Liberty University

School of Music

The Difference(s) Between Autistic Individuals and Neurotypical Individuals when Learning to Identify Pitch

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By

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Abstract

This study aimed to compare and determine possible differences between autistic and neurotypical individuals in learning to identify pitch. This study investigates whether autistic individuals are more accurate at pitch-matching than neurotypical individuals. This study employs a quantitative approach and a variation of the pitch-matching test. The population for this study consisted of males and females from West Virginia, with 20 autistic and neurotypical participants aged 18 years and older. The study included 50% of participants with autism and 50% of neurotypical participants. In each group, there were an even number of males and females, neurotypical and neuroatypical, and a mix of ages within the age range. This study was conducted primarily in a private classroom in Barboursville, West Virginia, and partly via FaceTime calls. This relatively small room contained only a keyboard and two chairs to avoid distractions. Many findings can be derived from this study. This study will potentially improve music education for autistic students and impact their communities. Identifying the number of autistic individuals with perfect or exceptional relative pitches could greatly affect their music learning. Making these connections between pitch-matching and neuroatypical students could also benefit music educators when designing curricula. The results of the study show that the neurotypical participants scored higher on accurate pitch matching than the neuroatypical participants.

Keywords: pitch-matching, autism, neurotypical, students

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CHAPTER ONE: INTRODUCTION

There is evidence that autistic individuals can identify pitch more accurately than neurotypical individuals. Studies show that one to five people per ten thousand have absolute pitch, or perfect pitch, according to estimates. Perfect pitch occurs in musicians at a higher rate, from less than one percent up to eleven percent. Absolute pitch, more commonly known as perfect pitch, is considered a rare "gift" that some people are born with. Research suggests a genetic link to absolute pitch, and it occurs most often in people who had musical training in their early childhood.[1] This study used a quantitative approach, including a pitch matching test among participants. The results were determined by various factors, including genetics, learning environment, home environment, early childhood musical training, and interest in the subject of music.

Background

According to a study by the Robert S. Boas Center, "Individuals with absolute pitch hear musical pitches and identify them immediately and effortlessly using letter names (for example, 'C' or 'F-sharp'), without looking at the instrument being played or being given a reference."[2] In the same way that most people can identify the color of certain objects at a glance, people with perfect pitch can identify the letter names of musical notes without a reference. Throughout the

[1] Marina Sarris, "Perfect Pitch: Autism's Rare Gift," Interactive Autism Network at Kennedy Krieger Institute, July 2, 2015, https://www.kennedykrieger.org/stories/interactive-autism-network-ian/perfect-pitch-autism-rare-gift.

[2] Peter K. Gregerson, "Absolute Pitch and Synthesia," Feinstein Institutes for Medical Research, 2024, https://feinstein.northwell.edu/institutes-researchers/institute-molecular-medicine/robert-s-boas-center-for-genomics-and-human-genetics/absolute-pitch-and-related-cognitive-traits.

centuries, well-known musical artists have claimed or been reported to have this "enhancement," including Charlie Puth, Ella Fitzgerald, and Wolfgang Amadeus Mozart.

While some may argue that an individual can achieve perfect pitch through intensive ear training, there is little to support this theory.[3] According to a research study on absolute pitch and synthesia, absolute pitch has a genetic basis. The location of absolute pitch genes on chromosomes two and six were identified in this study and are focused on identifying the specific genes. Aside from the genetic source, this rare trait can be identified and shaped in an individual through the learning environment, the home environment, early childhood musical training, and an interest in the subject of music. It is possible to develop relative pitch in childhood or adulthood. However, it is not as evident that an individual can develop absolute pitch in childhood or adulthood.

Autism Spectrum Disorder is a "neurodevelopmental disorder characterized by deficits in social communication and the presence of restricted interests and repetitive behaviors."[4] It requires a diagnosis, which is usually made at an early age. However, it may go undiagnosed until adulthood, which unfortunately leads to misunderstandings among some individuals. While the cause of autism is uncertain, studies suggest that "Autism is a neurobiological disorder influenced by both genetic and environmental factors affecting the developing brain. Ongoing research continues to deepen our understanding of potential etiologic mechanisms in autism, but currently, no single unifying cause has been elucidated."[5] This new, evolving study has the

[3] Gregerson, "Absolute Pitch and Synthesia."

[4] Holly Hodges, Casey Fealko, and Neelkamal Soares, "Autism Spectrum Disorder: Definition, Epidemiology, Causes, and Clinical Evaluation," *Translational Pediatrics* 9, no. 1 (February 9, 2020): 55, https://doi.org/10.21037%2Ftp.2019.09.09.

[5] Ibid.

potential to raise awareness about people with disabilities and their different abilities, including perfect pitch or exceptional relative pitch. It will also raise awareness of the musical aspect and bring more understanding to music teachers, music students with autism, and their families.

According to Marina Sarris, there is not an exact percentage of how many individuals with autism have perfect pitch. However, the percentage is often theorized to be higher than the rate found in the general population. Several studies have examined these pitch abilities in autistic individuals, but there is not enough evidence to say how common it is in autism.[6] This study investigated the difference(s) between neurotypical and neuroatypical students in learning to identify pitch. This topic was further identified by building on existing knowledge of this and related subjects. Sarris noted, "In 2009, British researchers found that 20 percent of the 72 teens with autism they studied had a superior ability to distinguish pitch. Other studies found superior pitch ability to be more widespread in ASD. Children with ASD were exceptionally sensitive to changes in pitch contours compared to other children, one British study concluded."[7]

Statement of the Problem

Many people may not realize the significant possibility that individuals with autism can more accurately identify pitch than neurotypical individuals. Certain aspects of this topic have been studied, but very few studies have directly addressed this specific issue. Neurological and genetic links to neuroatypical individuals with perfect pitch need further investigation. It is important to address these issues for future music education and a better understanding of the strengths of individuals with autism. Researchers have theorized to explain why perfect pitch

[6] Sarris, "Perfect Pitch."

[7] Ibid.

may be more common in people with autism. One study of musicians showed that, “those with perfect pitch had an asymmetry to their brain's planum temporale, which is part of an area known for language function.[8] This structural difference led to other research into musicians with perfect pitch. For instance, are they more likely to have some characteristics found in autism?”[9] This study justifies the basis of this topic: whether or not neuroatypical individuals show an increased ability for pitch matching.

Statement of Purpose

This study compares and determines the differences between autistic and neurotypical individuals in learning to identify pitch. As part of this study, both neurotypical and autistic individuals were invited to a private lesson setting and/or a Zoom meeting, where they completed a test to measure their pitch identification skills. The independent variables were defined by genetics, the learning environment, and the home environment. The dependent variables were early childhood musical training and an interest in music as a subject. The relationship between the independent variables was critical, as the participants' environment and genetics significantly influenced the study’s outcome. The results also relied on the correlation between the dependent variables and how they were formed from the independent variables.

[8] Sarris, “Perfect Pitch.”

[9] Ibid.

Significance of the Study

This study is significant because it addresses an ability of autistic students that is rarely researched in music education. In comparison with studies on social and cognitive impairments in autistic individuals, "much less research has focused on studying enhanced abilities sometimes associated with the diagnosis. Many terms have been introduced to describe enhanced abilities in autism."[10] Many outcomes may develop from this study. This study will potentially improve music education for autistic students and impact their communities. Autistic individuals with these enhanced abilities are often referred to as "twice-exceptional," or "exceptional both for having an ASD diagnosis and for having enhanced cognitive abilities in some domains. The phenomenon of 'cognitive divergence' refers to exceptional cognitive strengths in one domain coupled with profound deficits in another."[11] Identifying the number of autistic individuals who achieve perfect pitch or exceptional relative pitch could have significant implications for their music learning. Making these connections between pitch matching and neuroatypical students also potentially benefits music educators throughout the curriculum design process.

Research Question and Hypothesis

As stated above, the purpose of this study was to compare and find the difference(s) between music students with autism and neurotypical students when learning to identify pitch. The single research question for this study was whether there was a difference in pitch matching abilities between autistic and neurotypical individuals. The goal of this question was to

[10] Lucina Q. Uddin, "Exceptional Abilities in Autism: Theories and Open Questions," *Current Directions in Psychological Science* 31, no. 6 (December 2022): 509-517, https://doi.org/10.1177%2F09637214221113760.

[11] Ibid.

determine the relationship between neurotypical and neuroatypical individuals when learning to accurately identify pitch. The hypothesis for this study was that there is a difference in pitch matching abilities between autistic and neurotypical individuals. The goal of this hypothesis was to enhance the future of music learning for neuroatypical students.

Definition of Terms

Autism: A neurological disorder that has been increasing in the world's population in recent years. Autism is considered a condition that affects brain development and affects how an individual perceives and socializes with other individuals.

Perfect Pitch: A rare, genetic gift that can also be developed through intense training in early childhood. It is a person's ability to correctly identify a musical note before hearing a reference pitch.

Neurotypical: This term refers to individuals who have average neurological abilities and do not exhibit atypical patterns or behaviors. It is when a person's brain function and processing are considered standard in society.

Neuroatypical: This term refers to individuals who have a cognitive impairment that is medically considered different from a neurotypical brain. This is a variant word for autism but can include other disabilities.

Relative Pitch: The ability to identify a musical note in comparison to a reference note. This is quite common among musicians.

Tinnitus: Tinnitus pitch matching is when the frequency of an external sound is manipulated and matches the pitch of the tinnitus.

Audiometric: A measurement of an individual's hearing abilities. This refers to the range and sensitivity of hearing.

Summary

Despite the variability, dramatic impairments in communicative abilities are the main feature of autism. There is an inability to express and understand emotions, which has often been assumed to be an important link to this impairment. There is a lack of knowledge about the ability of autistic people to recognize emotions conveyed by stimuli, including music. Music can evoke and convey strong and consistently positive and negative emotions healthily. The ability to process the emotional aspects of music appears to be preserved in individuals with autism.

This study provides insight regarding, potentially, unknown knowledge about autism, perfect pitch, and how each topic correlates. According to Creswell and Creswell, quantitative researchers will test theories deductively and build against any bias. Researchers also control for alternative explanations while seeking to generalize and replicate their findings.[12] The results from pitch matching between autistic and neurotypical individuals followed this outline. Ultimately, identifying the number of autistic individuals who achieve perfect pitch or exceptional relative pitch could have important implications for their music learning.

[12] John W. Creswell and J. David Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (Thousand Oaks: SAGE Publications, 2022), 4.

CHAPTER TWO: LITERATURE REVIEW

This pitch matching study thoroughly investigates the difference(s) between neurotypical and neuroatypical students in learning to match pitch. This topic is further clarified by building on previous knowledge of the subject. Other studies have shown evidence that autistic individuals can match pitch more accurately than neurotypical individuals. The following sections provide information on previous studies related to pitch matching between neurotypical and neuroatypical students. In addition to pitch matching methods, the following sections describe the independent variables and dependent variables for this study. These sections also identify the gap in current research that this study attempted to investigate.

Pitch Matching Methods

Pitch matching accuracy and temporal auditory processing are tests used in certain research studies. The pitch matching test is an evaluation of pitch matching ability measured through vocal imitation of sounds of different musical tones that are perceived aurally. There are ten sound tasks in the sequence, the first five include piano recordings and the last five include recordings of the human voice.[13] This method was designed and tested to "correlate pitch-matching accuracy and auditory processing in individuals without musical training."[14] Five researchers contributed to designing and testing this instrument: Congeta Bruniere Xavier Fadel, Angela Ribas, Débora Lüders, Vinicius Ribas Fonseca, and Monica Nunes Lima Cat.

[13] Congeta Bruniere Xavier Fadel et al., "Pitch-Matching Accuracy and Temporal Auditory Processing," *International Archives of Otorhinolaryngology* 22, no. 2 (April 2018): 113, https://doi.org/10.1055/s-0037-1603763.

[14] Ibid.

Other research studies employed pitch matching or a similar test. Patrick Neff and other researchers compared three established methods for tinnitus pitch matching in terms of reliability, matching duration, and subjective satisfaction.[15] Tinnitus pitch matching is the frequency of a sound that is manipulated to pitch match the one of the tinnitus. The pitch of a tinnitus sound is one of the characteristics that is "of importance to research and sound therapies relying on exact tinnitus pitch matches. The identification of this tinnitus pitch is a challenging task as there is no objective measurement available."[16] The results showed that the three pitch matching methods had good reliability, and there were differential aspects of improvement identified in all methods.

The second example of a different pitch matching method is a comparison of the tinnitus pitch matching procedure with other pitch matching tests. "Tinnitus pitch matching is a procedure by which the frequency of an external sound is manipulated in such a way that its pitch matches the one of the tinnitus. The correct measure of the tinnitus pitch plays an important role in the effectiveness of any sound-based therapies."[17] Both methods tested in the research showed good reliability, and the intraclass correlation and octave difference values obtained suggest that both methods may measure a different aspect of tinnitus. The results showed that a multi-choice method for tinnitus pitch matching is as reliable as other conventional methods in the clinical population.

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[15] Patrick Neff et al., "Comparing Three Established Methods for Tinnitus Pitch Matching with Respect to Reliability, Matching Duration, and Subjective Satisfaction," *Trends in Hearing* 23 (December 5, 2019): 1, https://doi.org/10.1177%2F2331216519887247.

[16] Ibid.

[17] Jose L. Santacruz, Emile de Kleine, and Pim van Dijk, "Comparison Between Two Self-Guided Tinnitus Pitch Matching Methods," *Frontiers in Aging Neuroscience* 16 (June 2024): 1, https://doi.org/10.3389%2Ffnagi.2023.1095178.

The third example is a study that compared self-administered tinnitus pitch matching with a conventional audiometric procedure. Audiometry is a branch of audiology that measures the range and sensitivity of an individual's hearing ability. Obtaining an accurate tinnitus pitch match is, "an initial and critical requirement for tinnitus evaluation and treatment, particularly for applying tailor-made notched music training."[18] The results showed that the self-administered tinnitus pitch matching was as accurate as the audiological procedure and can be used instead of the conventional audiometric procedure when octave confusion is minimal. This example adds another layer behind pitch matching and the number of aspects involved in choosing a pitch matching test.

The final example of pitch matching methods is a research study on pitch perception. Pitch is a primary auditory sensation that is essential in music, speech, and auditory scene analysis. Oxenham found that "the effects of other acoustic parameters on pitch judgments, and the complex interactions between perceptual organization and pitch, have uncovered interesting perceptual phenomena that should help to reveal the underlying neural mechanisms."[19] However, some interactions can complicate the relationship between the stimulus and the perception of pitch. Each example illustrates an additional aspect of the complexity of pitch matching. Several physical correlations and musical aspects make up the auditory matching of a pitch or musical tone.

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[18] Tae Su Kim et al., "Self-Administered Tinnitus Pitch Matching versus a Conventional Audiometric Procedure," *Audiology & Neuro-otol*ogy 22, no. 1 (2017): 1-8, https://doi.org/10.1159/000465512.

[19] Andrew J. Oxenham, "Pitch Perception," The *Journal of Neuroscience* 32, no. 39 (September 26, 2012): 13335, https://doi.org/10.1523%2FJNEUROSCI.3815-12.2012.

Independent Variables

The independent variables for this pitch matching study were defined by genetics, learning environment, and home environment. Genetics are at the center of autism diagnosis and identifying perfect pitch. An individual's learning environment and home environment can be contributing factors, also vary depending on culture and other differences. These three main factors are discussed in the next sections and linked to autism, perfect pitch, and the possible correlation between the two.

The first example is a study of how cognitive abilities modulate the relationship between autism and pitch perception.[20] Ong et al. investigated pitch perception between autistic and neurotypical individuals. The research included adults and children. The results consisted of the following: Autistic individuals performed similarly or worse than neurotypical individuals on each pitch task; cognitive ability was associated with some pitch tasks; and cognitive ability modulated the relationship between autism diagnosis and pitch perception on some of the tasks presented. The findings highlighted the importance of taking the differences of an individual approach to understanding the strengths and weaknesses of pitch processing in individuals diagnosed with autism. Genetics and environmental factors contribute to the strengths and weaknesses of pitch processing in autism. It is important to consider individual differences and take different approaches to understanding the complexity of pitch processing.

In a different study, T. Wenhart et al. investigated autistic traits, resting-state connectivity, and absolute pitch in professional musicians, including shared and distinct neural

[20] Jia Hoong Ong et al., "The Relationship Between Autism and Pitch Perception is Modulated by Cognitive Abilities," *Journal of Autism and Developmental Disorders* (August 29, 2023): 1, https://doi.org/10.1007/s10803-023-06075-7.

features.[21] "Theoretical accounts connect both of these with shared neural principles of local hyper- and global hypoconnectivity, enhanced perceptual functioning, and a detail-focused cognitive style. This is the first study to investigate absolute pitch proficiency, autistic traits, and brain correlates in the same study."[22] The sample and methods included a graph theoretical analysis conducted on resting-state samples from thirty-one absolute pitch and thirty-three relative pitch professional musicians. Global clustering coefficient, and average path length were also related to autistic traits, passive and active absolute pitch proficiency, and previous musical training. The results demonstrated both common and distinct neural features between absolute pitch and autistic traits. Differences in the beta range were also associated with higher autistic traits within the same population. In general, musicians exhibit a widely interconnected brain with reduced functional integration and reduced small-world properties. This could be due to autism-specific brain connectivity, while the differences in path length reflect other skill-specific influences. Genetics and environment may also contribute to these different aspects of brain connectivity in autistic and neurotypical individuals.

Genetics

Every individual is different. The primary cause of an individual's differences relates to genetics or genes. Genes can simply be explained as the "instructions" in each cell. Genes can control or determine appearance and body functions. Personality traits can even affect whether a person has perfect pitch. Personality traits are, "enduring patterns of thoughts, feelings, and

[21] T. Wenhart et al., "Autistic Traits, Resting-State Connectivity, and Absolute Pitch in Professional Musicians: Shared and Distinct Neural Features," *Molecular Autism* 10, no. 20 (May 2, 2019): 2, https://doi.org/10.1186/s13229-019-0272-6.

[22] Ibid.

behaviors that reflect the tendency to respond in certain ways under certain circumstances."[23]

Dohn et al. provided empirical evidence that musicians with perfect pitch have more autistic traits than musicians without perfect pitch.[24] This included sixteen musicians with absolute pitch, eighteen musicians without absolute pitch, and sixteen nonmusicians. This pitch matching ability was measured by a pitch identification test using sine wave tones and piano tones. The findings revealed a genetic connection that linked absolute pitch to autism and demonstrated that absolute pitch ability was "most strongly associated with personality traits that vary widely within the normal population."[25]

Contrary to popular theories, individuals with autism have also been reported to have enhanced low-level pitch perception. This could be related to genetics or the mental abilities of an individual diagnosed with autism. In a 2017 study, twenty individuals with autism and twenty neurotypical individuals were tested by discriminating pairs of real syllables, pseudo-syllables, and non-speech contrasting in pitch levels.[26] Pitch perception is associated with different portions of the basilar membrane, which can cause an individual to be more sensitive to sounds or different frequencies. The results suggested that there was no significant difference between neurotypical and neuroatypical individuals when measuring pitch perception.

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[23] Sandra Sanchez-Roige et al., "The Genetics of Human Personality," *Genes, Brain, and Behavior* 17, no. 3 (March 17, 2018): 1, https://doi.org/10.1111%2Fgbb.12439.

[24] Anders Dohn et al., "Do Musicians with Perfect Pitch Have More Autism Traits than Musicians without Perfect Pitch? An Empirical Study," *PloS One* 7, no. 5 (May 30, 2012): 1, https://doi.org/10.1371/journal.pone.0037961.

[25] Ibid.

[26] Stella T. T. Cheng, Gary Y. H. Lam, and Carol K. S. To, "Pitch Perception in Tone Language Speaking Adults With and Without Autism Spectrum Disorders," *i-Perception* 8, no. 3 (June 5, 2017): 1, https://doi.org/10.1177/2041669517711200.

Rory Allen, Reubs Walsh, and Nick Zangwill investigated the hypothesis that musical emotions have naturalistic emotions while others are lacking.[27] The researchers suggested that both characteristics "make them useful in treating conditions where emotional processing is partially preserved, and partially disrupted."[28] If this theory is correct, then its value in this context includes neuroatypical individuals who exhibit both the same and different emotions. Emotional intelligence is of immense importance in the life of every individual. Emotions can often be difficult to manage or explain. This could also be related to an individual's genetics or environment. Individuals with autism have been found to have difficulty expressing their emotions effectively. Listening to music, creating music, singing, or playing musical instruments can certainly bridge this gap not only for individuals with cognitive disabilities but also for neurotypical individuals.

Learning Environment

Allen, Hill, and Heaton interviewed twelve high-functioning adults with autism spectrum disorder to measure their personal experiences with music.[29] The results revealed that most neuroatypical adults use music for cognitive, emotional, and social purposes. Compared to neurotypical adults, these participants relied more on internally focused language than externally focused language. The analysis for this study showed that most participants use music for several cognitive, emotional, and social purposes. However, the autistic group showed a greater

[27] Rory Allen, Reubs Walsh, and Nick Zangwill, "The Same, Only Different: What Can Responses to Music in Autism Tell Us About the Nature of Musical Emotions?" *Frontiers in Psychology* 4 (April 3, 2013): 156, https://doi.org/10.3389/fpsyg.2013.00156.

[28] Ibid.

[29] Rory Allen, Elisabeth Hill, and Pamela Heaton, "The Subjective Experience of Music in Autism Spectrum Disorder," *Annals of the New York Academy of Sciences* 1169, no. 1 (July 2009): 326-331, https://doi.org/10.1111/j.1749-6632.2009.04772.x.

dependence on internally focused rather than externally focused language. As mentioned in the previous section, listening to music, creating music, singing, or playing musical instruments can fill an emotional void. This creative form of self-regulation can also be used by individuals with cognitive disabilities and neurotypical individuals. Music can certainly enhance cognitive abilities and serve to form social connections. These are some of the main reasons why it is essential to include music in an individual's learning environment.

A music teacher's view and knowledge of students with disabilities are of great importance to the student's learning environment. A study conducted by Au and Lau investigated the knowledge and views of private music teachers about students with autism in Hong Kong.[30] The research also examined the relationship between the two factors. The data were collected through a survey and eleven interviews. The results were positive, as the teachers had a good understanding and attitude toward students with autism. Knowledge of and attitude toward these students were positively correlated with the results of the research. Teachers with previous training in special education needs had a better understanding of autism in comparison to those without related training. The results indicate that further public education could provide acceptance of and equal learning opportunities for students who are diagnosed with autism spectrum disorder.

Clegg examined the connections between perfect pitch, auditory processing disorders, and autism spectrum disorders and how this can potentially affect an individual's music education.[31] Some individuals have shared their findings from their research related to these

[30] Tsz-Chin Au and Ngar-Sze Lau, "Private Music Teachers' Knowledge of and Attitudes Toward Students with Autism Spectrum Disorder," *Journal of Autism and Developmental Disorders* 51, no. 4 (December 2021): 1-9, https://doi.org/10.1007/s10803-020-04809-5.

[31] Sarah G. Clegg, "Examining the Relationship Between Perfect Pitch, Auditory Processing Disorders, and Autism Spectrum Disorder," *The Corinthian* 20, Article 7 (2020): 1. https://kb.gcsu.edu/thecorinthian/vol20/iss1/7.

topics. These include the discovery of more autistic students with perfect pitch, the role of auditory processing in perfect pitch, and pitch processing and intonation in students with autism. These perspectives provide the opportunity to make more connections to the music education of students with autism. These are important perspectives to keep in mind when considering an individual's music learning environment.

Home Environment

The home environment is a major factor in the development of neurotypical and neuroatypical individuals. The term "environment" can refer to an individual's community, including where they live and the people around them. There can be strong influences both outside and inside the home. According to *The Psychology of Home Environments*,

> Homes provide an informative context for a wide variety of studies examining how social, developmental, cognitive, and other psychological processes play out in a consequential real-world setting. The topic of homes is also well suited to collaborations with a diverse array of disciplines ranging from architecture and engineering to sociology and law.[32]

Several books have also been published on similar topics, including how individuals with autism approach life in general.

In the book by Michael B. Bakan et al., ten conversations are featured with people ranging in age, gender, nationality, and neurodiversity.[33] Bakan et al. write about the topics of these dialogues, including music, autism, and life in general. The main questions that led to the

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[32] Lindsay T. Graham, Samuel D. Gosling, and Christopher K. Travis, *The Psychology of Home Environments: A Call for Research on Residential Space*, Perspectives on Psychological Science 10, no. 3 (May 2015): 346-356, https://doi.org/10.1177/1745691615576761.

[33] Michael B. Bakan et al., *Speaking for Ourselves: Conversations on Life, Music, and Autism* (Oxford: Oxford University Press, 2018), 1.

purpose of this book are as follows: "How do autistic people make, experience, and find meaning in music? And why does it matter to them that they do?"[34] An individual's home environment certainly affects how music is introduced to them and can determine their level of musical interest.

Bergmann et al. conducted a study on music-based autism diagnostics (MUSAD), a newly developed diagnostic measure for adults with intellectual developmental disabilities suspected of having autism.[35] The research aimed to evaluate the psychometric properties of this instrument. The results showed that this instrument was very promising for diagnosing individuals with intellectual disabilities. The findings can greatly improve their learning environment, home environment, and how other people perceive them.

In a stable home and learning environment, access to musical resources can flourish. Musical resources can benefit any individual in many ways—cognitively, socially, and emotionally. Music interventions are offered through trained music therapists, which can provide comfort and significantly reduce distress for individuals with physical and mental disabilities. This form of therapy can be beneficial for people of all ages with intellectual disabilities. An article by Simpson and Keen examined music interventions for children with autism.[36] This was a review of research from databases and twenty articles met the criteria for this study. Findings included music interventions, generalization and maintenance issues, and future research. There

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[34] Bakan et al., *Speaking for Ourselves: Conversations on Life, Music, and Autism*.

[35] Thomas Bergmann et al., "Music-Based Autism Diagnostics (MUSAD)–A Newly Developed Diagnostic Measure for Adults with Intellectual Developmental Disabilities Suspected of Autism," *Research in Developmental Disabilities* 43 (July 14, 2015): 123-135, https://doi.org/10.1016/j.ridd.2015.05.011.

[36] Kate Simpson and Deb Keen, "Music Interventions for Children with Autism: Narrative Review of the Literature," *Journal of Autism and Developmental Disorders* 41, no. 11 (November 2011): 1507-1514, https://doi.org/10.1007/s10803-010-1172-y.

was limited evidence to support the use of music interventions for autistic children to facilitate their social, communicative, and behavioral skills.

Dependent Variables

This study's dependent variables included early childhood musical training and interest in music. Musical training and musical interest are primarily dependent on an individual's learning environment, home environment, and even genes. An individual's musical training and interest can also vary according to culture and other differences. These two musical factors are identified in the next sections and are related to autism, perfect pitch, and the possible correlation between the two.

Musical training and musical interest may determine an individual's auditory pitch perception. Chen et al. conducted a study that provided a systematic review and meta-analysis of auditory pitch perception in autism.[37] Pitch is an essential component of auditory perception in music and speech. A systematic search of six electronic databases focusing on studies using non-speech stimuli was conducted to provide both a qualitative and quantitative assessment of existing studies on pitch perception in individuals with autism. The conclusion of Chen's study states, "Our study provides the first meta-analysis on auditory pitch perception in ASD and demonstrates the existence of different developmental trajectories between autistic individuals and neurotypicals."[38] Nonverbal ability was found to be a significant factor in the lower-level bias in autism spectrum disorder. The need for further investigation of pitch perception in autism

[37] Yu Chen et al., "Auditory Pitch Perception in Autism Spectrum Disorder: A Systematic Review and Meta-Analysis," *Journal of Speech, Language, and Hearing Research* 65, no. 12 (December 2022): 4866, https://doi.org/10.1044/2022_jslhr-22-00254.

[38] Ibid.

was highlighted in this study. Brain imaging studies are also needed to understand the neural mechanisms of neuroatypical pitch processing in autism and to further develop auditory-based interventions for improving language and social skills.

Applewhite et al. conducted a systematic review of scientific studies on the effects of music on individuals with or at risk for autism.[39] This study explored the fact that autism is on the rise worldwide and that the currently available interventions show varying degrees of success. There is also growing interest in other interventions, including music therapy. Music can often be used as an intervention or as physical and mental therapy. Prior musical training and musical interest may also help achieve the goals of the intervention or therapy for both neurotypical and neuroatypical individuals.

Musical Training

Complex topics such as music, autism, and emotion are discussed in Zangwill's 2013 article.[40] Zangwill argued that physiological responses show that the musical experiences of autistic individuals are normally compared to the musical experiences of neurotypical individuals. However, the emotional understanding, imagination, and description of autistic individuals are not "typical" in general or in response to music. Musical training involves skills that are useful in everyday life, such as cognitive skills, motor skills, and emotion regulation, which have been discussed in previous sections.

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[39] Briana Applewhite et al., "A Systematic Review of Scientific Studies on the Effects of Music in People with or at Risk for Autism Spectrum Disorder," *International Journal of Environmental Research and Public Health* 19, no. 9 (April 23, 2022): 5150, https://doi.org/10.3390%2Fijerph19095150.

[40] Nick Zangwill, "Music, Autism, and Emotion," *Frontiers in Psychology* 4, Article 890 (December 6, 2013): 1, https://doi.org/10.3389/fpsyg.2013.00890.

Malik and Sime conducted a study in 2020 on self-efficacy and trust in teammates, which are both essential for team effectiveness.[41] Their research focused on engineering students, and the relationship between neurotypical and neuroatypical students. A computer-assisted group learning environment is a successful way to enable all types of students to use social skills, communication skills, and teamwork. Elements of this learning environment can be applied to various subjects. This shows that autistic individuals can use subjects other than musical training to excel in daily living skills.

A similar study also suggested using COGLE for both neurotypical and neuroatypical students which stands for computer orchestrated group learning environment.[42] The aim is to stimulate, develop, and internalize teamwork skills. Elements of this study and learning environment could certainly be applied to any subject, including music. As previously stated, the self-efficacy of team members is critical to their effectiveness. COGLE was used with neurotypical and neuroatypical engineering students to study the impact on triggering existing regulation scripts in team work. Qualitative data from two identical cases were also analyzed. This showed how the different types of scripts in COGLE helped develop and improve regulation skills.

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[41] Malik Manish and Julie-Anne Sime, "Investigating Teams of Neuro-Typical and Neuro-Atypical Students Learning Together Using COGLE: A Multi Case Study," *IEEE Transactions on Education* Article 9273980 (December 4, 2020): 1-5, https://doi.org/10.1109/FIE44824.2020.9273980.

[42] Manish Malik; Julie-Anne Sime, "Triggering, Developing and Internalising Teamworking Skills in Neuro-Typical and Neuro-Atypical Students with a Computer Orchestrated Group Learning Environment: A Multi Case Study," *Universitat Politècnica de Catalunya* (September 1, 2022): 499-509, http://dx.doi.org/10.5821/conference-9788412322262.1163.

In their research article, Alice-Ann Darrow and Tammy Armstrong explored the implications of research on music and autism for music educators and explained the Handicapped Act of 1990.[43] Their article also discussed when autism was first identified, how many children had been diagnosed with autism, and how many males and females had been diagnosed with autism. Although research has developed a better understanding of autism over the past two decades, this resource lays a foundation and provides insight into when autism was even more of a mystery. The impact of music on autism has evolved significantly over the last two decades, including for music educators. This has enabled higher-quality training for all individuals.

Hammel and Hourigan's book covers topics related to teaching music to students with autism and begins with foundational elements by explaining the diagnosis of autism.[44] The authors also discuss understanding communication, classroom behavior, sensory dysfunction, and cognition. This book focuses on three of the challenges for music teacher education today and provides important resources to address these current challenges. The authors also state, "to truly understand a child with autism, music educators must understand the diagnosis and features of autism."[45] Characteristics and features of autism, typical interventions and treatment modes are discussed in the beginning of this book.

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[43] Alice-Ann Darrow and Tammy Armstrong, "Research on Music and Autism Implications for Music Educators," *Applications of Research in Music Education* 18, no. 1 (1999): 15-20, https://doi.org/10.1177/875512339901800103.

[44] Alice M. Hammel and Ryan M. Hourigan, *Teaching Music to Students with Autism* (New York: Oxford University Press, 2020), 1.

[45] Ibid.

Kupferstein and Rancer's book serves as a guide for educators, parents, and musically gifted individuals who have both autism and perfect pitch.[46] It is helpful for those struggling with their differences, and it shows how musical training can be used as a guide. The Rancer Method is often used to recognize and assess abilities, making connections between outstanding abilities and inabilities.[47]

Musical Interest

Molnar-Szakacs and Heaton explained how music provides a unique window into the world of autism.[48] There is evidence suggesting that many individuals with autism have a strong preference for music and an understanding of musical emotions. These signs can be shown throughout childhood and adulthood. Musical interest can be utilized for neuroatypical individuals in emotional and social aspects of life. There can often be a dissociation between emotional recognition in musical and social skills in individuals with autism. This allows for consideration of the nature of emotional processing difficulties which often characterize this disorder. "There has recently been a surge of interest in musical abilities in individuals with ASD, and this has motivated new behavioral and neuroimaging studies."[49]

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[46] Henny Kupferstein and Susan Rancer, *Perfect Pitch in the Key of Autism: A Guide for Educators, Parents, and the Musically Gifted* (Bloomington: iUniverse, 2016), 1.

[47] Ibid.

[48] Istvan Molnar-Szakacs and Pamela Heaton, "Music: A Unique Window into the World of Autism," *Annals of the New York Academy of Sciences* 1252, no. 1 (2012): 318-324, https://doi.org/10.1111/j.1749-6632.2012.06465.x.

[49] Ibid.

Mottron et al. provide a specific look at absolute pitch in autism.[50] This involved one participant, a low-functioning adolescent with autism. An assessment of pitch perception and processing systems relevant to current cognitive models of autism was used. The participant's performance was compared with that of neurotypical peers. No abnormalities were found, but a few deficits were identified in different aspects of this study. This study suggests that absolute pitch in autism may not result from a multimodal deficit in processing information. However, it may result from the lack of cognitive flexibility in an individual who may be interested in auditory stimuli which occurred at the age for absolute pitch to appear.

A 2023 study tested musical beat perception skills in autistic and neurotypical children.[51] "Many autistic children show musical interests and good musical skills, including pitch and melodic memory. Autistic children may also perceive temporal regularities in music such as the primary beat underlying the rhythmic structure of music given some work showing preserved rhythm processing in the context of basic, nonverbal auditory stimuli."[52] The research examined autistic children for their perceptual sensitivity to the primary beat of music. This data was compared with the musical beat perception abilities of autistic and neurotypical children. The study involved twenty-three autistic children and twenty-three neurotypical children aged six to thirteen years. There were no group differences in birth age or mental age. Each group completed a musical beat perception task in which they were asked to recognize whether beeps superimposed on the musical excerpts were on or off the musical beat. Overall task performance

[50] Laurent Mottron et al., "Absolute Pitch in Autism: A Case Study," *Neurocase* 5, no. 6 (May 11, 1999): 485-501, https://doi.org/10.1080/13554799908402744.

[51] Hadas Dahary, Charlotte Rimmer, and Eve-Marie Quintin, "Musical Beat Perception Skills of Autistic and Neurotypical Children," *Journal of Autism Developmental Disorders* 54, no. 4 (April 2024): 1453-1467, https://doi.org/10.1007/s10803-022-05864-w.

[52] Ibid.

was above 50 percent but not above the 70 percent threshold in all groups. On-beat accuracy was higher for the autistic group but not for the neurotypical group. The autistic group was also accurate in recognizing beat alignments, but it was less precise at detecting off-beats than the neurotypical group.

A 2018 study by Sharda et al. revealed that music improved social communication and auditory-motor connectivity in children with autism.[53] "Music has been identified as a strength in people with autism spectrum disorder; however, there is currently no neuroscientific evidence supporting its benefits. Given its universal appeal, intrinsic reward value, and ability to modify brain and behavior, music may be a potential therapeutic aid in autism."[54] Sharda's study provided the first evidence that eight to twelve weeks of music intervention could significantly improve social communication and functional brain connectivity. This also supports further investigations into music interventions for individuals with autism. Prior musical training may also make these interventions and therapies more effective for individuals with autism.

Chowdhury et al. researched auditory pitch perception in autism and found that it is associated with nonverbal skills.[55] Neuroatypical sensory perception and heterogeneous cognitive abilities are common characteristics in autistic individuals. However, there are mixed findings in previous studies on auditory sensory processing in autism. Auditory perception is related to cognitive abilities in individuals diagnosed with autism but is commonly

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[53] Megha Sharda, et al., "Music Improves Social Communication and Auditory-Motor Connectivity in Children with Autism," *Translational Psychiatry* 8, no. 1 (October 23, 2018): 231, https://doi.org/10.1038%2Fs41398-018-0287-3.

[54] Ibid.

[55] Rakhee Chowdhury, et al., "Auditory Pitch Perception in Autism Spectrum Disorder is Associated with Nonverbal Abilities," *Perception* 46, no. 11 (November 2017): 1298-1320, https://doi.org/10.1177/0301006617718715.

misunderstood. The main finding of Chowdhury's study was that auditory perception in autistic and neurotypical children is related to nonverbal reasoning but not to verbal abilities. These results also provided evidence for pitch processing in children with autism and an average IQ. This suggests that there may be a subgroup of people with autism who do not have perceptual or cognitive difficulties. Musical training may also help these individuals to improve their language disorders or perceptual impairments.

Gaps in the Literature

These various studies on perfect pitch and autism contain a wealth of background information on autism, pitch perception, speech disorders, and music interventions. This information sets the stage for expectations and perceptions about the topics studied. Although the findings are rich, there are still unanswered questions and more information to be discovered. The following sections outline areas that still need to be thoroughly explored. These include misconceptions about people with autism, as well as further recommendations for music interventions for people with autism.

The Stigma of Autism

There are myths about individuals diagnosed on the autism spectrum. Some of these myths include that all such individuals are intellectually disabled or lack emotional and social skills. While this disability has some neurological and physical limitations, these individuals have other enhanced abilities compared to neurotypical individuals. Perfect pitch and the ability to perceive or process the complexity of music are some of the many skills these people can naturally acquire. However, there are other recommendations for research studies that include

missing information about neuroatypical individuals in various aspects of their lives.

Caria, Venuti, and De Falco suggest that little is known about the ability of individuals with autism to experience emotions mediated by music.[56] Both autistic and neurotypical individuals underwent an fMRI session while listening to both happy and sad music. The article states that individuals diagnosed with autism activate cortical parts of the brain which is known to be associated with emotional processing. Autistic participants demonstrated a decrease in brain activity when processing positive music excerpts, as opposed to neurotypical individuals. The findings revealed neurobiological correlations of emotional processing in autism.

Individuals with autism are often stigmatized by their neurotypical peers, according to parents, teachers, and self-reported measures. Quantitative studies report negative attitudes toward people with autism; however, it is still unclear how the understanding of autism influences these attitudes. An exploratory study examined participants who believed myths about individuals diagnosed with autism.[57] This was investigated using focus groups. Purposive sampling was used to recruit undergraduate and graduate students. Adults with and without experience with autism were also recruited for one of the five focus groups. The findings showed that people with various experiences or knowledge about autism hold inaccurate biases about autism. The findings improved the understandings of these beliefs about autism and will potentially assist the implementation of interventions which are designed to improve knowledge of autistic characteristics.

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[56] Andrea Caria, Paola Venuti, and Simona De Falco, "Functional and Dysfunctional Brain Circuits Underlying Emotional Processing of Music in Autism Spectrum Disorders," *Cerebral Cortex* 21, no. 12 (December 2011): 2838-2849, https://doi.org/10.1093/cercor/bhr084.

[57] Rachael P. John; Fiona J. Knott, and Kate N. Harvey. "Myths About Autism: An Exploratory Study Using Focus Groups," *Autism* 22, no. 7 (October 2018): 845-854, https://doi.org/10.1177/1362361317714990.

"Understanding Stigma in Autism: A Narrative Review and Theoretical Model" is a study that examines the stigmatization of autism which is influenced primarily by public and professional understanding of autism in conjunction with the interpretation of visible autistic traits.[58] Contributing factors include the quality and quantity of contact with autistic people, cultural diversity, gender, and individual differences. Stigmas can affect well-being and reinforce the presence of behaviors that may mask autistic traits. "A variety of interventions and approaches to reduce stigma are discussed, including "autism-friendly" spaces, positive media representation, educational and psychosocial training for the public and professionals, as well as cultural and systemic shifts that foster inclusivity and recognize neurodiversity."[59]

Music and Autism

Several neurological connections between music and autism have only been partially researched thus far. There are many claims that individuals with autism have perfect pitch or exceptional relative pitch. Others claim that these individuals have exceptional rhythm or a special ear for music. Although some studies show that there is some truth to this, there is no outstanding evidence in the research. However, these individuals benefit greatly from musical interventions and music therapy, which is also recommended for further study.

[58] Alice Turnock; Kate Langley, Catherine R G Jones. "Understanding Stigma in Autism: A Narrative Review and Theoretical Model," *Autism Adulthood* 4, no. 1 (March 2022): 76-91, https://doi.org/10.1089%2Faut.2021.0005.

[59] Ibid.

An analysis by Whipple focuses on music as an intervention for children and adolescents with autism.[60] This meta-analysis includes twelve dependent variables from nine quantitative studies comparing music to no-music conditions during the treatment of children and adolescents with autism, resulting in an overall effect size of $d = .77$ and a mean weighted correlation of $r = .36$ ($p = .00$).

> The significant effect size, combined with the homogeneity of the studies, leads to the conclusion that all music intervention, regardless of purpose or implementation, has been effective for children and adolescents with autism. Included studies are described in terms of the type of dependent variables measured, theoretical approach; number of subjects in treatment sessions; participation in and use, selection, and presentation of music.[61]

Clinical implications and further recommendations for future research are also discussed in this analysis. This suggests that, while there were significant findings, there is still missing information.

Feldhaus et al. explore the links between the effects of loneliness, stress, and self-efficacy on people with autism and their neurotypical peers.[62] The participants in the research were all male and ranged in age from fifteen to twenty-seven. Half of the participants were diagnosed with autism, while the other half were neurotypical. "They completed several self-reported measurements. We found significant differences between the two groups in reported loneliness, life satisfaction, and self-efficacy. The conclusions point towards the need for broader studies of self-efficacy and life satisfaction of people with ASD and a reconsidering of the universality of

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[60] Jennifer Whipple, "Music in Intervention for Children and Adolescents with Autism: A Meta-Analysis," *Journal of Music Therapy* 41, no. 2 (2004): 90-106, https://doi.org/10.1093/jmt/41.2.90.

[61] Ibid.

[62] Carmen Feldhaus et al., "Students with Autism Spectrum Disorders and Their Neuro-Typical Peers—Differences and Influences of Loneliness, Stress and Self-Efficacy on Life Satisfaction," *Universal Journal of Educational Research* 3, no. 6 (2015): 375-381, https://eric.ed.gov/?id=EJ1066253.

developmental tasks."[63] Musical intervention or music therapy could certainly help these individuals improve with these skills and missing elements of their daily lives.

The final example of further research on music and autism includes a review of music- and sound-based interventions for autism spectrum disorders.[64] This review was conducted according to the criteria using Google Scholar, PubMed, CINAHL, MEDLINE, and Scopus. Five steps were included in the review such as: identification of inclusion criteria, search for relevant studies, search for study selection, data extraction and preparation, and data analysis and presentation. The four main themes emerged from the inclusion criteria, including the forms of sound therapy, which discussed the methods of sound therapy and the stimuli used; the duration of the intervention, which was explained in terms of listening time and total number of listening sessions; the clinical characteristics of the intervention, exploring the main interest of sound therapy studies in autism; and the evidence for the effectiveness of the intervention, examining the results of previous studies.

> This review demonstrated the need for further studies to address several issues, including identifying the effectiveness of sound-therapy intervention for ASD according to the individual sound types, the minimum duration for ASD sound-therapy intervention, and more details on the use of technology, and clinical features of the sound-therapy intervention. These elements are important to further demonstrate the effectiveness of sound therapy intervention for ASD children.[65]

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[63] Feldhaus et al., "Students with Autism Spectrum Disorders and Their Neuro-Typical Peers—Differences and Influences of Loneliness, Stress and Self-Efficacy on Life Satisfaction."

[64] Fatin Amira Shahrudin, et al., "Music and Sound-Based Intervention in Autism Spectrum Disorder: A Scoping Review," *Psychiatry Investigation* 19, no. 8 (August 2022): 626-636, https://doi.org/10.30773%2Fpi.2021.0382.

[65] Shahrudin, et al., "Music and Sound-Based Intervention in Autism Spectrum Disorder: A Scoping Review."

Summary

Scholars have addressed the relationship between autism and learning music, as well as the independent and dependent variables for this study. Particularly, one article highlighted twelve high-functioning adults with autism who were interviewed to measure their personal experiences with music.[66] The results revealed that most of the adults used music for cognitive, emotional, and social purposes. Compared to neurotypical adults, these participants relied more on internally focused language than externally focused language. The article also expressed the need for further studies on self-efficacy and life satisfaction for people with autism and reconsideration of their developmental tasks.[67]

The literature also included current information and gaps in previous studies on pitch matching between neurotypical and neuroatypical students. There is some evidence that suggests many individuals diagnosed with Autism show music preferences and clearly understand musical emotions from an early age and throughout their lives.[68] However, the evidence for these various aspects of the relationship between autism and music still needs to be further refined for music education to be more effective among individuals with autism.

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[66] Allen, Hill, and Heaton, "The Subjective Experience of Music in Autism Spectrum Disorder."

[67] Allen, Hill, and Heaton, "The Subjective Experience of Music in Autism Spectrum Disorder."

[68] Molnar-Szakacs and Heaton, "Music."

CHAPTER THREE: METHODS

This chapter describes the methods used for this study which was based on a quantitative design approach that included a pitch matching given to the participants individually. This was a quasi-experimental study with a few limitations. Determining whether autistic individuals recognize pitch more accurately than neurotypical individuals based on factors such as genetics, learning environment, home environment, early childhood training, and interest in the subject of music was a primary focus for this study.

Design

The quantitative method was utilized. This design was chosen because it most accurately measured the comparison of autistic and neurotypical students' abilities to match pitch through a pitch matching test. Quantitative research is an "approach for testing objective theories by examining the relationship among variables or a comparison among groups."[69] This approach was used as a foundation for collecting and comparing data.

An example of using this approach involves a study that provides the framework for parent coaching of music interventions for children with autism. Further research could include the investigation of other methods through these music interventions such as teaching the music, session scheduling, and measuring the parental response.[70] Janet Preis et. al found that background music did not affect spontaneous verbalization or engagement in young people with

[69] Creswell and Creswell, *Research Design,* 3.

[70] Eugenia Hernandez-Ruiz, "Feasibility of Parent Coaching of Music Interventions for Children with Autism Spectrum Disorder," *Music Therapy Perspectives* 38, no. 2 (December 8, 2019): 195-204, https://doi.org/10.1093/mtp/miz016.

autism.[71] "Results of the 28-week, alternating treatments design study consistently found that background music had no effect on either spontaneous verbal expression or engagement in the five young participants with autism. In addition, the type of music played, classical, children's songs, or reggae did not affect these outcome measures."[72]

The final example of the issue of this design approach involves a study that concluded, "All music intervention, regardless of purpose or implementation, has been effective for children and adolescents with autism."[73] This study also stated, "Included studies are described in terms of the type of dependent variables measured; theoretical approach; the number of subjects in treatment sessions; participation in and use, selection, and presentation of music; researcher discipline; published or unpublished source; and subject age. Clinical implications as well as recommendations for future research are discussed."[74]

The specific limitations of this design included a lack of resources to analyze the results and difficulty in data analysis. Quantitative research is naturally empirical and is also known as the "scientific research paradigm." This type of research gives valid results by rigorous clarification, definition, and use of experiments. This includes testing out the instrumentation before a study, proving the relevance with other researchers, and determining the reliability using statistical tests. This type of research can also be classified as inferential, experimental, or

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[71] Janet Preis, Roxanne Amon, Dara Silbert Robinette, and Ashley Rozegar, "Does Music Matter? The Effects of Background Music on Verbal Expression and Engagement in Children with Autism Spectrum Disorders," *Music Therapy Perspectives* 34, no. 1 (March 20, 2015): 106-115, https://doi.org/10.1093/mtp/miu044.

[72] Ibid.

[73] Whipple, "Music in Intervention for Children and Adolescents with Autism: A Meta-Analysis."

[74] Ibid.

simulation in research.[75] Regarding data analysis in quantitative design, the quantitative research approach strives for accurate instrumentation and measurements, allowing for an analysis that utilizes statistics. Throughout an analysis of each research method, it becomes clear to choose the most accurate, informed, and reliable approach.

Participants

The population for this study included both males and females from West Virginia, United States. The population also included both autistic and neurotypical participants. The age range of participants included individuals eighteen years of age and older. Although this is more common in qualitative research, snowball sampling was primarily used. This allowed the initial contacts to approach their contacts and consider who might be interested in participating in this study. The snowball system has advantages and disadvantages. For this study, the snowball method was used for the ten autistic participants.

There were a total of twelve participants, both neurotypical and autistic. It is important to consider the calculation and sample size. The sample size calculations depend on which type of data and distribution. These elements include the considerations of meaningful differences, alpha error, beta error, and the variables or deviation. Most importantly, sample size calculations should consider funding, all available data, facilities, and the ethics of research participants.[76] The initial participants were selected from established contacts who were willing to participate.

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[75] Pamela A. Ochieng, "An Analysis of the Strengths and Limitation of Qualitative and Quantitative Research Paradigms," *Problems of Education in the 21st Century* 13 (2009): 13-18, https://www.proquest.com/scholarly-journals/analysis-strengths-limitation-qualitative/docview/2343816184/se-2.

[76] Nithya J. Gogtay, "Principles of Sample Size Calculation," *Indian Journal of Ophthalmology* 58, no. 6 (2010): 517-518, https://doi.org/10.4103/0301-4738.71692.

Participants were identified through the initial selection of participants. The researcher selected two participants to assist in identifying the remaining participants. The researcher published a Facebook post to recruit and increase the number of participants.

The purpose of this study and the test factors were explained to each participant. This was initially done by email, telephone, or in person. This study included 50 percent of participants with autism and 50 percent neurotypical participants. The groups were randomly assigned to have an even number of each factor. The neurotypical and neuroatypical group included a wide age range from eighteen and above. Participants also had varying levels of prior musical knowledge. This study was conducted in a private classroom in Barboursville, West Virginia, where each participant was tested individually. This relatively small room contained only a keyboard and two chairs to eliminate distractions. The test used in this study was also administered via Zoom when necessary.

Instrumentation

The pitch matching accuracy and temporal auditory processing test has been used in certain studies and a variation of this test was included in this study particularly.[77] The pitch matching test determines an individual's pitch matching ability, which is shown through the vocal imitation of sounds heard from reference tones. There are ten sound tasks in total including the first five being recordings of a piano and the other five being recordings of a human voice singing a vowel. This instrument was designed to "correlate pitch-matching accuracy and auditory processing in individuals without musical training."

[77] Fadel et al., "Pitch-Matching Accuracy."

There were ten stimulus sequences for the pitch matching test, which gave a total score. The instrumentation was administered neutrally. Each participant focused primarily on the test, which allowed for no additional conversation or distractions. Each participant was treated equally. The test was administered on the same day as each of the participants were selected and agreed to participate in this study. Each participant took no longer than five minutes to complete the test for this study. No permission was required to utilize this test as it was a modification of the test and not the exact procedure.

	AG ($n = 28$)			IG ($n = 34$)			AG and IG ($n = 62$)		
	Mean (SD)	Median	Min-Max	Mean (SD)	Median	Min-Max	Mean (SD)	Median	Min-Max
Synt	62.9 (20.9)	60	40–100	17.9 (20.0)	20	0–60	38.2 (30.3)	40	0–100
Vocal	96.4 (9.5)	100	60–100	34.1 (30.2)	20	0–100	62.3 (38.9)	80	0–100
p	< 0.001*			0.01*			< 0.001*		

Abbreviations: AG, accurate match group; IG, inaccurate match group; SD, standard deviation; Synt, number of correct responses to synthesized sounds; Vocal, number of correct responses to vocalized sounds.
Note: *Wilcoxon test.

Figure 1. An example of calculating the results for the original pitch matching and temporal accuracy test.

Sequence	Source	Female Tones	Male Tones
1st	Piano	C4	C3
2nd	Piano	G4	G3
3rd	Piano	A4	A3
4th	Piano	D4 & F#4	D3 & F#3
5th	Piano	A#4 & F# 4	A#3 & F#3
6th	Voice	G4	G3
7th	Voice	D4	D3
8th	Voice	F#4	F#3
9th	Voice	A4 & F4	A3 & F3
10th	Voice	E4 & G#4	E3 & G#3

Figure 2. The reference tones of the pitch matching test for males and females.

Procedures

Participants were recruited by email, telephone, or in person. The information sheets were sent by email or handed out in person. No training was required for this study. The researcher administered the pitch matching test and recorded the results. Data collection was conducted through the following steps: (1) The information sheets were sent via text message, email, or in person. (2) The test administrator accessed the pitch matching test online. (3) The student listened to audio samples followed by verbal questions from the test administrator. (4) The test administrator recorded each participant's verbal responses. (5) The test responses were transferred to a protected computer file.

Data Analysis

Correlational research and inferential statistics were chosen to potentially obtain the most accurate results.[78] Sample size and power analysis were not used for this study.[79] To limit instances of researcher bias, the main assumption to be addressed was the idea that autistic students have a greater ability to match pitch and dictate rhythm than neurotypical students. The effect size was reported by identifying the "strength of the conclusions about group differences or the relationships among variables" from the study.

[78] Xiaohou Ke. et al., "Effectiveness of Music Therapy in Children with Autism Spectrum Disorder: A Systematic Review and Meta-Analysis," *Frontiers in Psychiatry* 13 (October 6, 2022): 905113, https://doi.org/10.3389%2Ffpsyt.2022.905113.

[79] Megha Sharda. et al., "Music Improves Social Communication and Auditory-Motor Connectivity in Children with Autism," *Translational Psychiatry* 8, no. 1 (October 23, 2018): 231, https://doi.org/10.1038%2Fs41398-018-0287-3.

Summary

The design chosen for this study was chosen to determine accurate and pertinent findings. Quantitative research is a method of design that can provide standard data collection and general findings across different populations and settings. This design also improves reliability, eliminates bias, and provides specific variables for a more focused result. “These variables, in turn, can be measured, typically on instruments, so that numbered data can be analyzed using statistical procedures.”[80] The results give a set structure that compromises an introduction, methods, results, implications, and discussion.

[80] Creswell and Creswell, *Research Design,* 5.

CHAPTER FOUR: RESEARCH FINDINGS

The dates for testing were chosen after IRB approval, which was a notice of exemption. The initial IRB submission was completed on March 22, 2024. One missing file was submitted on March 26, 2024, and six minor corrections were subsequently submitted on April 12, 2024. The IRB granted a waiver for this pitch matching study on April 17, 2024, almost one month after the initial submission. Compared to the variables and hypotheses for this study, the results were opposing as the neuroatypical participants did not match pitch as accurately as the neurotypical participants.

Preparation

This study began on April 18, 2024. The neurotypical participants were first given the pitch matching test between April 18 and April 24, 2024. All but two of the neurotypical participants were tested in a private lesson room located in Barboursville, West Virginia. The neuroatypical participants were tested between April 30 and May 3, 2024. The neuroatypical participants were also able to be tested in a private lesson room. Only two participants used the FaceTime option to take the test.

The neurotypical participants were recruited through the researcher's coworkers and friends. The neuroatypical participants were recruited through snowball sampling. The researcher first contacted a family member, Dr. Tammy Collins, Associate Director of the Center of Excellence for Recovery at Marshall College in Huntington, West Virginia. Dr. Collins connected the researcher with Dr. Marc Ellison, Director of the West Virginia Autism Training Center, which is also located at Marshall College in Huntington, West Virginia. Dr. Ellison was interested in the study, and the Marshall College IRB permitted him to send the information

sheets to all autism specialists in the state of West Virginia. The researcher also contacted Dr. Jimmie Beirne, the executive director of the Autism Services Center in Huntington, West Virginia. The researcher's last contact was with Mainstream Services in Lavalette, West Virginia, which supports clients with autism and other developmental disabilities.

Neurotypical Participants

The variables in this study included the home environment, learning environment, genetics, musical knowledge, and musical interest. The neurotypical participants had varying levels of musical training before taking the test. There were three trained musicians, and the rest of the participants had some previous musical knowledge. The learning environment included previous musical training in a public school setting. This study did not include genetic testing, but it will be considered in future studies. Most of the neurotypical participants expressed an interest in music. Each participant typically enjoyed music, but not all expressed an interest in learning how to play instruments or sing, nor were they interested in learning about music theory or music history.

Each participant was randomly selected based on their willingness to participate. Their participation involved taking part in a pitch matching test in which they were asked to listen to ten different tones and compare the pitch of the tone with their voice. This test was designed to correlate an individual’s pitch matching accuracy and auditory processing without prior musical training. As mentioned in the preparation section, eight neurotypical participants completed the pitch matching test in a private classroom. The remaining two participants chose to complete this test via a FaceTime call. Each group member listened to a two-second tone played from the Dropbox app on an iPhone. The sound was loud enough for participants to hear it clearly and

match the pitch to their voices. Most of the participants were afraid to take the test. Each person was encouraged, verbally reassured, and given a positive environment to complete the test.

The individuals in this group had to match had to match ten musical pitches. Five of these tones were recorded piano notes. The remaining five sounds were vocal recordings of the vowel /u/. In total, there were one hundred sounds among the participants. Of these participants, sixty of the one hundred sounds were accurately matched. Figure three shows the results of the neurotypical participants matching the pitch to their voices.

Figure 3. The independent variables for this pitch matching study were genetics, learning environment, and home environment. While genetics is critical to autism diagnosis and perfect pitch identification, an individual's learning environment and home environment can also contribute to these issues. An individual's learning environment and home environment can also vary depending on culture and other differences. Figure three shows the three main factors related to autism and perfect pitch. There are many possible correlations between these two issues.

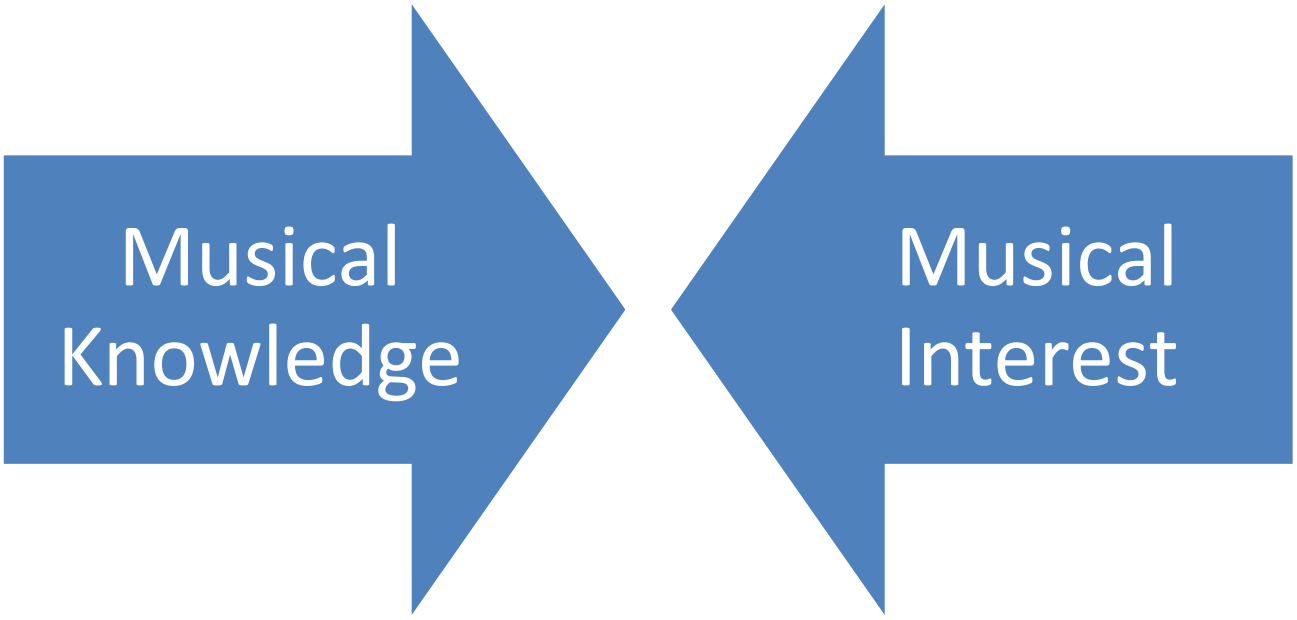

Figure 4. The dependent variables for this study included early childhood musical training and interest in music as a subject. Musical training and musical interest mainly depend on a person's learning environment, home environment, and even genetics. An individual's musical training and interest may vary according to culture and other differences. Figure four shows the two musical factors related to autism and perfect pitch.

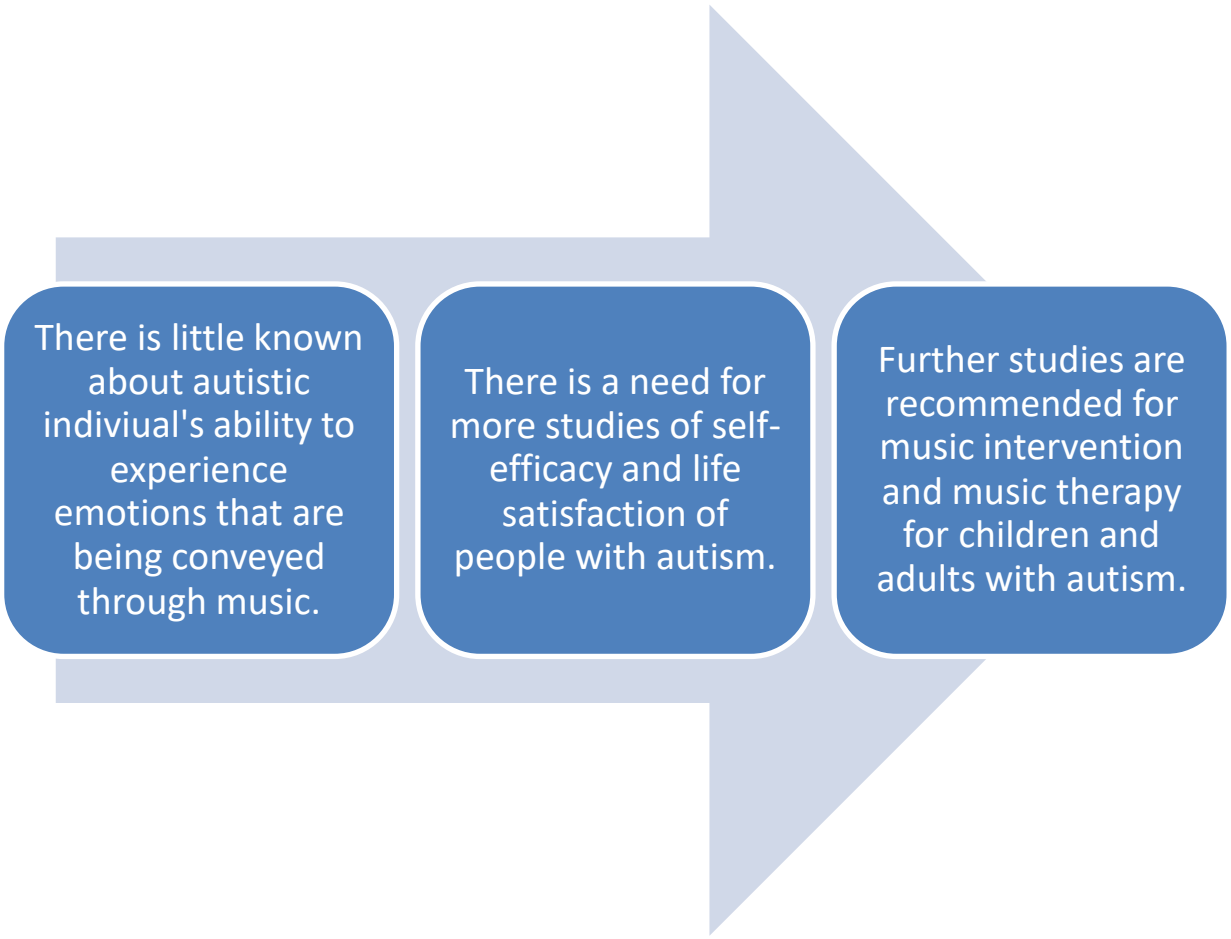

Figure 5. Although the results of studies on autism and perfect pitch are numerous, there are still unanswered questions and more information to be discovered. Figure five shows areas that still need to be investigated. These include misconceptions about individuals with autism and further recommendations for music interventions for individuals with autism.

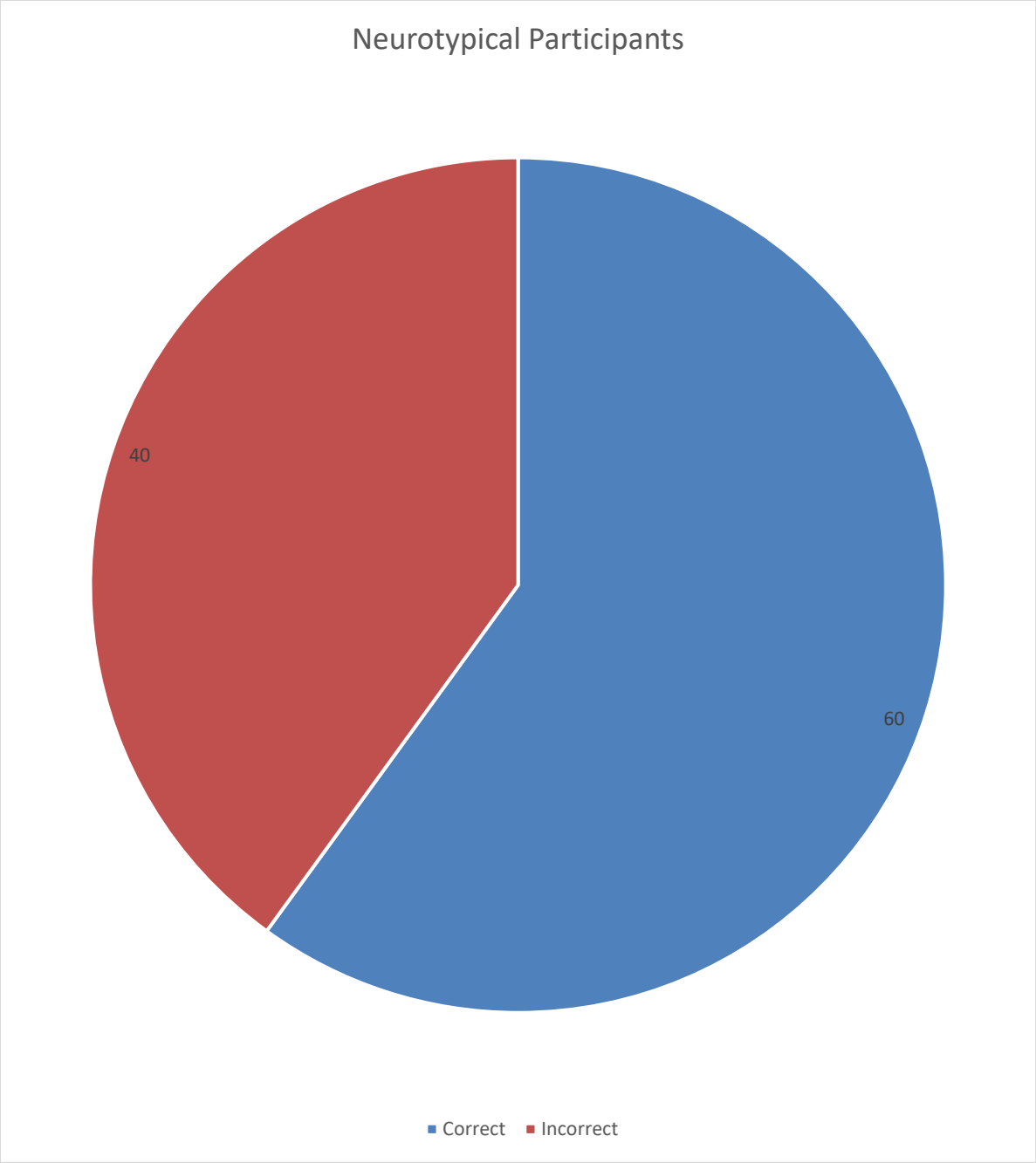

Figure 6. The neurotypical participants for this research study collectively scored 60/100 accurate pitch matching tasks.

Neuroatypical Participants

Considering independent and dependent variables for this study, the neuroatypical participants also had varying levels of musical training before taking the test. Each participant was not musically trained but had some previous musical experience through classes and activities. Most of the neuroatypical participants also expressed an interest in music. Each participant enjoyed listening to music, but none of them expressed interest in learning how to play instruments or sing. They were also not interested in learning various aspects or contributions to music.

All ten neuroatypical participants took the pitch matching test in person in a private classroom. Each participant listened to a two-second tone played from the Dropbox app on an iPhone. The sound was played at a volume that participants could hear clearly and were able to match the pitch to their voice. Each participant was encouraged, reassured, and given a positive testing environment.

There were ten individual tones that each participant in this group had to match. Five of these tones were recorded piano tones. The remaining five tones were vocal recordings of the vowel /u/. In total, there were one hundred sounds played for the participants in this group. Among these participants, twenty-seven of the one hundred sounds were accurately matched. Figure seven shows the results of the neuroatypical participants matching the pitch to their voices.

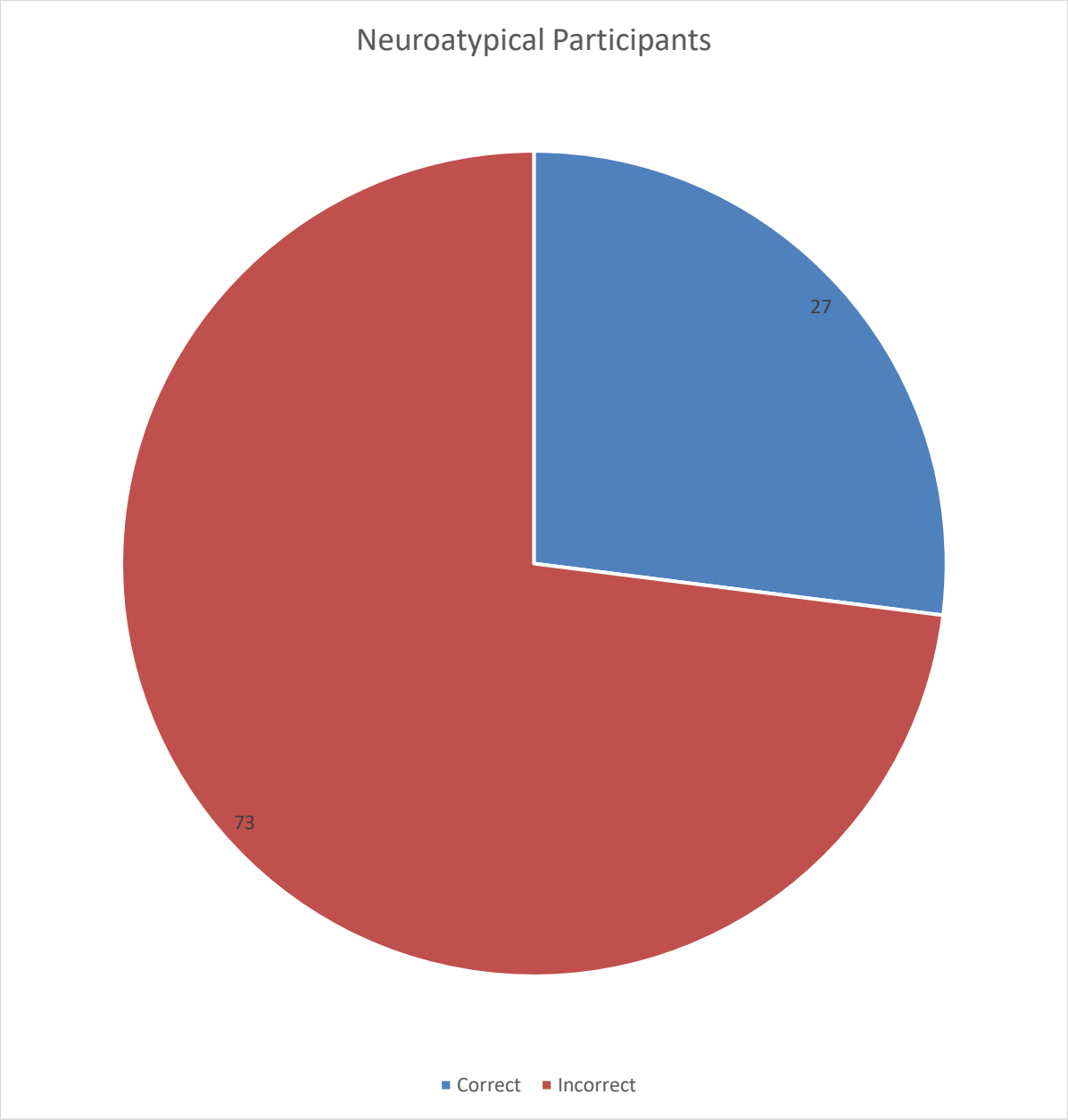

Figure 7. The neuroatypical participants collectively scored 27/100 accurate pitch matching tasks.

Comparing Results

The first group of neurotypical individuals had a higher score than the second group of neuroatypical individuals. The environment provided for the test and the actual pitch matching test were the same for each participant. This test was also administered to each participant in the same way by the same test administrator. On average, each group had the same level of musical knowledge and interest. Figure seven compares the results of this pitch matching study.

Other sources may also provide a comparison of this study's results. One example is a study conducted by Ong et al., which had similar findings regarding autistic participants and their pitch matching abilities based on cognitive abilities. This includes autistic individuals who demonstrated similar or worse task performance than neurotypical individuals, cognitive abilities were associated with some pitch matching tasks, and cognitive abilities influenced the relationship between autism and pitch perception.[81]

The results of this study highlight the importance of understanding the strengths and weaknesses of pitch processing in autistic individuals. It is important to recognize that the results cannot be generalized when comparing and testing neurotypical and neuroatypical individuals. Many underlying factors can lead to different results. These factors include hearing loss, comprehension, auditory processing, mental ability, and the testing environment.

[81] Ong et al., "The Relationship Between Autism and Pitch Perception."

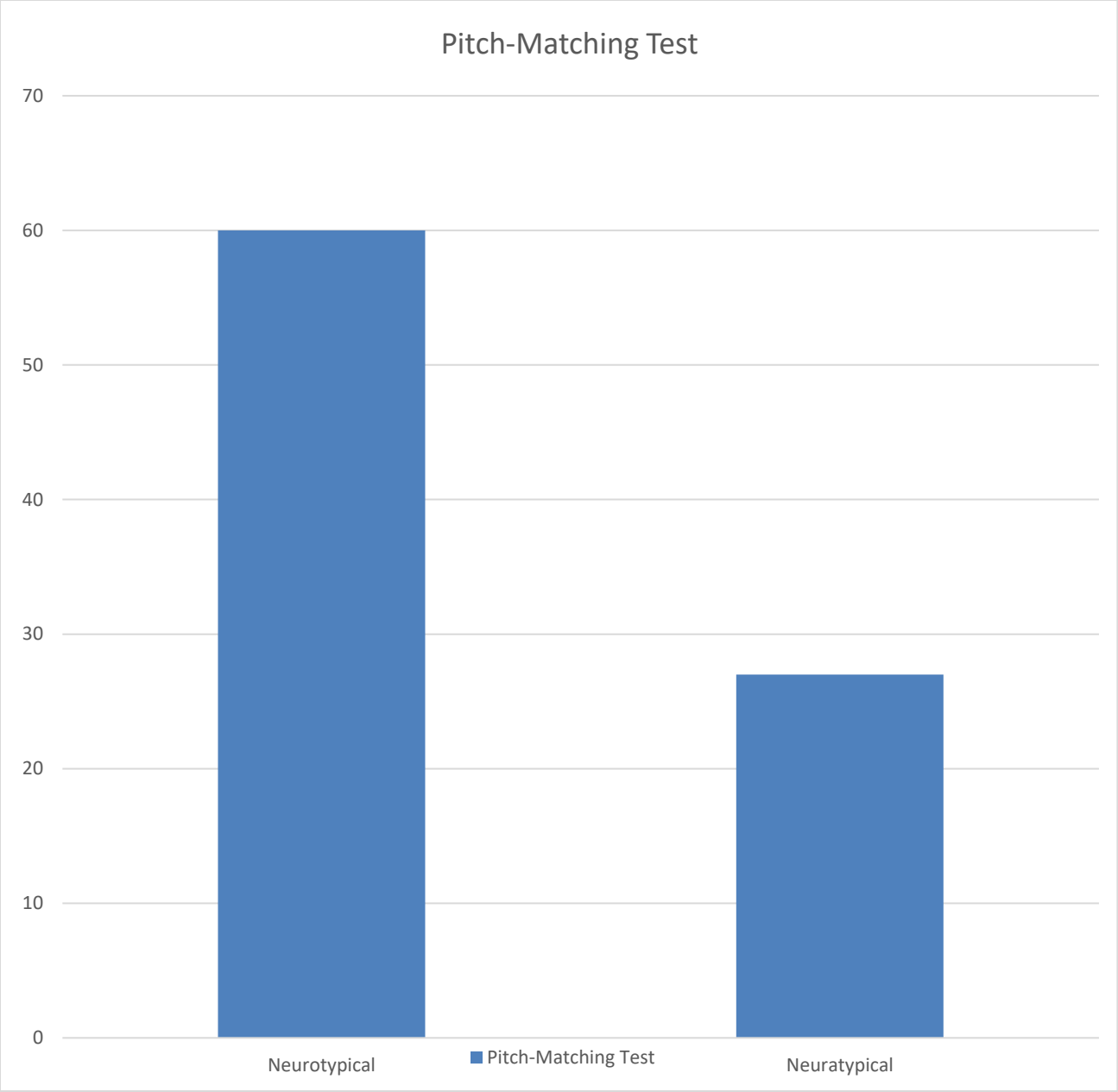

Figure 8. A comparison of the collective scores from both groups.

Other similar studies involved a pitch matching test or something related. The first example is a study on tinnitus. The exact pitch of a tinnitus sound is one of the characteristics that is important in research and sound therapies which rely on the tinnitus pitch matches. Identifying the exact tinnitus pitch is rather challenging because there is no objective measurement to obtain.[82]

The second example is a comparison of the tinnitus pitch matching procedure with other pitch matching tests. As mentioned in previous chapters, tinnitus pitch matching is when the frequency of a sound is manipulated to where its pitch matches the tinnitus. The correct measurement of the tinnitus is an important role and effective for therapy which is sound-based.[83] This example shows another layer behind pitch matching and the many aspects involved in selecting a pitch matching test.

The third example is a study that compared self-administered tinnitus pitch matching with a conventional audiometric procedure.[84] This study investigated whether computerized, self-administered tinnitus pitch matching could be compared with a conventional audiometric procedure. The results suggested that the self-administered tinnitus pitch matching was as accurate as the audiologic procedure, which can be used in place of the conventional audiometric procedure when octave confusion is minimal.

The final example of pitch matching methods is a research study on pitch perception.[85] Pitch is a primary auditory sensation that is essential in music, speech, and auditory scene

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[82] Neff. Et al., "Comparing Three Established Methods for Tinnitus Pitch Matching with Respect to Reliability, Matching Duration, and Subjective Satisfaction."

[83] Santacruz, de Klein, and van Dijk, "Comparison Between Two Self-Guided Tinnitus Pitch Matching Methods."

[84] Su Kim et al., "Self-Administered Tinnitus Pitch Matching."

[85] Oxenham, "Pitch Perception."

analysis. Oxenham found that the main correlates of pitch were acoustic periodicity and repetition rate; however, some interactions can complicate the relationship between the stimulus and the perception of pitch. Each example illustrates an additional aspect of the complexity of pitch matching. Several physical correlations and musical aspects make up the auditory matching of pitch or musical tone.

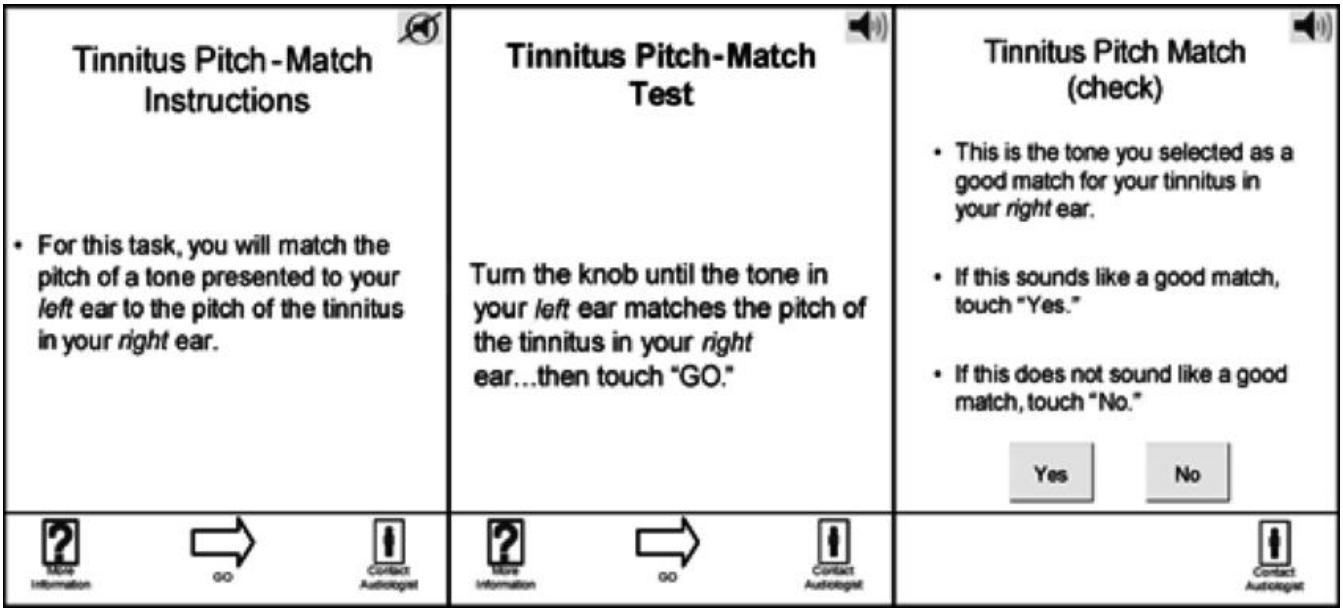
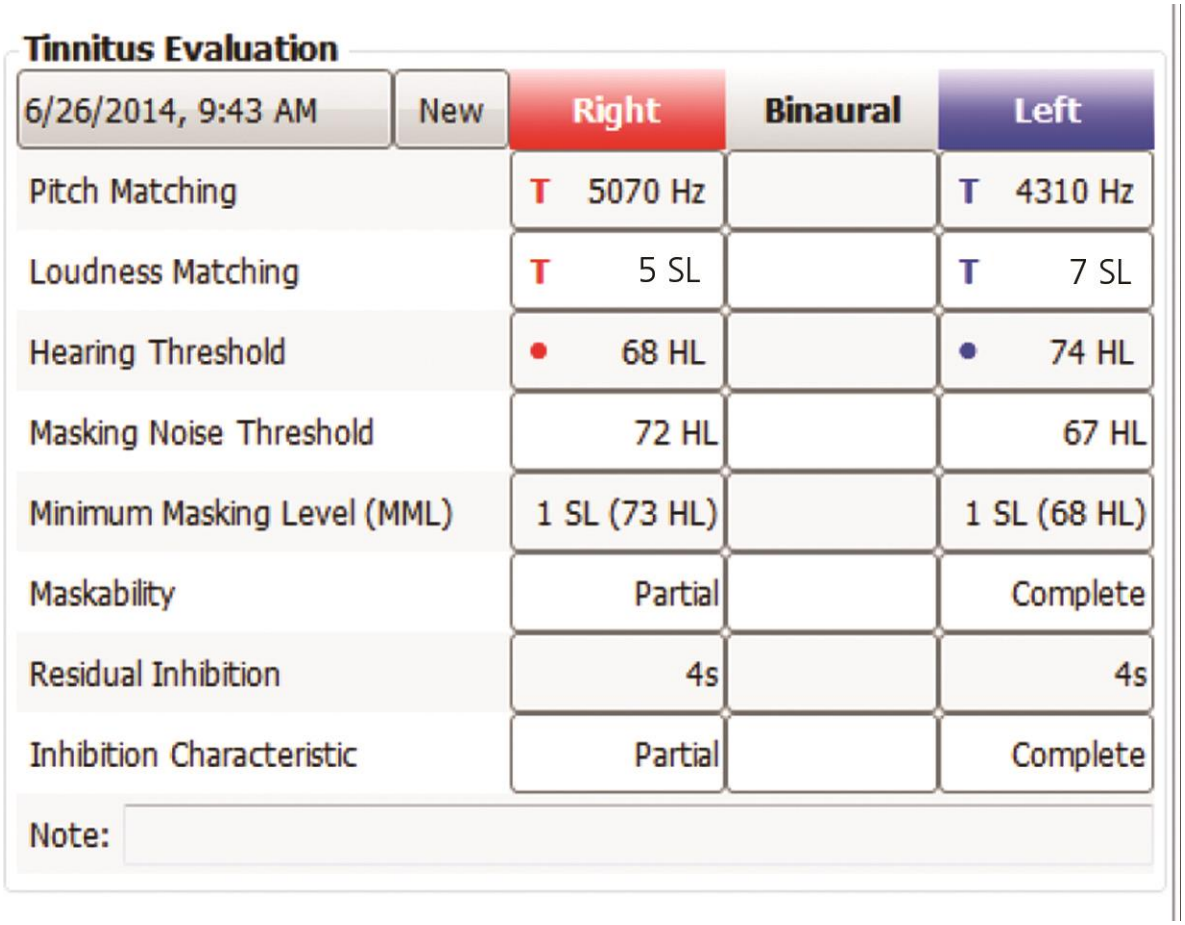


Figure 9. General tinnitus pitch matching instructions for individuals tested with an automated system.



Tinnitus Evaluation

6/26/2014, 9:43 AM	New	Right	Binaural	Left
Pitch Matching		T 5070 Hz		T 4310 Hz
Loudness Matching		T 5 SL		T 7 SL
Hearing Threshold		● 68 HL		● 74 HL
Masking Noise Threshold		72 HL		67 HL
Minimum Masking Level (MML)		1 SL (73 HL)		1 SL (68 HL)
Maskability		Partial		Complete
Residual Inhibition		4s		4s
Inhibition Characteristic		Partial		Complete
Note:				

Figure 10. The components for a tinnitus pitch matching evaluation.

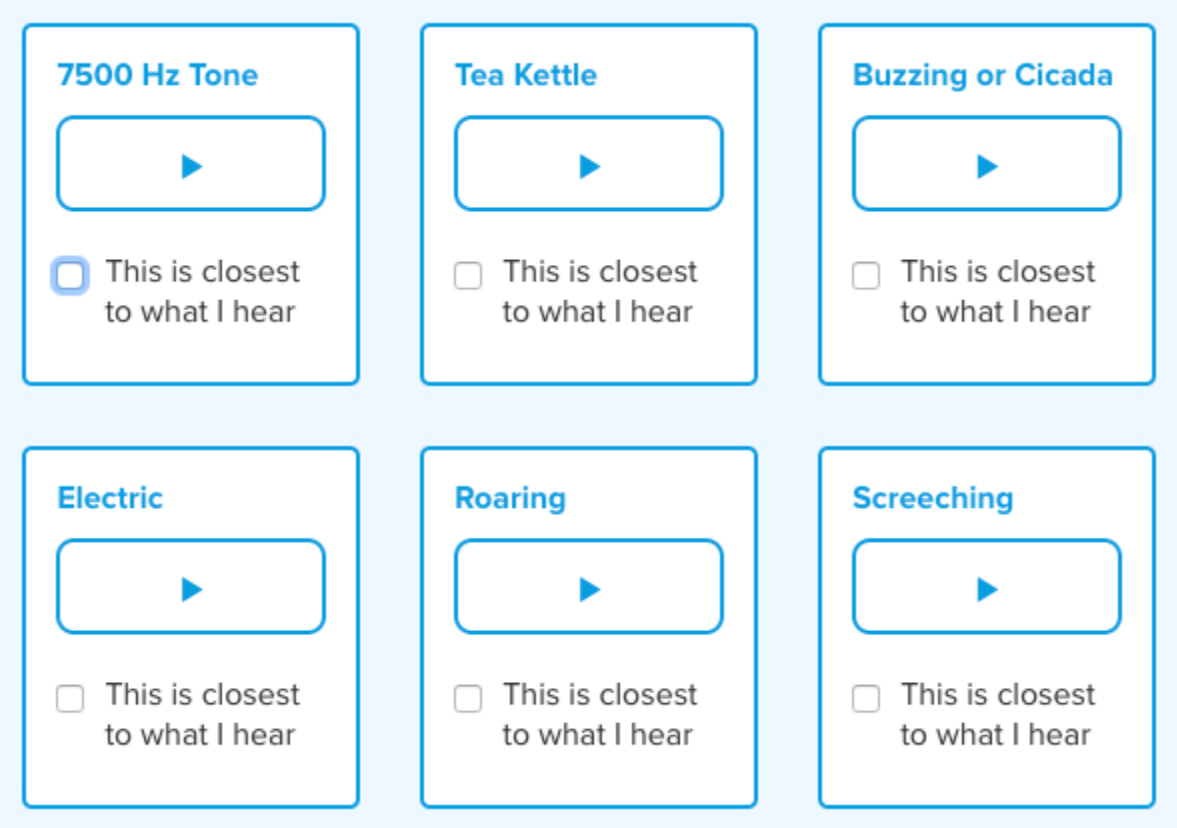


Figure 11. A sound match tool for the tinnitus pitch matching test.

Comparison	ICC (95% CI)	Freq (kHz)	OD	Loudness (dB SPL)
Between sessions, within-method				
Method of Adjustment (MOA)	0.77 (0.49–0.90)	4.4 ± 2.4	0.53 ± 0.60	78 ± 12
Multiple-Choice Method (MCM)	0.92 (0.81–0.97)	4.0 ± 2.8	0.39 ± 0.48	–
Within-session, between methods				
Session 1	0.43 (0.02–0.73)	4.4 ± 2.7	0.80 ± 0.97	
Session 2	0.62 (0.25–0.83)	4.1 ± 2.5	0.62 ± 0.55	

ICC, intraclass correlation; OD, difference in octaves. Mean values and standard deviations are presented, unless stated otherwise.

Figure 12. A comparison between two tinnitus pitch matching methods.

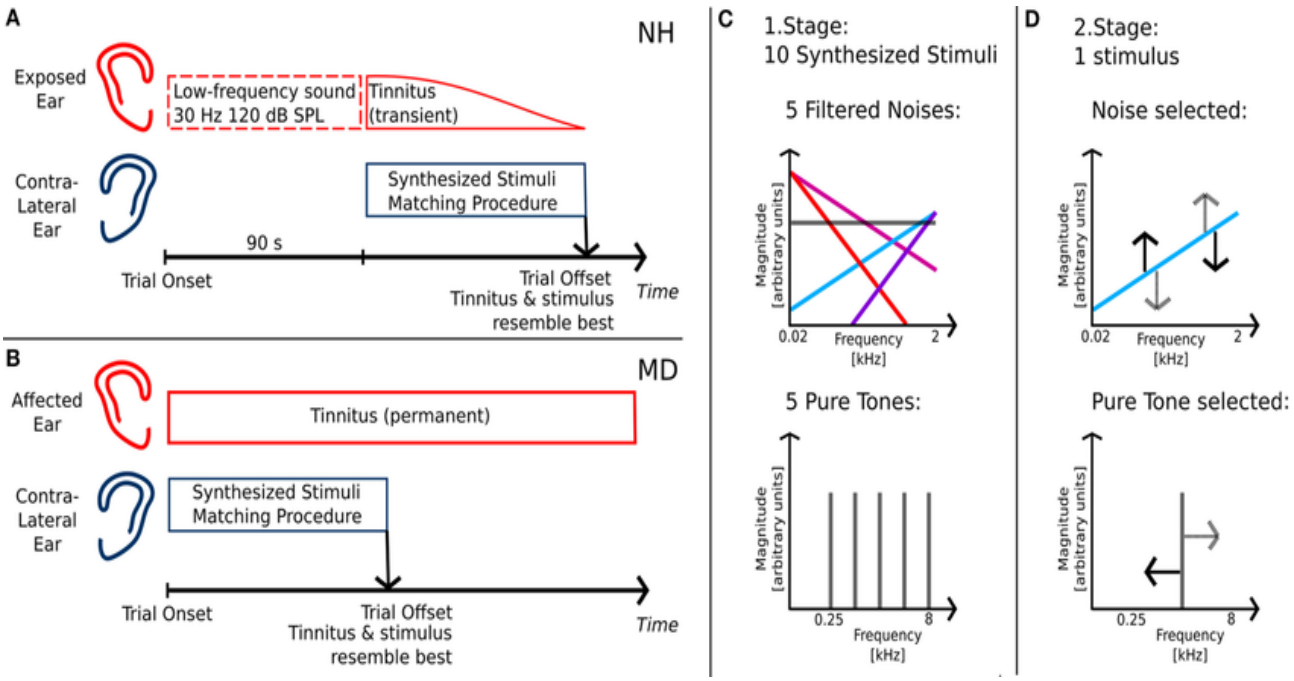


Figure 13. An audiogram of tinnitus pitch matching procedures.

Summary

The results of this study have only scratched the surface of this topic, allowing for further research questions and further studies on this topic. Factors that may prevent these people from fully grasping this concept include hearing loss, comprehension, and auditory processing. These factors are common among people with special needs. Even though the results show that these individuals do not recognize pitch as well, it is evident that they have other challenges that music educators can consider when developing curricula. Another study on auditory pitch perception in autism determined the different developmental paths between autistic and neurotypical individuals.[86] The need for further investigation of pitch perception in autism can be evident throughout these studies.

[86] Chen. Et al., "Auditory Pitch Perception in Autism Spectrum Disorder: A Systematic Review and Meta-Analysis."

CHAPTER FIVE: CONCLUSION

The general population may not be aware of the possibility that individuals with autism can recognize pitch more accurately compared to neurotypical individuals. Certain aspects of this topic have been studied, but very few studies have directly addressed this specific issue. Neurological and genetic correlations with neuroatypical individuals with perfect pitch need to be further investigated. It is important to address these issues for future music education and further understanding of the strengths of autistic individuals. Researchers have offered various theories to explain why perfect pitch may or may not be more common in individuals with autism.

The aim of this study was to compare and find out the differences between autistic and neurotypical individuals in learning pitch. This study aimed to recruit both neurotypical and autistic individuals to a private classroom and/or Zoom meeting, where they were given a test to measure their pitch recognition skills. The independent variables were defined by genetics, the learning environment, and the home environment. The dependent variables included early childhood musical training and an interest in music as a subject. The relationship between the independent variables in this study was important to consider because the participants' environment and genetics could significantly affect the outcome of the study. The correlation behind the results also depends on the relationship between the dependent variables and how each was formed from the independent variables.

While this study addressed the learning of pitch identification between neurotypical and autistic individuals, there are other research questions on this topic that need to be discussed. Factors that may prevent these individuals from fully grasping this concept include hearing loss, comprehension, auditory processing, level of mental ability, and testing environment. Although

the results showed that these individuals do not recognize pitch as well as neurotypical individuals, it is evident that these individuals with special needs have other challenges that music educators can consider when developing curricula.

Summary of Study

For this study, a pitch matching test was administered individually to twenty participants. The first group consisted of ten adult participants who were classified as neurotypical. The second group included ten adult participants who had been diagnosed with high-functioning autism. This study took place primarily in a private classroom in West Virginia and partially via FaceTime calls. Each participant was given ten stimuli aurally before they matched the musical tones through vocal imitation. The results were calculated by the administrator. The findings will allow for further discussions and conclusions about music education for neuroatypical students and the impact of music on their community.

Purpose

The purpose of this study was to determine which group was more accurate when perceiving a musical tone aurally and then matching the pitch with their voice. Each participant was tested individually. According to the results, the neurotypical group had a higher number of accurate pitch matching scores. However, these individuals with special needs have other challenges that music educators could incorporate when developing curricula. This includes auditory and cognitive disabilities that are associated with autism. Accounting these various disabilities will allow for educators to design and develop curricula accordingly. Potentially,

through music education, these results will also improve various skill sets among individuals with autism.

Procedures

Participants were recruited by email, telephone, and in person. Information sheets were sent by email or handed out in person. No training was required for the administrator or participants prior this study. The researcher conducted the pitch matching test and recorded the test results. The data collection included sending the information sheets by phone, email, and in person, accessing the pitch matching test online through the Dropbox iPhone app, participants listening to ten audio samples, verbal questions following the test from the test administrator, recording each participant's verbal responses by the administrator, transferring the test responses to a protected computer file.

Analysis

This study aimed to compare and identify possible differences between autistic and neurotypical individuals in learning to identify pitch. The study investigated whether autistic individuals recognize pitch more accurately than neurotypical individuals. The study used a quantitative approach and utilized a variant of the Pitch Matching Test. The population for this study included both males and females from West Virginia. In addition, the population included both autistic and neurotypical participants aged eighteen years and older. There was a total of twenty participants, including both neurotypical and autistic individuals. One group included ten neurotypical participants while the other group included ten neuroatypical participants. Both

groups were compared through each of their test scores to give findings and results with further discussions.

Results

The results of the study showed that the neurotypical participants scored higher on accurate pitch matching than the neuroatypical participants. The results do not align with the hypothesis, however, there are conclusions and further discussions for this gap which can be addressed. Many possible outcomes can still be derived from this study moving forward. This study will potentially improve music education for autistic students and impact their communities. Identifying the number of autistic individuals with perfect or exceptional relative pitch could greatly impact their music learning. Making these connections between pitch matching and neuroatypical students could also be useful for music educators when designing curricula.

Significance

This study shows that neuroatypical individuals may have a higher potential to understand pitch. Factors that may prevent these individuals from fully grasping this concept include hearing loss, comprehension, and auditory processing. These factors are common among individuals with special needs. While the results show that these individuals do not recognize pitch as well, they may also have other issues that music educators can address. There are several sources for similar studies covering various topics related to autistic individuals and education. This emphasizes the significance of this study for music education and the considerations for music educators teaching students with autism.

Enhanced Abilities

As mentioned in previous chapters, this study was significant because it addresses the abilities of autistic students which is rarely researched in music education. In comparison with studies on social and cognitive impairments in autistic individuals, research has not focused on studying the enhanced abilities that are often associated with autism. There are certain terms which have been introduced to describe these enhanced abilities in autism.[87] Autistic individuals with these enhanced abilities are often referred to as "twice-exceptional." They are exceptional for having an autism diagnosis and for having enhanced cognitive abilities in certain areas of the brain. Another enhanced ability term "cognitive divergence" refers to the cognitive abilities associated with certain neurological areas and disabilities in other areas.[88]

Music Education for Autistic Students

Further research studies including autistic individuals who achieve perfect pitch or exceptional relative pitch could have significant implications for their music learning. Making these connections between pitch matching and neuroatypical students will also potentially benefit music educators throughout designing and implementing curriculum. This can apply to other musical aspects as well. The results from this study could potentially affect and have further recommendations for private lesson settings, training for music educators or music therapists, and modifying classroom settings.

[87] Uddin, "Exceptional Abilities in Autism: Theories and Open Questions."

[88] Ibid.

Summary of Prior Research

Previous studies have found no significant difference between neurotypical and neuroatypical individuals when identifying pitch. However, it has been reported that neuroatypical individuals may be more likely to have perfect pitch than neurotypical individuals. It is possible that larger studies will show different results, as indicated below. The independent and dependent variables are the main determinants of whether someone has absolute pitch. Perfect pitch or exceptional relative pitch does not appear to be random among individuals, according to most studies.

Ear Training

However, a 2013 study argues that valproate, which is a drug, could allow for this critical period. This would give some adults the opportunity to learn to identify the pitch of musical notes through ear training. Later research was conducted at the University of Chicago by which showed that drugs may not be necessary. With brief ear training, some adults learned to remember the pitch of musical notes and correctly identified them months later. Their pitch identification skills were with higher accuracy than they were beforehand.[89]

[89] Max Witynski, *Perfect Pitch, Explained*, UChicago News, https://news.uchicago.edu/explainer/what-is-perfect-pitch.

Lack of Information

Previous research also indicates a lack of information on the comparison of neurotypical and neuroatypical individuals. This includes music- and emotion-related subjects. There have been some studies on the ability of individuals with autism to experience emotions mediated by music. As mentioned in the first chapter, impairments in communicative abilities are considered the main feature of autism. There is a lack of expression and understanding emotions, which has often been assumed to be an important link to this cognitive impairment. There has been a lack of knowledge about the ability of autistic people to recognize emotions conveyed by various stimuli. Music can evoke and convey strong and consistent positive and negative emotions in a healthy way. The ability to process the emotional aspects of music has proven to be preserved in individuals with autism.

Neurological Correlations

Carea et al. conducted a study that shows individuals with autism and neurotypical individuals underwent magnetic resonance imaging while perceiving both happy and sad musical excerpts. These results show, that while listening to both happy and sad music, these individuals with autism activated brain regions were involved in emotion processing. Comparing autism participants with neurotypical individuals demonstrates a decreased brain activity, particularly in response to the happy music excerpts. The findings reveal neurobiological correlations of emotional processing in participants who are diagnosed with autism.[90]

[90] Caria, Venuti, De Falco, "Functional and Dysfunctional Brain Circuits Underlying Emotional Processing of Music in Autism Spectrum Disorders."

Music through Intervention

Prior research has also focused on music in intervention for children and adolescents with autism. An analysis of twelve dependent variables from nine quantitative studies were compared to music and no-music conditions throughout treatment of young children and adolescents diagnosed with autism. The results included overall effect size of d =.77 and a mean weighted correlation of r =.36 (p =.00). The confidence interval for this analysis did not include zero which gave significant results. Every effect suggested benefits for the use of music therapy and music intervention.[91] The homogeneity value was not significant; therefore, the results of the included studies were considered homogeneous. The significant effect size combined with the homogeneity of the studies indicates that all music interventions, regardless of their implementation, were effective in both children and adolescents diagnosed with autism. The included studies were described in terms of the type of dependent variable measured, theoretical approach, number of participants in treatment sessions, participation and use of choice, presentation of music, discipline of researcher, published and unpublished sources, and age of participants. Clinical implications and recommendations for future research are also discussed at the conclusion of this research study.

Effects of Self-Efficacy

Finally, some studies have explored the relationships between the effects of loneliness, stress, and self-efficacy on people with autism and their neurotypical peers. One study examined the relationships between the effects of loneliness, stress, and self-efficacy in the lives of

[91] Whipple, "Music in Intervention for Children and Adolescents with Autism: A Meta-Analysis."

individuals diagnosed with autism spectrum disorder and neurotypically developed peers.[92] The participants, all males, were between fifteen and twenty-seven years old. Half of them were diagnosed with autism, while the other half were classified as neurotypical. Each participant completed self-report measures. Significant differences were found between these two groups in terms of loneliness, life satisfaction, and self-efficacy.

This study concluded that more research is needed on self-efficacy and life satisfaction in individuals diagnosed with autism, as well as a rethinking of developmental tasks. Each of these issues and previous studies are important to consider in music education for neuroatypical individuals. Recognizing how effective music can be provides a solid foundation for future research studies on how neuroatypical students perceive and express themselves through music.

Limitations

The limitations of this study included a lack of participants willing to complete the test, a lack of funding, a lack of resources, and geographic diversity. Specific limitations in the design of this study also included a lack of resources to analyze the results and difficulty in analyzing the data. Quantitative research is empirical and is also referred to as a scientific research paradigm. This research method gives validity through the process of clarification, definition, and use of experiments. Testing out, checking the relevance, and statistically assessing the reliability of the instruments prior to the study is essential to this method. This research design can be considered inferential, experimental, and simulation research studies.[93]

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[92] Feldhaus et al., "Students with Autism Spectrum Disorders."

[93] Ochieng, "An Analysis of the Strengths and Limitation of Qualitative and Quantitative Research Paradigms."

Compensation

Different backgrounds allow for diversity in participants, account upbringing, musical interests, and environments. Although the twenty participants required for this pitch matching study were successfully recruited, it proved challenging to recruit each of the twenty participants promptly. The population and resources in southwest West Virginia are limited. There was no budget for this study. With no prizes or cash to offer, this study was not successful when advertised on social media. Compensation for research participants can often be referred to as participant rewards. This is an essential consideration of research studies or surveys which are conducted by institutions, corporations, and organizations. Providing compensation for these individuals shows appreciation for those who put forth time, effort, and information to research participation.[94] The participants for this study particularly were recruited through snowball sampling.

Narrow Topic

The next limitation was the objective of the research topic. The original idea for this study was to test participants for pitch matching and rhythm dictation. However, focusing on measuring one specific aspect of music was limiting in terms of gathering information and collecting data. Sensitivity to a beat alignment is proven to give support for music processing among children with autism. This also gives the accessibility of using musical rhythms for developing related skills and certain behaviors.[95] References to prior research and more

[94] Signe Hegart, "Research Participant Compensation: Unlocking the Power of Rewards," *Huuray,* 2023, https://huuray.com/inspiration/research-incentives/research-participant-compensation/.

[95] Dahary, Rimmer, and Quintin, "Musical Beat Perception Skills of Autistic and Neurotypical Children."

recommendations or discussions for future research studies allowed the information from this study to expand.

Advanced Technology

The lack of modern technology was another limitation. The resources used for this study included audio files from an iPhone. Participants listened to these audio files before verbally matching the pitch of the recording. This strategy of administering the test worked adequately, but more advanced technology could be used for future research. Advanced technology would include high-quality speakers or headphones that would allow participants to hear the audio files more clearly and potentially provide more accurate responses. The use of advanced technology could provide more accurate and reliable information, resulting in higher-quality data.[96]

Geographical Diversity

The last limitation of this study was the lack of diversity among participants.[97] Each participant in this study was of the same race and from the same geographical area: West Virginia, United States. Geographical diversity among the participants would provide more general diversity and variety in results for future studies. "The lack of racial/ethnic diversity in

[96] Ahmed Hassan Murshed and Abdullah Alasali, Marwan, "The Significant Role of Technology in Conducting the Academic Research," *Research Gate*, 2020, https://www.researchgate.net/publication/355969902_The_Significant_Role_of_Technology_in_Conducting_the_Academic_Research.

[97] Talia H. Swartz. Et al., "The Science and Value of Diversity: Closing the Gaps in Our Understanding of Inclusion and Diversity," *The Journal of Infectious Diseases* 220, no. 2 (August 20, 2019): 33-41, https://doi.org/10.1093%2Finfdis%2Fjiz174.

research potentially limits the generalizability of findings to a broader population, highlighting the need for greater diversity and inclusion in clinical research."[98]

Recommendations for Future Study

For future studies, the researcher would recommend a larger study with participants that vary in terms of location, age, and mental ability. Geographical diversity among participants would also provide greater general diversity and a variety in the results of future studies. A research study on the implementation of diversity in the biomedical sciences can also be applied to any other field or research study.

Diversity

Diversity can certainly enhance excellence and innovation throughout research studies. The inclusion of neurologically diverse individuals can provide an increase of depth in biomedical and clinical inquiries. This can improve the approach to problems that effect various factors to society.[99] Various backgrounds would also allow for a diversity of participants, account education, musical interests, and environments.[100]

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[98] Lisa Shea et al., "Improving Diversity in Study Participation: Patient Perspectives on Barriers, Racial Differences and the Role of Communities," *Health Expect* 25, no. 4 (June 28, 2022): 1979-1987, https://doi.org/10.1111%2Fhex.13554.

[99] Talia H. Swartz et al., "The Science and Value of Diversity: Closing the Gaps in Our Understanding of Inclusion and Diversity," *The Journal of Infectious Diseases* 220, no. 2 (August 2019): 33-41, https://doi.org/10.1093%2Finfdis%2Fjiz174.

[100] Shea et al., "Improving Diversity in Study Participation: Patient Perspectives on Barriers, Racial Differences and the Role of Communities."

Higher-Quality Technology

The next recommendation for future studies involves the use of higher-quality modern technology. In most cases, the use of modern technology will provide more accurate and reliable information, resulting in higher-quality data. The use of technological advancements in research studies save time, effort, and cost which contributes to research without affecting the quality, diversity, experiences, knowledge, and skills which lead to conducting scientific research.[101] The use of advanced technology can greatly affect researchers who use technology to collect data for the academic research they need for their programs. There are several reasons why technology is used in scientific research. These may include the elimination of old research methods that significantly reduce time, labor, and cost. Modern research methods and technologies also help the researcher understand new concepts in a simple way that is appropriate for other researchers. This also helps to achieve a higher standard of quality in scientific research. Studies that are published among a large group of people through modern communication, lead to a higher achievement among researchers and an increased number of study fields.[102]

Measuring Musical Aspects

Another recommendation for future studies is to measure rhythm dictation and other musical aspects when comparing neurotypical and autistic individuals. Children who are diagnosed with autism perceive temporal normality in music including the underlying beat of a rhythmic structure of music. This shows the enhanced rhythm processing in a basic context involving nonverbal auditory stimuli. This normality and predictions of rhythmic beats in music

[101] Murshed and Marwan, "The Significant Role of Technology in Conducting the Academic Research."

[102] Ibid.

could potentially be utilized for skills involving non-musical areas of growth for autistic children and adolescents.[103] While pitch and rhythm are the two main variables in music, several elements could be measured in these individuals for future studies. These could include melody, harmony, dynamics, tempo, duration, and expression. The ability to identify these elements could greatly enhance understanding for future studies and music education for neuroatypical individuals.

Budget

The final recommendation includes adding a budget for awards to participants and individuals who allow their buildings to be used as a space for the research. Compensation is likely to incentivize potential participants, even if the study has minimal risk. Compensation also shows appreciation and value toward participants for their time, effort, views, and contribution in scientific research. It is important for each participant to provide their views, opinions, experiences, and data throughout data collection in a research study.[104] Finally, offering compensation can motivate participants, provide accurate and reliable information, increase engagement, and increase commitment to the study. Each of these factors leads to higher-quality data.

[103] Dahary, Rimmer, and Quintin, "Musical Beat Perception Skills of Autistic and Neurotypical Children."

[104] Hegart, "Research Participant Compensation: Unlocking the Power of Rewards."

Implications for Practice

This study showed that neuroatypical individuals may have a higher potential to understand pitch. Factors that may prevent these individuals from fully grasping this concept include hearing loss, comprehension, and auditory processing. These factors are common among individuals with special needs. While the results established that these individuals do not recognize pitch as well, it is also revealed that they may have underlying auditory or cognitive disabilities that music educators can work with. Many studies address various topics related to autistic individuals and education. These include the challenges and obstacles that arise when educating people with autism.

Modifying Educational Settings

One example is a study which claims that certain strategies to modify educational settings in mainstream education for neuroatypical students are under-researched. This review aimed to identify research results of the modification and implementation strategies to allow further inclusion for autistic students in educational classroom settings.[105] Music educators need professional development to gain an autism-specific understanding and strategies for accommodating autistic students. This can also help school leaders in the development and implementation of professional development programs.

[105] Linda Petersson-Bloom and Mona Holmqvist, "Strategies in Supporting Inclusive Education for Autistic Students—A Systematic Review of Qualitative Research Results," *Autism & Developmental Language Impairments*, 7 (2022): 1, https://doi.org/10.1177/23969415221123429.

Training for Educators

Another source discussed the lack of training for educators about students with autism. According to this 2022 study, "certain additions to the curriculum of pre-service university education programs for GE teachers are suggested. In addition, the research found that schools must make certain resources, including technology, available to GE teachers to meet the requirements of United States law regarding educating students with disabilities, including ASD, in the least restrictive environment."[106]

Private Lesson Settings

In private lesson settings, these implications will most likely be easier for the music educator to meet. One-on-one lessons or activities allow lessons to be more individually tailored to students' specific needs. In public schools or in groups of adults, it is more difficult to generalize these effects. However, the education of these individuals may be more helpful if these implications are kept in mind. Music helps regulate emotions and has countless other benefits. Music should be used by everyone, especially individuals with developmental disabilities. Because music could significantly improve their quality of life, it is important to consider these implications in the practice of music education. A research study on the effectiveness of music education in improving social communication for students who are diagnosed with autism spectrum disorder includes findings that "indicate that ASD students have improved their attitudes toward using different music-based teaching techniques. Teachers also

[106] Mohammed Al Jaffal, "Barriers General Education Teachers Face Regarding the Inclusion of Students with Autism," *Frontiers in Psychology* 13 (August 2022): 873248, https://doi.org/10.3389%2Ffpsyg.2022.873248.

reported that students easily grasp the learning process's fundamentals, and that learning becomes more enjoyable."[107]

Music Interventions

This study has shown that music therapy and musical interventions have a strong impact on the lives of neurotypical and neuroatypical people. Social interaction and communication are often seen as the main difficulties for individuals with autism. Music therapy and musical interventions are often used to promote communication and expression to overcome some of the major challenges for autistic individuals. Music therapy has been used with individuals with autism since the early 1950s; however, its availability and accessibility to autistic individuals can vary from country to country and environment to environment. The application of music therapy requires specialized academic and clinical training, which enables therapists to tailor various techniques to the specific needs of the individual through intervention.[108]

Music Therapy

In research studies, music therapy has been shown to improve social behaviors and attention spans in individuals diagnosed with autism spectrum disorder. However, more research on music therapy is needed before determining the impact of group music therapy on autistic individuals. In a research study on the effects of music therapy group interventions for enhancing

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[107] Nor Amalina Rusli, "The Effectiveness of Music Education in Improving Social Communication for Autism Spectrum Disorder (Asd) Students," *Studia Universitatis Babeş-Bolyai Musica* 68, no. 1 (July 2023): 261-274, http://dx.doi.org/10.24193/subbmusica.2023.spiss1.15.

[108] Monika Geretsegger et al., "Music Therapy for People with Autism Spectrum Disorder," *The Cochrane Database of Systematic Reviews* 6 (June 17, 2014): 1, https://doi.org/10.1002%2F14651858.CD004381.pub3.

social skills, the results support further research utilizing music therapy group interventions to improve social skills in children diagnosed with autism.[109]

Neurological Development in Autism

The final implication for practice is to reconsider the role of music in the neurological development of autism. In the clinical and research literature on autism, music has played a prominent role in the diagnosis, therapy, and behavioral observation of exceptional artistic abilities in the autistic population. Music therapy for autism has focused primarily on social interaction, communication skills, and emotional behaviors. The importance of motor skills and attention span in the diagnosis of autism has gained significance. This may have significant implications for the use of music as an intervention for people with autism. In an article on the role of music in the neurological development of autism, the aim was to provide music therapists and researchers with new research evidence to reevaluate the role of music as an intervention. This was to support healthy neurological development in people with autism and potentially expand the current role of music therapy in autism. This could be the main indicator of structural brain dysfunction in autistic individuals.[110]

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[109] A. Blythe LaGasse, "Effects of a Music Therapy Group Intervention on Enhancing Social Skills in Children with Autism," *Journal of Music Therapy* 51, no. 3 (2014): 250–275, https://doi.org/10.1093/jmt/thu012.

[110] Thenille Braun Janzen, Marion Haase, and Michael H. Thaut, "Rethinking the Role of Music in the Neurodevelopment of Autism Spectrum Disorder," *Music & Science* 64 (April 2019): 355-365, https://doi.org/10.1177/2059204318769639.

Summary

This study has raised more research questions that have yet to be answered. Discovering these various topics will potentially improve music education for both music educators and students. Previous research was also used to develop and conduct this study.[111] This research suggested that there was a lack of information regarding the comparison of neurotypical and neuroatypical individuals, including music-related and emotional-related topics.[112] There are some studies on the ability of individuals with autism to experience emotions conveyed through music.[113] The limitations of this study included a lack of participants willing to complete the test, a lack of funding, a lack of resources, and geographic diversity.[114]

Recommendations for future studies include a larger study with participants that vary in location, age, and mental ability.[115] Other recommendations included measuring rhythm dictation and other aspects of music with neurotypical and autistic individuals.[116] The use of advanced technology and providing compensation for participants were also suggested.[117] Rethinking the role of music in the neurodevelopment of autism spectrum disorder was also discussed, as music has played a prominent role in the diagnosis, therapy, and behavioral observations of exceptional artistic abilities in the autistic population. Implications for practice will allow music educators to

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[111] Witynski, *Perfect Pitch, Explained*.

[112] Feldhaus et al., "Students with Autism Spectrum Disorders."

[113] Caria, Venuti, De Falco, "Functional and Dysfunctional Brain Circuits Underlying Emotional Processing of Music in Autism Spectrum Disorders."

[114] Swartz et al., "The Science and Value of Diversity: Closing the Gaps in Our Understanding of Inclusion and Diversity."

[115] Shea et al., "Improving Diversity in Study Participation: Patient Perspectives on Barriers, Racial Differences and the Role of Communities."

[116] Dahary, Rimmer, and Quintin, "Musical Beat Perception Skills of Autistic and Neurotypical Children."

[117] Murshed and Marwan, "The Significant Role of Technology in Conducting the Academic Research."

develop and provide curricula that are inclusive of individuals with special needs and the specific challenges they may have, such as hearing loss, comprehension, and auditory processing.[118] These instructional techniques and implications can be applied to group or private classroom settings. The implications of music therapy and music intervention were also discussed in the findings and conclusions of this study.[119]

[118] Petersson-Bloom and Holmqvist, "Strategies in Supporting Inclusive Education for Autistic Students—A Systematic Review of Qualitative Research Results."

[119] LaGasse, "Effects of a Music Therapy Group Intervention on Enhancing Social Skills in Children with Autism."

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APPENDIX A: TOPIC APPROVAL

MA: Ethnomusicology / MA: Music Education / MA: Music and Worship

Proposal Decision

The Thesis Advisor and Reader have rendered the following decision
concerning the proposal decision for
Kayla Bostic
on the Thesis:
The Difference(s) Between Music Students with Autism and Neurotypical Students when Learning to Identify Pitch
as submitted on 3/14/2024

__x__ **Full Approval to proceed with no proposal revisions.**
The student may fully engage the research and writing process according to the established the timeline. Upon full approval, the student may apply for IRB approval, if applicable (see STEP 4 concerning IRB approval process).

_____ **Provisional Approval to proceed with proposal pending cited revisions.**
This is the most common decision. The student must resubmit the proposal with cited revisions according to the established timeline. The Advisor will indicate the committee's status on your response to the required revisions. The student may NOT apply for IRB approval until full approval is granted.

_____ **Redirection of Proposal**
The student is being redirected to develop a new proposal, as minor revisions will not meet the expectations for the research project. The student may NOT apply for IRB approval.

Rebecka E. Rose	[redacted]	3/18/2024
Print Name of Advisor	**Signature**	**Date**
	[redacted]	
Print Name of Reader	**Signature**	**Date**

APPENDIX B: IRB EXEMPTION LETTER

LIBERTY UNIVERSITY.
INSTITUTIONAL REVIEW BOARD

April 17, 2024

Kayla Bostic
Rebecka Rose

Re: IRB Exemption - IRB-FY23-24-1593 The Difference(s) Between Autistic Individuals and Neurotypical Individuals when Learning to Identify Pitch

Dear Kayla Bostic, Rebecka Rose,

The Liberty University Institutional Review Board (IRB) has reviewed your application per the Office for Human Research Protections (OHRP) and Food and Drug Administration (FDA) regulations and finds your study to be exempt from further IRB review. This means you may begin your research with the data-safeguarding methods described in your IRB application, and no further IRB oversight is required.

Your study falls under the following exemption category, which identifies specific situations in which human participants research is exempt from the policy set forth in 45 CFR 46:104(d):

Category 2.(ii). Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:
Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or

For a PDF of your exemption letter, click on your study number in the My Studies card on your Cayuse dashboard. Next, click the Submissions bar beside the Study Details bar on the Study Details page. Finally, click Initial under Submission Type and choose the Letters tab toward the bottom of the Submission Details page. Your information sheet and final versions of your study documents, **which you must use to conduct your study,** can also be found on the same page under the Attachments tab.

This exemption only applies to your current research application, and any modifications to your protocol must be reported to the Liberty University IRB for verification of continued exemption status. You may report these changes by completing a modification submission through your Cayuse IRB account.

If you have any questions about this exemption or need assistance in determining whether possible modifications to your protocol would change your exemption status, please email us at irb@liberty.edu.

Sincerely,
G. Michele Baker, PhD, CIP
Administrative Chair
Research Ethics Office

APPENDIX C: INSTRUMENTATION

Sequence	Source	Female Tones	Male Tones
1st	Piano	C4	C3
2nd	Piano	G4	G3
3rd	Piano	A4	A3
4th	Piano	D4 & F#4	D3 & F#3
5th	Piano	A#4 & F# 4	A#3 & F#3
6th	Voice	G4	G3
7th	Voice	D4	D3
8th	Voice	F#4	F#3
9th	Voice	A4 & F4	A3 & F3
10th	Voice	E4 & G#4	E3 & G#3

APPENDIX D: SCREENING QUESTIONS

The Difference(s) Between Autistic Individuals and Neurotypical Individuals when Learning to Identify Pitch

Participant Name:_____ Date:_____

Screening Questions

1. Are you 18 years of age or older?	YES_____NO_____
2. Do you live in the state of West Virginia?	YES_____NO_____
3. Are you considered neurotypical?	YES_____NO_____
4. Have you been diagnosed with high-functioning autism?	YES_____NO_____
5. Do you require guardianship?	YES_____NO_____
6. Do you have any previous musical knowledge?	YES_____NO_____

APPENDIX E: DATA COLLECTION SHEET

Data Collection Sheet

Participant:_____ Date:_____

Sequence:	Correct:	Incorrect:
1st		
2nd		
3rd		
4th		
5th		
6th		
7th		
8th		
9th		
10th		