*: Oxford University Press.


processing in the brain shaped by cultures. *Proceedings of the National Academy of Science USA, 103*, 10775–10780.


Van Lancker-Sidtis, D. (2004). When only the right hemisphere is left: language and communication studies, *Brain and Language, 91*(2), 199-211.


Appendix A: Post-test Survey for Musicians

POST-STUDY QUESTIONNAIRE (A)

Experiment: __________________________   Subject #: __________________________

Date: __________________________

What is your birth date (month and year)? __________________________

Please list the cities, states, and countries in which you lived as a child.

- __________________________   - __________________________

Did you grow up speaking any other language(s) aside from English? If so, how well do you know your other language(s)?

- __________________________

What is your main instrument? __________________________

At what age did you begin playing? __________________________

At what age did you begin taking private lessons? __________________________

For how many years total have you taken private lessons? __________________________

Did you take Suzuki lessons? If so, for how long? __________________________

Please list any additional instruments you play, and the total number of years you have played them.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Total Years Played</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Did you notice anything strange about the sentences or melodies in the experiment?

- __________________________

What do you think this experiment was about? Even if you have no idea, make a best guess.

- __________________________
- __________________________
Appendix B: Post-test Survey for Non-Musicians

POST-STUDY QUESTIONNAIRE (B)

Experiment: ____________________________  Subject #: ____________________________

Date: ____________________________

What is your birth date (month and year)? ____________________________

Please list the cities, states, and countries in which you lived as a child.

- ____________________________
- ____________________________

Did you grow up speaking any other language(s) aside from English? If so, how well do you know your other language(s)?

__________________________________________________________________________

Do you plan any instruments? If yes, please list them, at what age you began playing them, and for how many years? Also, please mark with a ✓ the instruments you have had formal lessons in (i.e., with a music teacher in private lessons).

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Age began</th>
<th>Years of practice</th>
<th>Private lessons?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Have you been in a band or any other musical ensemble (including dance)? If yes, then please list the ensemble below and the cumulative amount of years you have been a member. For example, “Rock band, 3 years”.

- ____________________________ Years
- ____________________________ Years

Did you notice anything strange about the sentences or melodies in the experiment?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

What do you think this experiment was about? Even if you have no idea, make a best guess.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
Appendix C: Edinburgh Handedness Inventory

Please indicate your preferences in the use of hands in the following activities by putting a √ in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put a √√. If in any case you are really indifferent, put a √ in both columns. Some of the activities require both hands. In these cases the part of the task or object for which hand preference is wanted is indicated in brackets. Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

<table>
<thead>
<tr>
<th></th>
<th>LEFT</th>
<th>RIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Writing</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Drawing</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Throwing a Ball</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Scissors</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Toothbrush</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Knife (without fork)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Spoon</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Broom (upper hand)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Striking Match (match)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Opening Box (lid)</td>
<td></td>
</tr>
</tbody>
</table>

In the following chart, please put a √ check in the appropriate boxes. A box can be checked more than once. For example, if you have two brothers and both are right-handed you would put two checks in the box under "Right" on the line alongside where it says "Brothers". Note also that the chart is concerned with blood relatives only.

<table>
<thead>
<tr>
<th>How many?</th>
<th>LEFT</th>
<th>RIGHT</th>
<th>Ambidextrous</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Father</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father’s Father</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father’s Mother</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother’s Father</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother’s Mother</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Older Sister(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Younger Sister(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Older Brother(s)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Younger Brother(s)</td>
<td></td>
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</tr>
<tr>
<td>Father’s Brother(s)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Father’s Sister(s)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Mother’s Brother(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother’s Sister(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D: Debriefing Form

Understanding Prosody and Melody

The voice is a universal instrument utilized in the conveyance of human emotion and communication. Both singing and speaking are involved in organized acoustic processing that engage complex cognitive and motor processes. Fundamentally, each is reliant upon frequency, amplitude, and duration, and both provide means of emotional expression through the manipulation of such variables.

Through behavioral and physiological testing, studies have shown that musicians have greater accuracy in detecting pitch violations in speech and melody as compared to non-musicians. These results were due to extensive musical training early in life (Schön et. al., 2004; Fujioka et. al, 2004). In comparing prosody, melody, and musical potential, we are attempting to better understand the domain specificity of melodic processing found within speech and music.

In this study, we were interested in how you perceive various phrases and melodies, and how you produce them. We want to learn more about how prosody and melody may or may not be understood and produced similarly. The benefits to this study are in its potentiality in finding a relationship between language and music, which may advance the field of music, speech, and cognitive psychology and inform future teaching and comprehension methods.

If you have any questions about this work, please contact Dr. Duane Watson (dgwatson@illinois.edu) at 333-0280, Naomi Copeland (ncope3@illinois.edu), or Scott Jackson (srjacksn@illinois.edu). If you have any questions or concerns about your right as a participant in the experiment, you should contact the University of Illinois Institutional Review Board (irb@uiuc.edu) 333-2670.

Thanks for your help.

Suggestions for further reading


Appendix E: Task Instructions

TASK 1 Read Instructions: SPEECH

When people are talking to each other, very often it makes a difference how the words are said. In other words, you can get really different kinds of meaning from a sentence depending on how you say it. In this first task, you will hear several different sentences, said in several different ways. Your task is simply to imitate back what you hear as accurately as possible, trying to capture not only the words, but also the meaning behind how the words are said.

Please do not add to or change the words in the sentences; just imitate them back as closely as possible. We realize that this may be a difficult task for some people, and that is okay. How well different people do at these different tasks is exactly what we’re interested in, so you should not feel bad if you find this task to be very difficult. Just do your best!

At the beginning of each trial in the experiment, a trial number will be displayed. After that, you will hear the target sentence. Please listen carefully, because you will only be able to hear it once.

After the target sentence plays, the screen will prompt you to record your response. Please speak with a clear voice. If you make a slip (cough, stutter, etc.), you can respond more than once, but please try to make your best imitation on the first try.

When you are done with your response, click the mouse to continue to the next item. Every 16 items, you will be prompted to take a short break, to clear your voice, etc. To help you get used to the task, we will start with four practice items. After each practice item, the computer will play back the sound you recorded. If the sound quality of these recordings seems poor, please let the experimenter know before continuing.

Thank you!

TASK 1 on-screen instructions:

Screen 1: You will hear a series of sentences, said in different ways to get different kinds of meanings.

Screen 2: For each sentence that you hear, your task is to repeat the sentence, imitating not just the words, but the way it is said.

Screen 3: Recording will start automatically after you hear each sentence. Please speak clearly, but in your normal speaking voice.

Screen 4: When you are done recording your response, click the mouse to start the next trial.

Screen 5: There are 64 trials in all, but you will have an opportunity to pause to clear your voice every 16 trials.

Screen 6: We will start with 4 practice trials, so you can get used to the task.

Screen 7: The practice trials will work like the real trials, except that your recording will be played back to you after each trial, to give you feedback on the recording sound quality.

Screen 8: If the sound quality of the playbacks is poor, please let the experimenter know.

Screen 9: If you have any questions, please ask the experimenter now.
Screen 10: Now let’s start the practice trials. Good luck, and thank you!

After practice:
Screen 11: Practice complete! Click the mouse to exit.
Screen 12: Now we will start the task. This will work the same as the practice, except your recording will NOT be played back to you. Good luck, and thank you!

**TASK 2 Read Instructions: TONES**

The second task is somewhat similar to the first, but instead of hearing sentences, you will hear a series of tones. Your task is to imitate back what you hear as accurately as possible, focusing especially on imitating the pitch of the tones. When imitating the tones, use the syllable “na”.

In some items, the tones will go by fairly quickly. We realize that this may be a difficult task for some people, and that is okay. How well different people do at these different tasks is exactly what we’re interested in, so you should not feel bad if you find this task to be very difficult. Just do your best!

At the beginning of each trial in the experiment, a trial number will be displayed. After that, you will hear the target sentence. Please listen carefully, because you will only be able to hear it once.

After the target sentence plays, the screen will prompt you to record your response. Please speak/sing with a clear voice. If you make a slip (cough, stutter, etc.), you can respond more than once, but please try to make your best imitation on the first try.

When you are done with your response, click the mouse to continue to the next item. Every 16 items, you will be prompted to take a short break, to clear your voice, etc. To help you get used to the task, we will start with four practice items. After each practice item, the computer will play back the sound you recorded. If the sound quality of these recordings seems poor, please let the experimenter know before continuing.

Thank you!

**TASK 2 on-screen instructions:**

Screen 1: You will hear a series of tone sequences.
Screen 2: For each trial, your task is to repeat the tones as accurately as possible, focusing on the pitch.
Screen 3: Recording will start automatically after you hear each tone sequence. Please imitate the tones using the syllable “na”.
Screen 4: When you are done recording your response, click the mouse to start the next trial.
Screen 5: There are 64 trials in all, but you will have an opportunity to pause to clear your voice every 16 trials.
Screen 6: We will start with 4 practice trials, so you can get used to the task.
Screen 7: The practice trials will work like the real trials, except that your recording will be played back to you after each trial, to give you feedback on the recording sound quality.

Screen 8: If the sound quality of the playbacks is poor, please let the experimenter know.

Screen 9: If you have any questions, please ask the experimenter now.

Screen 10: Now let’s start the practice trials. Good luck, and thank you!

After practice:
Screen 11: Practice complete! Click the mouse to exit.
Screen 12: Now we will start the task. This will work the same as the practice, except your recording will NOT be played back to you. Good luck, and thank you!

TASK 3 Read Instructions: MLIC

The third task is nearly identical to the second task, with the only difference being the tones you will hear. You will again hear a series of tones for each trial, and your task is to imitate back what you hear as accurately as possible, focusing especially on imitating the pitch of the tones. When imitating the tones, use the syllable “na”.

In some items, the tones will go by fairly quickly. We realize that this may be a difficult task for some people, and that is okay. How well different people do at these different tasks is exactly what we’re interested in, so you should not feel bad if you find this task to be very difficult. Just do your best!

At the beginning of each trial in the experiment, a trial number will be displayed. After that, you will hear the target sentence. Please listen carefully, because you will only be able to hear it once.

After the target sentence plays, the screen will prompt you to record your response. Please speak/sing with a clear voice. If you make a slip (cough, stutter, etc.), you can respond more than once, but please try to make your best imitation on the first try.

When you are done with your response, click the mouse to continue to the next item. Every 16 items, you will be prompted to take a short break, to clear your voice, etc. To help you get used to the task, we will start with four practice items. After each practice item, the computer will play back the sound you recorded. If the sound quality of these recordings seems poor, please let the experimenter know before continuing.

Thank you!

TASK 3 on-screen instructions:

Screen 1: You will hear a series of tone sequences.
Screen 2: For each trial, your task is to repeat the tones as accurately as possible, focusing on the pitch.
Screen 3: Recording will start automatically after you hear each tone sequence. Please imitate the tones using the syllable “na”.

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Screen 4: When you are done recording your response, click the mouse to start the next trial.
Screen 5: There are 64 trials in all, but you will have an opportunity to pause to clear your voice every 16 trials.
Screen 6: We will start with 4 practice trials, so you can get used to the task.
Screen 7: The practice trials will work like the real trials, except that your recording will be played back to you after each trial, to give you feedback on the recording sound quality.
Screen 8: If the sound quality of the playbacks is poor, please let the experimenter know.
Screen 9: If you have any questions, please ask the experimenter now.
Screen 10: Now let’s start the practice trials. Good luck, and thank you!

After practice:
Screen 11: Practice complete! Click the mouse to exit.
Screen 12: Now we will start the task. This will work the same as the practice, except your recording will NOT be played back to you. Good luck, and thank you!
Appendix F: IRB Approval Letter

UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Office of the Vice Chancellor for Research
Institutional Review Board
528 East Green Street
Suite 203
Champaign, IL 61820

June 16, 2009

Duane Watson
829 Psychology
MC-716
RE: Relationship Between Music and Language
IRB Protocol Number: 09229

Dear Duane:

Thank you very much for forwarding the modifications to the University of Illinois at Urbana-Champaign Institutional Review Board (IRB) office for your project entitled Relationship Between Music and Language. I will officially note for the record that these minor modifications to the original project, as noted in your correspondence received June 3, 2009, revising consent form used for subjects receiving course credit to clarify what their time commitment is in order to receive credit, have been approved. The expiration date for this IRB protocol, UIUC number 09229, is 11/19/2009. The risk designation applied to your project is no more than minimal risk.

As your modifications involved changes to consent forms, I am enclosing the revised forms with date-stamp approval. Please note that copies of date-stamped consent forms must be used in obtaining informed consent. If modification of the consent form is needed, please submit the revised consent form for IRB review and approval. Upon approval, a date-stamped copy will be returned to you for your use.

Please note that additional modifications to your project need to be submitted to the IRB for review and approval before the modifications are initiated. To submit modifications to your protocol, please complete the IRB Research Amendment Form (see http://irb.illinois.edu/q=forms-and-instructions/research-amendments.html). Unless modifications are made to this project, no further submittals are required to the IRB.

We appreciate your conscientious adherence to the requirements of human subject research. If you have any questions about the IRB process, or if you need assistance at any time, please feel free to contact me or the IRB Office, or visit our Web site at http://www.irb.illinois.edu.

Sincerely,

Sue Keehn, Director, Institutional Review Board
Enclosure(s)

c: Naomi Copeland
    Scott Jackson

telephone (217) 333-2676 • fax (217) 333-0405 • email IRB@illinois.edu
Appendix G: Subject Consent Form

I L L I N O I S
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Informed Consent

This research is being conducted by Dr. Duane Watson of the Department of Psychology at the University of Illinois at Urbana-Champaign. All participants must be at least 18 years of age.

The goal of this experiment is to investigate how people understand and use language and music. You will be asked to listen to and answer questions about stimuli or repeat spoken or sung phrases. You will also be asked to take a pen and paper assessment. Participation is dependent on your willingness to have your voice recorded.

The results are kept in strict confidence, and are available to no one apart from those individuals immediately involved with the research project. After the experiment is completed, we will analyze your results along with the results of many other research participants. Your name will not be recorded or associated with your responses. We will record your name only to make sure that you do not take part in the same experiment twice.

The decision to participate, decline, or withdraw from participation will have no effect on your grades at, status at, or future relations with the University of Illinois. If, after learning more about the nature of this experiment and the behavior expected of you, you do not wish to participate or do not want your responses recorded, tell the researcher. While you may withdraw your participation at any time, you will only receive credit for the time in the experiment that you complete, but you will be eligible for further scheduling. The results of this study may be disseminated in a dissertation, conference presentations, and/or journal articles.

You will receive two hours of credit for the purposes of Psychology course requirements at UIUC. If you withdraw early but still participate at least an hour, you will receive one credit. The entire session will take no more than 110 minutes. There are no known risks associated with the procedures beyond those risks that exist in daily life. You will benefit from participation in the experiments by gaining some knowledge of the methods and results of psychological research. Participation is voluntary.

You will receive a copy of this consent form. For further information about the experiment, you may contact Dr. Duane Watson (dgwatson@illinois.edu) at 333-0280, Naomi Copeland (ncpoe3@illinois.edu), or Scott Jackson (srajackan@illinois.edu). If you have complaints or concerns, or questions about your rights as a research participant you may contact the University of Illinois Institutional Review Board at 333-2670 or irb@illinois.edu. You may call the Institutional Review Board collect. If you have questions about course credit or the subject pool, contact Summer Curry in the Department of Psychology at subjects@cyrus.psych.uiuc.edu or 333-6350.

I understand the preceding information and agree to participate in this experiment. With my permission, I also understand responses and recordings may be used in future presentations. No information that might associate me with my results will be presented.

____________ Yes, the researchers may audiotape my session and play audio recordings in presentations.
____________ No, the researchers may not audiotape my session or play audio recordings in presentations.

Signature: ________________________________ Date: ________________
Print Name: ________________________________

UNIVERSITY OF ILLINOIS
APPROVED CONSENT
VALID UNTIL

NOV 19 2009

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