RSGC
Royal St. George's College

The Young Researcher

2019 Volume 3 | Issue 1

Effect of Musical Properties on Cognitive Abilities of High School Students

Rida Bonday

Recommended Citation
Bonday, R. (2019). Effect of musical properties on cognitive abilities of high school students. *The Young Researcher*, 3 (1), 60-69. Retrieved from http://www.theyoungresearcher.com/papers/bonday.pdf

ISSN: 2560-9815 (Print) 2560-9823 (Online) Journal homepage: http://www.theyoungresearcher.com

Effect of Musical Properties on Cognitive Abilities of High School Students

Rida Bonday

This research paper tests the hypothesis that the musical properties of tempo and/or pitch and cognitive abilities of high school students are causally related. All five treatment groups completed the same 20-question spatial-temporal reasoning test in 10 minutes and listened to versions of the same piece: K448. The control group listened to K448 unmodified. One tempo group listened to a slower-tempo version of the piece, and the other listened to a faster-tempo version. One pitch group listened to a lower-pitch version of the piece, and the other listened to a higher-pitch version. Four 2-sample t-tests demonstrated that the slow tempo group and both pitch groups did not score significantly better than the control group, while the fast tempo group did score significantly better than the control group. The conclusion section discusses scientific and educational implications of these findings and delves into future research objectives.

Keywords: cognitive abilities, spatial-temporal reasoning, tempo, pitch, music, brain.

Introduction

The relationship between music and the human brain has its roots in the adaptation of rhythmic recognition with the advent of bipedalism, which enabled early man to distinguish between the walking patterns of his fellow humans and those of other animals (Trimble, 2017). Music, like all other auditory stimulus, is processed by the temporal lobe, but recent research in the field of cognitive musicology suggests that the effect of music on the human brain may be more profound than that of other auditory stimuli. Even beyond music-induced foot tapping and other physical reactions to music, there is evidence that music could bolster the brain's intellectual capacity and have short and long term effects on the way the brain processes information.

Measuring the effect of music on the brain has proven to be a difficult task due to the abstract nature of the construct to be measured: cognitive ability. With such an abstract variable comes the challenge of picking an appropriate system of quantification. Seeing as intelligence is defined not as the ability to perform any one task, but rather as the ability to apply foundational knowledge to an array of undertakings, it is important to select a measure of intelligence that comprises a skill set applicable across multiple fields and disciplines (Oswalt). A commonly referenced dependent variable in biomusicology is spatial-temporal reasoning, defined as the ability to mentally visualize and manipulate objects in space and time (APA Dictionary). Spatial-temporal reasoning is clearly critical for success in a variety of professional disciplines, and was the dependent variable used in a pioneering biomusicology study conducted by Frances Rauscher that introduced the Mozart Effect in 1994. The Mozart

Effect posits that listening to classical music yields optimal spatial-temporal reasoning performance as opposed to other genres of music (Rauscher et al., 1994). At the time, this research seemed to have far-reaching implications in education and in the workplace.

However, since its introduction in 1994, the Mozart Effect has been the subject of widespread criticism because researchers who repeated the experiment were unable to replicate its results, and other studies conducted under similar conditions found that other genres of music were more effective than classical music in stimulating the brain's intellectual capacity (New York Times, 2018). Here lies a gap in the research: music appears to have some impact on the brain, but the specific impact has yet to be identified by biomusicologists. Notably, previous research on the relationship between music and cognitive abilities focuses on the differences between genres of music in comparison to silence or in comparison to other auditory stimuli, but it remains unknown what exactly it is about music that stimulates the brain's information processing capabilities.

At this point, it is worth looking at the situation from the point of view of a musician to add to the conversation. Music is not defined merely by genres, but by intrinsic properties that distinguish one piece from another. Among the most fundamental of these properties are tempo and pitch, both of which have noticeable impacts on the sound and feel of a piece (The Elements of Music). Existing research on music and the brain has not taken into account the variety that these properties bestow upon music. This consideration led me to an important question: to what extent do varying musical properties impact cognitive abilities? My study examined the effects of varying tempo and pitch of the piece K448, also known as Mozart's Sonata for Two Pianos in D Major, on spatial-temporal reasoning test scores of high school students. Modified tempo and pitch specifically are meaningful relative to the original piece because, of all the musical properties, they have the most discernible effects on a given piece of music; these effects are obvious even to someone with no musical training, as compared to more complex qualities such as rhythm or tone color. The concepts behind this study have potential implications in education, particularly for students and teachers to determine what qualities background music for studying and test-taking should have.

Literature Review

Counterarguments

Laurel Harmon, a researcher in educational psychology at Western Connecticut State University, provides an important counterargument to much of the field research done in cognitive musicology. This counterargument was critical to the formation of my research question. Her study consisted of two experiments. In the first experiment, the researchers hypothesized that participants who listened to Mozart would score significantly higher on a listening comprehension test than participants who listened to rock music or silence (Harmon, 2008). In the second experiment, the researchers hypothesized that participants who listened to rock music would have lower reading comprehension scores than participants who listened to classical music or silence. Interestingly, an ANOVA (Analysis of Variance) test indicated that the results for both experiments were non-significant. The results of this experiment are debatable due to possible bias in the experimental design. Subjects could have ascertained which group they were in based on what music they were listening to (or based on the fact that they were listening to silence), especially if they were familiar with the concept that classical music is most conducive to studying and comprehension. While this bias undermined the reliability of the experiment's results, there was still a lesson to be learned here for when I set up my own experiment: because I played the same piece for all groups, and because the changes in tempo and pitch were difficult to ascertain for subjects who were unfamiliar with the piece, my experiment was single-blinded. Single-blinding is an efficient way to avoid bias on the part of the participants. The counterargument to the Mozart Effect presented by this study was useful to me because rather than testing the effect of classical music versus other genres on cognitive abilities, I aimed to pinpoint the specific properties of classical music that are conducive to learning. These properties can be highlighted and manipulated in any genre of music, not just classical music, so my results could conceivably be applied to other genres of music.

In agreement with Harmon's dismissal of the Mozart Effect, a study published by the University of Tsukuba in Japan explored possible potential relationships between emotion and concentration (Mori). Music that appeals to emotional extremes rather than being neutral can impact the subjects' perception of their performance on the given task. For example, happy music can make subjects feel like they are performing better than they really are, and can cause them to lower the level of effort they put into the task. At the other end of the spectrum, sad music can make subjects feel like they are performing worse than they actually are, stressing them out and distracting them. The study randomly assigned subjects to one of three groups: the control group took the test in silence, one experimental group listened to songs of their preference, and the other experimental group listened to unfamiliar music. The results were that the control group made the most mistakes on the test, the group that listened to unfamiliar music made fewer mistakes, and the group that listened to preferred music made the least mistakes. The study, although published by the University of Zurich, is questionable because by allowing subjects in the preferred music group to listen to any music they would like, the researchers introduced an additional variable to their study. The results seem to show that listening to unfamiliar music is not as optimal for concentration as listening to preferred music; however, this is more likely because of the variation in musical properties between pieces rather than because of the subjects' familiarity with the background music. To avoid this added variation in my research project, rather than having vague categories such as "preferred" and "unfamiliar" for background music, I played the same piece for all subjects and I only manipulated the musical properties of tempo and pitch. This way, I had complete control over the independent variables in my study.

Expectation and Attentiveness

A study published by Elsevier Clinical Psychology explores the brain's response to dissonant harmonies that defy subconscious expectation of what will happen next in the music. Participants were presented with excerpts from classical piano sonatas that were taken from commercial CDs, and continuous electroencephalograms were recorded by the researchers (Koelsch, 2002). The control group was presented with expected chords at the end of chord sequences, and the experimental group was presented with unexpected chords at the end of chord sequences. The results were that unexpected chords elicited negative responses in both hemispheres of the brain, with notable negativities in the right temporal lobe. This study was useful to me in my experimental design because it illustrates that expressive music with noticeable melodies can distract participants from the task at hand instead of helping them. To avoid this problem, I used a piece with subtle melodies that was neutral rather than very expressive.

Expanding on the idea that expectation has a strong impact on hemispheric brain activity, an article by the Stanford Medicine News Center details the findings of a Stanford study that monitored participants' brain activity while a piece by an obscure 18th-century composer was played for them (Stanford Medicine, 2007). The results were that brain activity in regions associated with attentiveness peaked in the moments between movements. This occurred because of subjects' anticipation of what would happen after the transitioning silence between movements, even though they were unfamiliar with the music they were listening to. The article includes a video of a participant's hemispheral brain activity, with the number of seconds until the transition shown at the bottom of the screen. Subjects in the study showed improved attentiveness, but they were only listening to music and were not performing another task in the foreground. In my study, the music is in the background while subjects complete a spatial-temporal reasoning test. To avoid drawing subjects' attention to the transitions between movements, as was seen in the Stanford study, I will play a single continuous piece instead of a piece with multiple segmented movements.

Other Auditory Stimuli

Michael Widerman, a psychologist at George Mason University, explored the effect of different pre-testing auditory stimuli on participants' recall of studied material. All participants studied the same long reading comprehension passages and vocabulary words before being tested (Widerman, 2013). Participants were randomly assigned to one of two groups: the control group studied in silence while the experimental group listened to self-selected music. The dependent variable was cerebral blood flow velocity, which indicates levels of sustained attention over a period of time. The results were that there was no statistically significant difference between the groups, although post-test surveys indicated that the self-selected music group struggled to focus on the test and were listening to the music instead. There is one notable flaw in the experimental design of this study: by allowing subjects in the self-selected music group to listen to music of their own choosing, the researchers introduced an additional variable to their study, similar to Mori's study. This added variation could be one of the reasons for Widerman's inconclusive results. To avoid confounding variables associated with self-selecting music, I did not allow subjects to self-select lyrical music in my study, but instead used an obscure classical piece with subtle melodies and minimal distracting factors.

Concurring with Widerman's findings that the effect of music on test scores is unclear, a study published in the American Journal of Undergraduate Research explored the effect of different pre-test stimuli on participants' performance on a spatial reasoning test. The control group sat in silence, one experimental group listened to Mozart, and the other experimental group played active games (Gonzalez 2003). The study outlines that the purpose of assigning groups this way is to test the impact of a phenomenon known as "arousal effect" on spatial reasoning performance. The "arousal effect" posits that improved cognitive performance after listening to classical music, such as Mozart, may be due to the subjects' personal enjoyment of the music rather than due to subconscious interactions between music and the brain. Thus, the study included active games as one of the experimental groups to see if that group's performance would be affected by the subjects' enjoyment of the physically stimulating activities. The results of the study were that both the Mozart group and the active group performed better than the control group on the spatial reasoning test, and both experimental groups had similar results to each other. The study did an excellent job of controlling the effects of unknown variables and performing insightful statistical analysis on their results. This study is critical for my research and experimental design because it alerted me to the fact that if I play well-known classical music in the background for all treatment groups, the "arousal effect" may skew the results because of the subjects‘ personal enjoyment of the music. To minimize the effect of personal enjoyment, I will play an obscure piece that is unlikely to be recognized by subjects and that will not have familiar melodies and motifs to distract them.

Summary

Existing research in the field focuses on independent macroscopic variables when attempting to evaluate the potentially causal relationship between music and heightened cognitive abilities. Keeping in mind the shortcomings of previous studies—such as loosely defined auditory stimuli that allow subjects to pick their own background music or that categorize music only by genre—I narrowed the lens of my study to acutely assess the impact of specific musical variables—tempo and pitch—on cognitive abilities. To avoid having subjects' personal preferences or subconscious following of the plot of a musical piece skew results, as seen in the arousal effect, I played an obscure song in the background while subjects took their spatial reasoning tests. I performed statistical analysis tests on the results to ensure that if I rejected my null hypothesis, it was because the difference between the control and experimental groups was too large to be explained by randomness alone.

Methods

Study Design

This study sought to uncover the relationship, or lack thereof, between manipulated musical variables—tempo and pitch—and the cognitive abilities of high school students. The study was analytical in nature and aimed to test the alternative hypothesis that one or both of the aforementioned musical variables would have an effect on cognitive (spatial-temporal reasoning) abilities, as opposed to the null hypothesis that none of these variables would affect cognitive abilities. The study was experimental in nature, as I conducted randomized controlled trials; I directly manipulated the independent variables, while keeping all other conditions constant to minimize the effect of confounding variables. I gave all subjects the same spatial-temporal reasoning test, an example question of which is shown in Figure 1 (Newton).

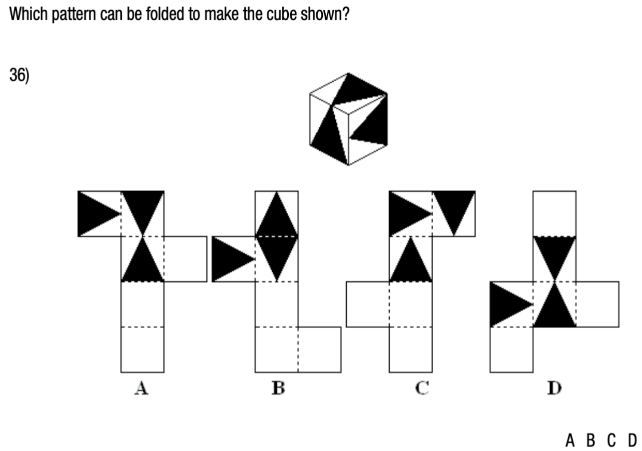


Figure 1 (above): An example of the types of spatial-temporal reasoning questions subjects saw on their tests. (Answer: A)

Ethical Consideration

I cleared my research with the Institutional Review Board. No sensitive information was collected from subjects; in fact, no personal information was collected from subjects at all. To ensure the privacy of each subject's scores on the spatial-temporal reasoning test, I numbered each test and informed participants that, should they wish to view their scores at a later date, they could ask to see the paper with their number on it. This way, I did not know who each test and score belongs to, but I could still categorize each test by its appropriate treatment group and include it in data analysis at the conclusion of the study.

Selection of Participants

This study was conducted in an empty classroom over the course of three Student Resource Time (SRT) periods in February 2019. When recruiting subjects, I visited high school classrooms that had potential participants and handed out information sheets that detailed the goal of the study and what subjects would be asked to do. At the bottom of the information sheet, I asked students four questions: (1) Name? (2) Email? (3) Are you a high school student? (4) Are you willing to make a total time commitment of 10 minutes for this study? I asked subjects to email their answers to me and include their first and last name in the email. My only inclusion criteria was that subjects answered "yes" to questions 3 and 4. For this study, I selected 75 participants who met the criteria.

Procedure

The study used a Completely Randomized design. To begin, I assigned each subject a number from 1 to 75. I randomly assigned subjects to treatment groups to equalize the effects of unknown sources of variation on the dependent variable of the test score. I used a random number generator to pick 15 subjects for the control group and 15 subjects for each experimental group. It should be noted that due to limited room capacity, the test could only be administered to one treatment group at a time. It should also be noted that all groups initially had 15 subjects, but four subjects had scheduling conflicts at their assigned time of test administration. To avoid losing the element of randomness, I used a random number generator to assign each of these four subjects to a new treatment group. Testing conditions were consistent for all treatment groups: all subjects were given 10 minutes to answer 20 questions, and took their tests in the same room with the same setup. The control group listened to Mozart's Sonata for Two Pianos in D major, also known as K448, in its original form without any modifications (Mozart). Experimental group 1 listened to K448 at 0.75x speed. Experimental group 2 listened to K448 at 1.25x speed. Experimental group 3 listened to K448 with the pitch modulated three half-steps higher. Experimental group 4 listened to K448 with the pitch modulated three half-steps lower. The purpose of experimental groups 1 and 2 was to assess the relationship between tempo and cognitive abilities, and the purpose of experimental groups 3 and 4 was to assess the relationship between pitch and cognitive abilities. YouTube's speed settings were used to alter the tempo of the piece, and Apple's GarageBand software was used to modulate the pitch of the piece.

Results

The mean score of each treatment group was compared to the mean score of the control group using a 2-sample t-test. Thus, a total of four t-tests were conducted. To conduct this statistical test, three conditions must be met. First, randomness must be involved in the study design. Second, subject test scores must be independent between and within treatment groups. Third, the data for the control group and the treatment group it is being compared to must be approximately normally distributed. The first condition is met for all four t-tests because, as described in the methods section, subjects were randomly assigned to treatment groups. The second condition is met for all four t-tests because groups were sequestered from one another, and no cheating occurred in any of the treatment groups. The third condition is met by the control group because, as seen in Figure 2a, the NPP for the control group is approximately linear, suggesting normality, and the boxplot in Figure 2b indicates that there are no outliers.

Figure 2a: Normal Probability Plot for control group.

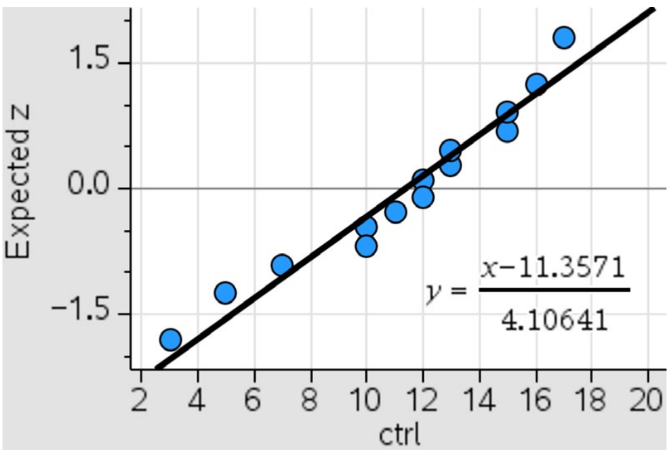


Figure 2b: Box Plot for control group.

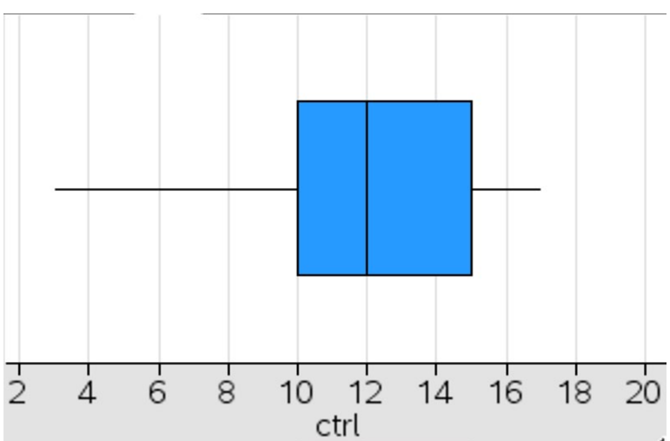


Figure 3a: NPP for slow tempo group.

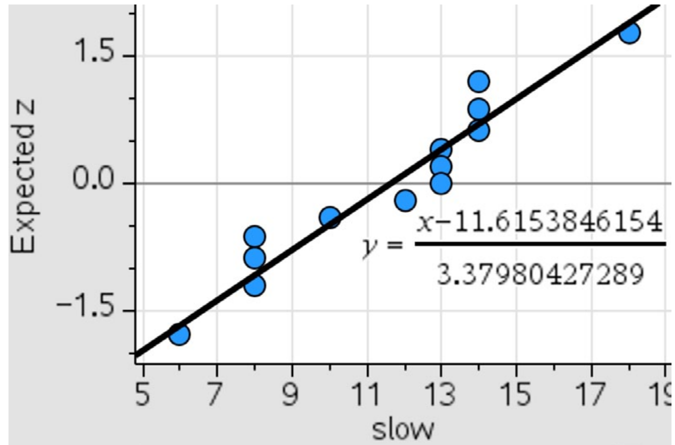
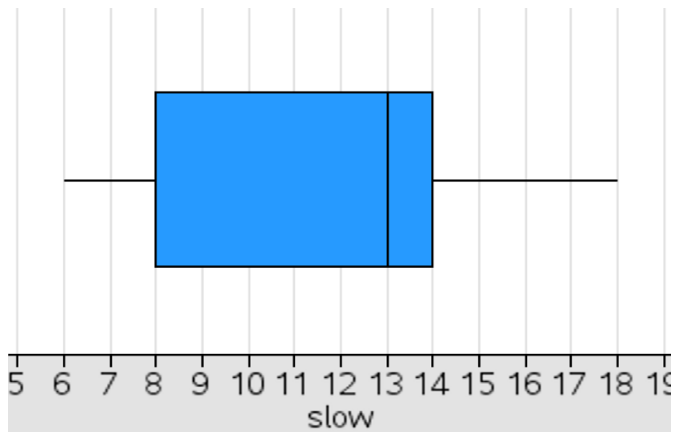


Figure 3b: Box Plot for slow tempo group.



Slow Tempo vs. Control. The third condition is met by the slow tempo group because, as seen in Figure 3a, the NPP for the slow tempo group is approximately linear, suggesting normality, and the boxplot in Figure 3b indicates that there are no outliers. To assess the difference between the results from the slow tempo group compared to control group, I conducted a 2-sample t-test for $\mu_{slow} - \mu_{control}$. With 24.66 degrees of freedom and a t-value of –0.178922, I found that the P-value was 0.4297.

Figure 4a: NPP for fast tempo group.

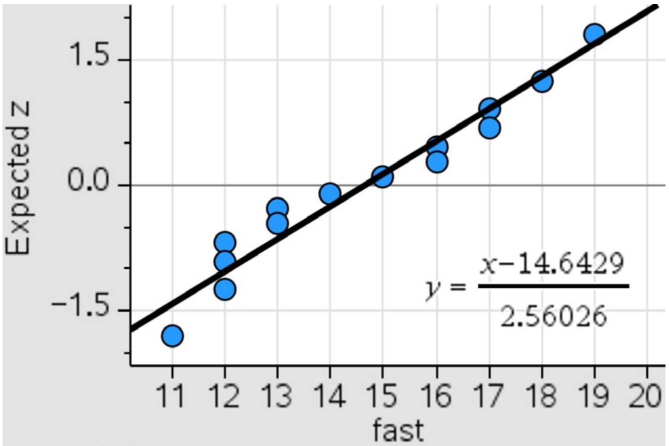
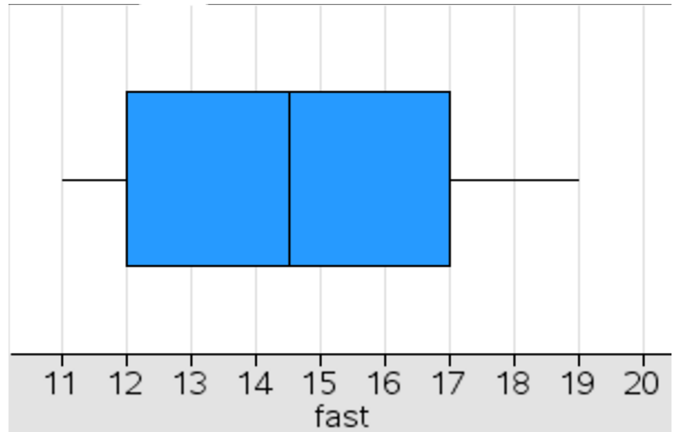


Figure 4b: Box Plot for fast tempo group.



Fast Tempo vs. Control. The third condition is met by the fast tempo group because, as seen in Figure 4a, the NPP for the fast tempo group is approximately linear, suggesting normality, and the boxplot in Figure 4b indicates that there are no outliers. To assess the difference between the results from the fast tempo group compared to control group, I conducted a 2-sample t-test for $\mu_{fast} - \mu_{control}$. With 21.78 degrees of freedom and a t-value of –2.540521, I found that the P-value was 0.009360.

		Test Scores (out of 20)				
		Control	Slow	Fast	Low	High
	1	17	8	15	18	12
	2	15	13	17	13	14
	3	13	13	16	12	11
	4	10	14	16	8	8
	5	16	8	12	19	11
	6	15	8	13	8	16
	7	5	18	19	12	14
	8	11	14	14	13	16
	9	7	13	12	16	19
	10	12	6	17	16	16
	11	12	14	11	14	15
Subject	12	13	10	18	14	10
	13	10	12	13	10	12
	14	3		12	17	11
	15				16	12
	16				11	12
	17				9	
	18				9	

Figure 5 (left): Data table with results from study. As described in the Procedure section, each group was meant to have 15 subjects, but some subjects had scheduling conflicts, and thus had to be randomly reassigned to another group.

Figure 6a: NPP for low pitch group.

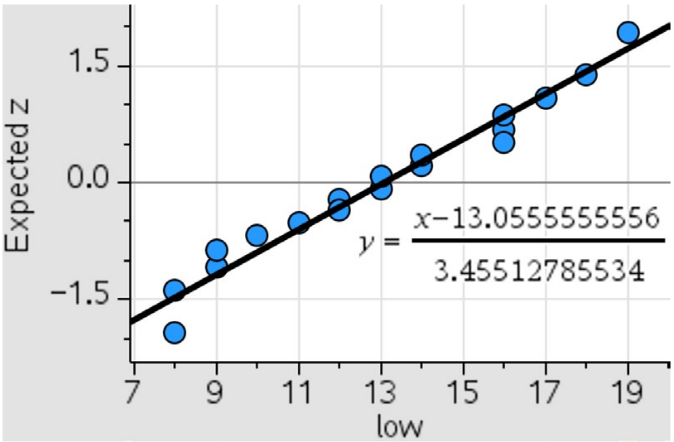
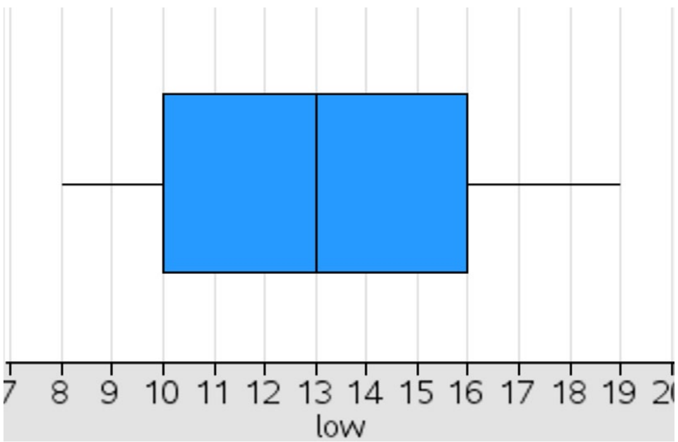


Figure 6b: Box Plot for low pitch group.



Low Pitch vs. Control. The third condition is met by the low pitch group because, as seen in Figure 6a, the NPP for the low pitch group is approximately linear, suggesting normality, and the boxplot in Figure 6b indicates that there are no outliers. To assess the difference between the results from the low pitch group compared to the control group, I conducted a 2-sample t-test for $\mu_{low} - \mu_{control}$. With 25.37 degrees of freedom and a t-value of −1.242770, I found that the P-value was 0.1127.

Figure 7a: NPP for high pitch group.

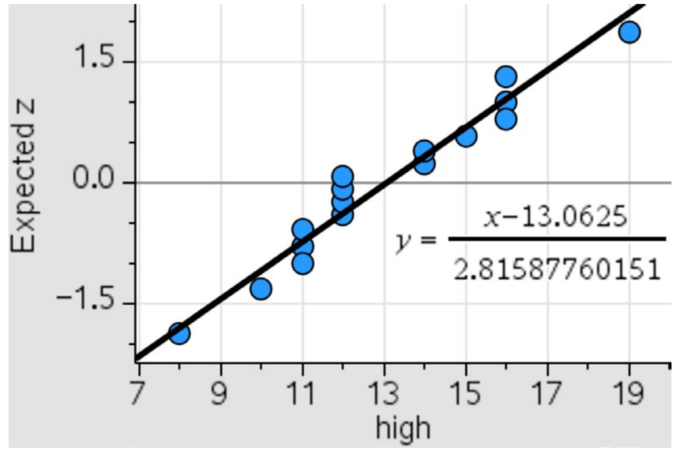
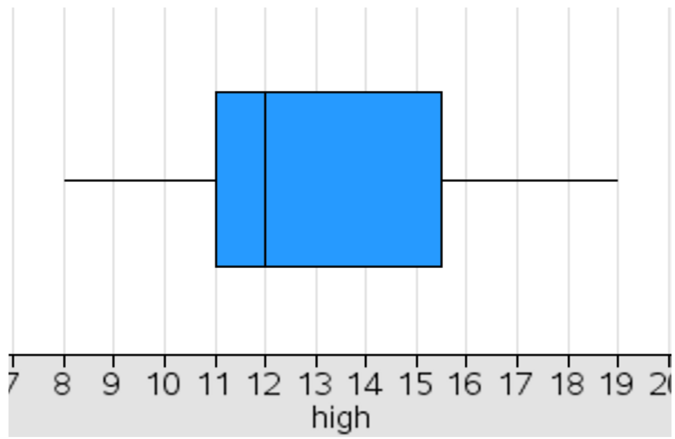


Figure 7b: Box Plot for high pitch group.



High Pitch vs. Control. The third condition is met by the high pitch group because, as seen in Figure 7a, the NPP for the high pitch group is approximately linear, suggesting normality, and the boxplot in Figure 7b indicates that there are no outliers. To assess the difference between the results from the high pitch group compared to the control group, I conducted a 2-sample t-test for $\mu_{high} - \mu_{control}$. With 22.58 degrees of freedom and a t-value of −1.307931, I found that the P-value was 0.1020.

Analysis

A significance level of α = 0.01 = 1% was used for all 2-sample t-tests.

Slow Tempo vs. Control. I fail to reject the null hypothesis that there is no difference in test scores between the slow tempo group and the control group due to P-value = 0.4297 > 0.01 = α. There is not statistically significant evidence to suggest that spatial-temporal reasoning test scores for high school students who listen to slow tempo music are greater than spatial-temporal reasoning test scores for high school students who listen to intermediate (unmodified) tempo music.

Fast Tempo Group vs. Control Group. I reject the null hypothesis that there is no difference in test scores between the fast tempo group and the control group due to P-value = 0.009360 < 0.01 = α. There is statistically significant evidence to suggest that spatial-temporal reasoning test scores for high school students who listen to fast tempo music are greater than spatial-temporal reasoning test scores for high school students who listen to intermediate (unmodified) tempo music.

Low Pitch vs. Control. I fail to reject the null hypothesis that there is no difference in test scores between the low pitch group and the control group due to P-value = 0.1127 > 0.01 = α. There is not statistically significant evidence to suggest that spatial-temporal reasoning test scores for high school students who listen to low pitch music are greater than spatial-temporal reasoning test scores for high school students who listen to intermediate (unmodified) pitch music.

High Pitch vs. Control. I fail to reject the null hypothesis that there is no difference in test scores between the high pitch group and the control group due to P-value = 0.1020 > 0.01 = α. There is not statistically significant evidence to suggest that spatial-temporal reasoning test scores for high school students who listen to high pitch music are greater than spatial-temporal reasoning test scores for high school students who listen to intermediate (unmodified) pitch music.

Conclusion and Future Research Objectives

The results are statistically significant at α = 1% and suggest that subjects who listened to the fast tempo version of the piece performed better on the spatial reasoning test than subjects who listened to the unmodified piece. These results agree with Rauscher et. al's original proposition that there is a link between music and spatial reasoning abilities, but this study supplements that finding by suggesting that there is a link specifically between fast tempo music and spatial reasoning.

If this study were to be repeated, one modification would be to have a larger sample size to confirm the results. Although the t-distribution used in statistical analysis increases the P-value as sample size decreases, thus minimizing the chance of incorrectly rejecting the null hypothesis, increasing the sample size would supplement the equalization of variability resulting from random assignment of subjects to treatment groups. Additionally, due to the abstract nature of the dependent variable of cognitive abilities, this study made use of spatial reasoning test scores as a way to quantify cognitive abilities, but there are other quantifying tests available to measure that variable. Repetition of this study could make use of multiple tests meant to measure cognitive abilities, such as quantitative reasoning, memory, and reading comprehension tests (Cognitive Ability Tests). Future versions of this study could also make use of a different piece as an auditory stimulus, whether it be a classical piece or a piece from another genre, provided that the piece meets the criteria outlined in the introduction of this paper.

The statistically significant results of this study open the gate to further research into the link between the properties of auditory stimuli and cognitive abilities. Noting the varying P-values obtained in the results section, which suggest that there were varying levels of significance among treatment groups, one question that can be explored further is whether combinations of altered musical properties have an impact on cognitive abilities. As an example, a control group could be compared to an experimental group that listens to fast tempo, high pitched music and to a second experimental group that listens to fast tempo, low pitched music.

This study takes the first step in attempting to answer the question of which specific musical properties—as opposed to which broad musical genres—augment cognitive abilities by singling out fast tempo music as a candidate for the ideal auditory stimulus for studying and test-taking. Identifying this ideal auditory stimulus would forward the goal of the field of biomusicology to uncover therapeutic and educational connections between music and the brain.

References

APA Dictionary of Psychology. (n.d.). Retrieved December 20, 2018, from https://dictionary.apa.org/spatial-temporal-reasoning

Cognitive Ability Tests. (n.d.). Retrieved March 19, 2019, from www.opm.gov/policy-data-oversight/assessment-and-selection/other-assessment-methods/cognitive-ability-tests

Gonzalez, M., Jr., Smith, G. E., IV, Stockwell, D. W., & Horton, R. S. (2003, August 8). The "Arousal Effect": An Alternative Interpretation of the Mozart Effect. *American Journal of Undergraduate Research,* 2(3) Retrieved from http://www.ajuronline.org/uploads/Volume 2/Issue2/22E-GonzalezJrArt.pdf

Harmon, L., Troester, K., Pickwick, T., & Pelosi, G. (2008). The Effects of Different Types of Music on Cognitive Abilities. *Journal of Undergraduate Psychological Research*, 3. Retrieved from http://library.wcsu.edu/dspace/bitstream/0/456/1/harmon.pdf

Koelsch, S., & Mulder, J. (2002, March 22). Electric brain responses to inappropriate harmonies during listening to expressive music. *Elsevier Clinical Neurophysiology*, 113(6). Retrieved from https://www.sciencedirect.com/science/article/pii/S1388245702000500

Mori, F., Naghsh, F. A., & Tezuka, T. (n.d.). The Effect of Music on the Level of Mental Concentration and its Temporal Change. *University of Tsukuba*. Retrieved October 30, 2018, from https://files.ifi.uzh.ch/stiller/CLOSER%202014/CSEDU/CSEDU/Information%20Technologies%20Supporting%20Learning/Full%20Papers/CSEDU_2014_40_CR.pdf

Mozart, Wolfgang Amadeus (2011, October 26). Mozart - Sonata for Two Pianos in D, K. 448 [Video File]. Perf. Gunther Hasselmann. Retrieved from https://www.youtube.com/watch?v=tT9gT5bqi6Y.

New York Times News Service. (2018, August 29). Critic: "Mozart Effect" Overplayed. Retrieved December 20, 2018, from https://www.chicagotribune.com/news/ct-xpm-1999-08-03-9908030302-story.html

Newton, P., & Bristol, H. (n.d.). *Spatial Ability Practice Test 1*.

Oswalt, A. (n.d.). *Intelligence: The Measurement Of Cognitive Capabilities*. Retrieved December 20, 2018, from https://www.mentalhelp.net/articles/intelligence-the-measurement-of-cognitive-capabilities/

Rauscher, F. H., Shaw, G. L., Levine, L. J., & Ky, K. N. (1994, August). *Music and Spatial Task Performance: A Causal Relationship*. Paper presented at the Annual Meeting of the American Psychological Association, Los Angeles, CA. Retrieved from https://files.eric.ed.gov/fulltext/ED390733.pdf

Stanford Medicine News Center. (2007, August 1). *Music moves brain to pay attention, Stanford study finds.* Retrieved from https://med.stanford.edu/news/all-news/2007/07/music-moves-brain-to-pay-attention-stanford-study-finds.html#mainContent

The Elements of Music. (n.d.). Retrieved October 30, 2018, from https://wmich.edu/mus-gened/mus170/RockElements.pdf

Trimble, M., & Hesdorffer, D. (2017). Music and the Brain: The Neuroscience of Music and Musical Appreciation. *BJPsych International*, 14(2), 28–31.

Widerman, M. S. (2013, April 29). Study Habits and Music: How They Affect Attention and Academic Performance. *George Mason University*. Retrieved from https://pdfs.semanticscholar.org/1e4b/bf8798fc24ebb35c9a0e0367d2917750c903.pdf