“Music and Mathematics: A proposed study to quantify and generalize mathematical skill improvement in adolescents at West Morris Central High School, Chester NJ”

By Nesha Deneshwar

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Rutgers, The State University of New Jersey

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May 6, 2019

Kurt Thoroughman, Director of CogNeuro

National Science Foundation

2415 Eisenhower Avenue

Alexandria, Virginia 22314

Re: Research on how musical training could improve mathematical brain functions

Dear Mr. Thoroughman,

The research on how musical training affects musician's brains in general has been extensive and well established. Such areas of expertise on the subject include studies on how musical training improves emotional control and lingual abilities. This extensive research on language abilities has overshadowed the study of mathematics and its relationship to music and the brain. While there are studies that have shown listening to music helps improve mathematical skills, there is limited research on how learning performance music affects mathematical skills in a biological way (Proverbio et al., 2018). Furthermore, there is a lack of research showing the effect of musical training in those who have passed the sensitive period for learning in their lives. If there was research supporting the idea that the brain can still change significantly to improve mathematical skills from musical training, this may then change the minds of those who think funding arts programs is not important.

The CogNeuro department of the National Science Foundation (NSF) is looking for more research on how learning is investigated in the field of cognitive neuroscience and how to do such a task with brain imaging technologies. In the study I am proposing, I will be investigating how musical training affects mathematical learning abilities while using brain imaging technologies like functional magnetic resonance imaging (fMRI) and electroencephalograms (EEG) to localize where these cognitive functions take place and their subsequent effect on activity and structure of the brain. Funding this study would help further investigate whether mathematical learning and cognition would be affected by musical training as current research cannot substantiate this claim.

If you would like to speak to me more about my proposed study and plan, please feel free to contact me via email at nesha.daneshwar@rutgers.edu or via phone at (908)798-8982. Thank you for your time. I look forward to hearing from you soon.

Sincerely,

Nesha Daneshwar

Nesha Daneshwar

Music and Mathematics: A proposed study to quantify and generalize mathematical skill improvement in adolescents at West Morris Central High School, Chester NJ

Nesha Daneshwar

173 Ryders Lane

New Brunswick, New Jersey 08901

Submitted to:

Kurt Thoroughman

Director of CogNeuro

National Science Foundation

2415 Eisenhower Avenue

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May 6, 2019

Scientific and Technical Writing

Section 49

Professor Jonathan Bass

Rutgers University

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Abstract

Since the era of fascination with music and the brain, it had become commonplace to investigate how musical training improved language learning abilities since it was known that listening to music would improve these skills. However, because of this there is less knowledge about how musical training effects mathematical skills and how they are learned. Studies have shown that adolescents are more at risk for not pursuing musical training due to budget cuts in schools since there is no research substantiating that musical training has an overall good effect on learning multiple academic subjects.

To investigate the effect of learning a musical craft on mathematical learning abilities in adolescents, several steps need to be taken into consideration to produce accurate and well-rounded results. To measure the changes physically in the brain two brain imaging technologies will be used, functional magnetic resonance imaging (fMRI) and electroencephalograms (EEG). The use of these two technologies will help localize the effect of musical training on the brain and how this will subsequently affect mathematical skills by showing if the areas of the brain affected by mathematics are also affected by musical training. To measure this, two groups of high school students will be either given vocal lessons or mathematics tutoring after school for an hour each day for an entire scholastic year. fMRIs and EEGs will be conducted at the beginning and end of the year to measure the changes physically and cognitively in each of the two groups. Previous research suggests that there will be a positive impact on mathematical learning abilities through learning a musical trade.

Table of Contents

Table of Figures

Introduction

Musical Training's Effect on the Brain

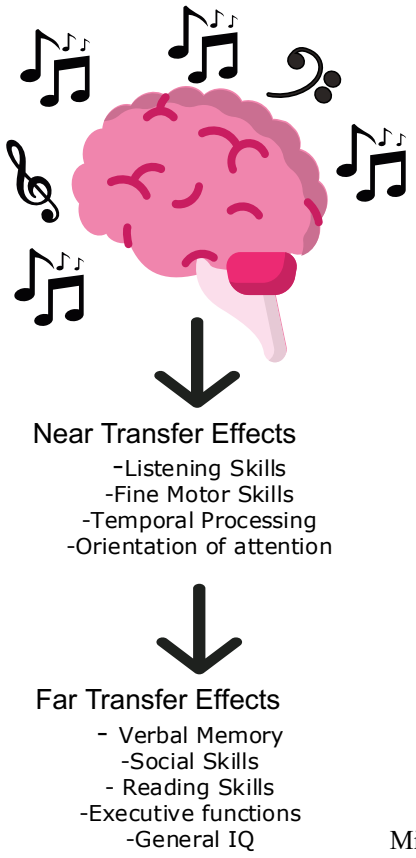
Musical training has been analyzed in other realms of effects rather than academic improvement. An analysis provides evidence that "apart from anatomical differences in auditory and motor cortices, there are structural differences (usually in the form of increased gray matter volume) also in somatosensory areas, premotor cortex, inferior temporal and frontal regions, as well as the cerebellum in the brains of musicians compared to non-musicians'" showing the use of brain imaging technologies being used to determine the changes of pure musical instruction on the brain (Miendlarzewska & Trost, 2014). In this study analyzed there were only results comparing how musician and non-musician brains differed structurally, however there is no comparison between how these structures contribute to language learning parts of the brain directly and if these regions affected overlap with the language learning parts of the brain.

Another study conducted by James, Oechslin, Michel, & De Pretto (2017) showed that there were more structural changes to the brain and was able to localize function of these parts of the brain to specific tasks. They were able to see that error detection was improved in those participants practicing music and that the reward system of the brain was also stimulated from musical training (James et al., 2017; Proverbio, De Benedetto, Ferrarini, & Ferrari, 2018). They were also able to localize where sound to meaning mapping exists in the brain with recent advancements in technology (James et al., 2017). However, this study also is focused on studying the effects of musical training on behavior. The error detection and reward system stimulation can only be taken in the context that the researchers are only interested in determining how musical training improves behavior. Improving behavior is something musical training can do because of this enhanced functionality of the error detection, empathy, and the reward parts of the brain. However, there needs to be more research on how musical training and mathematics are related. Many studies cited in James et al. (2017) correlate their results to other extensive research done on musical training and behavior. This shows that the relationship between music and behavior is now well established, it is time to do the same with mathematics and music.

Musical Training's Effect on Language Skills

Figure 1 shows that to measure the way mathematical skills affects the brain the far transfer effects of musical training must be utilized to determine if musical training affects mathematical abilities. As shown by Miendlarzewska & Trost (2014) the far transfer effects of music are the effects that are present after one month of musical training. As shown in figure 1 the skills attained from far transfer effects are what effect the language skills by way of verbal skills and reading skills. Therefore, it is inferable that the skills that would improve mathematical skills from musical training would also appear after a month as first the direct effects of musical training would appear first as changes in auditory and motor skills. Then continuing with musical training would allow for more changes in the brain due to plasticity and neurotransmitter stimulation in the brain and these changes subsequent changes all over the brain affecting academic skills. The far transfer effect of musical training and how they apply to language skills will be discussed in the next section.

Figure 1: Skills musical training directly and indirectly affects



Miendlarzewska & Trost (2014)

Since the conception and endless testing of the Mozart effect in the 1990s, music and its relationship with mathematical skills has been overlooked and understudied. A 2014 meta-analysis of multiple studies concerning musical training and its effects on the brain overall found that most research was aimed at the impact of this instruction on language learning skills and no other skills. It has also been found that musicians brains have higher resting state activity levels measured via fMRI than non-musicians indicating better connectivity of neurons throughout the brain which also helps them process language better and faster (Miendlarzewska & Trost, 2014). Musical training has brought about improved verbal intelligence and the better ability to control executive functions thus leading to improved grades (Miendlarzewska & Trost, 2014. This research suggests that there is ample evidence to support the idea that language learning and comprehension abilities are only enhanced by musical training but never focuses on mathematical abilities or even other academic subject areas. Topographic images of the brain have been utilized to show the discrimination in lexical versus musical tones as well when children are exposed to musical training (Nan et al., 2018).

However, there is little to no research supporting the idea of music having any effect on mathematical learning. Miendlarzewska & Trost (2014) even suggest that further research be conducted on how mathematical learning abilities are affected by musical training since in their meta-analysis they were only able to conclude that although mathematics scores improved when tested, there were no matter differences found in the brain that could correlate to the mathematical reasoning centers of the brain. Edel (2012) is a study said to be conducted about

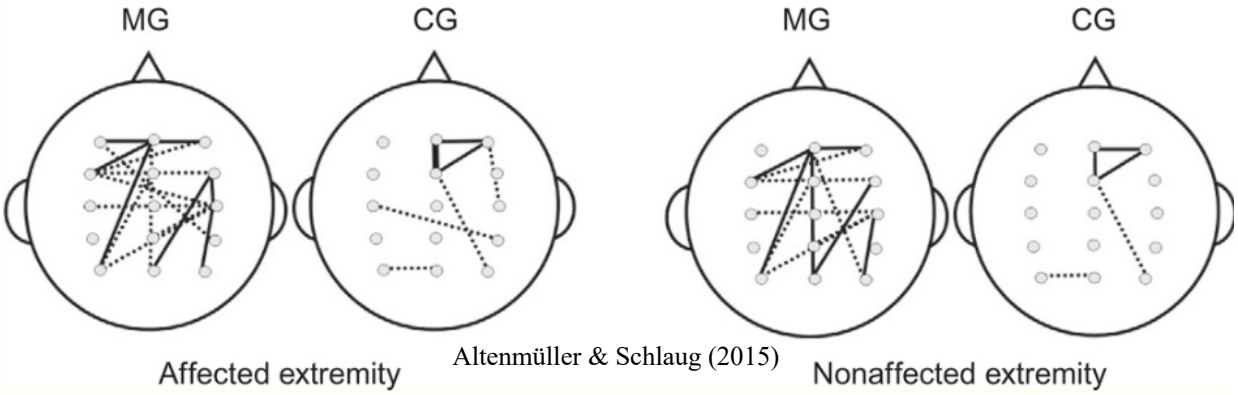
how mathematical abilities are affected by vocal training. However, while this study has a good plan and promising results, the conclusion of the study says that the study was never conducted or the results came back inconclusive making the researcher withdraw the data either supporting or negating his claim (Edel, 2012).To create a well-rounded understanding of how music affects the brain structurally, mathematical skills should be analyzed for a complete understanding of how musical training affects learning skills in general.

Therapeutic Effects of Musical Training

Since music has multiple effects on the brain and in language abilities, it comes at no surprise that music is being researched to provide therapy for neurologic conditions that cannot be treated with medicine or without other forms of therapy. One reason that musical training and musical listening is being used as therapy is because of enhanced neuronal plasticity and an increase of neurotransmitters that produce positive feelings in the brain (Altenmüller & Schlaug, 2015). The neurotransmitters that produce these calming and feel-good effects are dopamine and serotonin, dopamine is mainly responsible for having a positive effect on one's mood and attitude and serotonin calms and enhances the functional connectivity within the brain (Altenmüller & Schlaug, 2015). These improvements in plasticity are usually found in the motor and auditory cortexes faster and this type of rapid effect is what many patients suffering from stroke, Alzheimer's, or Parkinson's disease may benefit from (Altenmüller & Schlaug, 2015; Francois, Grau-Sanchez, Duarte, & Rodriguez-Fornells, 2015; Gallego & Garcia, 2017).

Research has shown that musical training and listening to music can help stroke patients with respect to motor loss, musical therapy with instruments has been proven to be effective in helping stroke patients regain their functional ability in limbs they have had a hard time with moving after the stroke. Since playing an instrument requires the use of the upper extremities it can help those having trouble with moving those extremities by insistent repetition and associating the movement with other stimuli (sound, emotion) to foster long term potentiation so that the movement is not suddenly lost after training stops (Francois et al., 2015). The review done by Francois et al. in 2017 has also shown that there is increased sensitivity in the sensorimotor cortex which will help those undergoing therapy to access the motion they have regained easier and learn new motions easier as well. Altenmüller & Schlaug (2015) have also shown that musical therapy improves timing, smoothness, and precision of motion that was inhibited due to stroke and figure 2 shows that there is increased functional connectivity in the musical group which allowed them to establish muscle memory better than just physical therapy alone. Figure 2 shows the strength of connectivity with how many lines are present, the increase in lines in the music group denoted by MG shows "significant increases in task-related coherence during the motor performance" meaning since these participants experience better functional connectivity they can comprehend the motor tasks that are difficult for them better than those without this musical therapy (Altenmüller & Schlaug, 2015).

Figure 2: Increased connectivity due to musical training



Altenmüller & Schlaug (2015)

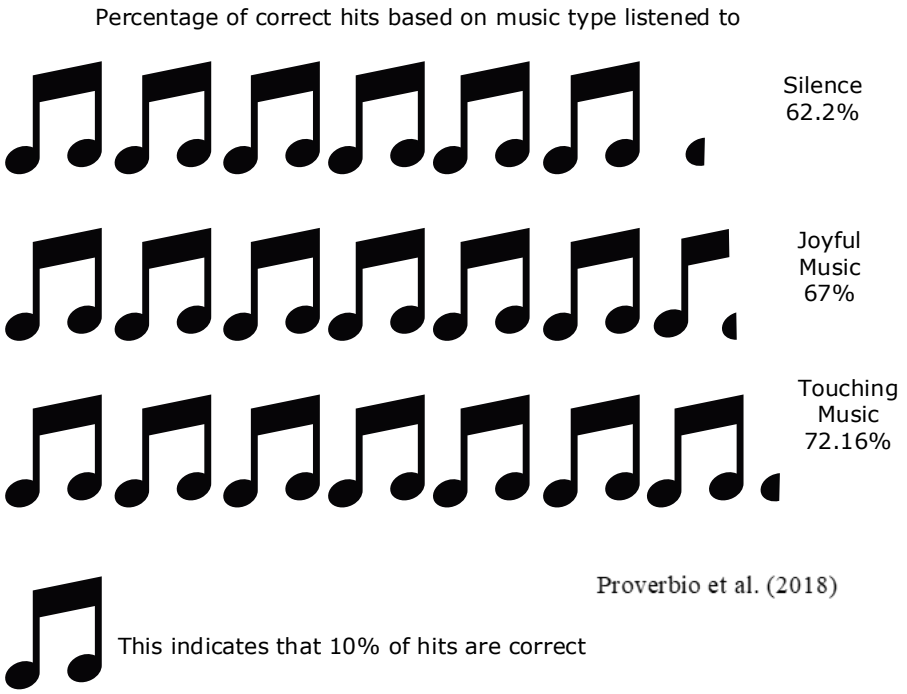
This amount of literature on how musical therapy by way of musical training is very good for those experiencing neurological conditions. However, it is still surprising that there are no studies trying to link mathematics and the brain. The extensive research done on how musical training can be a good therapy can be attributed to the extensive knowledge on how musical training positively affects motor skills and listening skills in those who practice music. However, there be some research trying to find out if other links between music and other brain functions such as mathematics exist because there is a lack of research on how these tasks are related in the brain. Even if there is no suspected correlation between these two functions, research should still be established to create a well-rounded view on how musical training affects all parts of cognition and the brain.

Literature Review

Listening to Music Improves Mathematical Performance

Recent research has shown that listening to music will improve mathematical learning and performance. Proverbio et al. (2018) shows that background music overall helps improve mathematical computational accuracy as shown by figure 3. As shown in the figure above, silence compared to musical conditions showed that music yielded better overall performance when difficult mathematical problems were presented to participants (Proverbio et al., 2018). The researchers had found that background music has been shown to increase brain activity overall in participants in the study which contributed to the musical conditions performing better than those in the silent condition (Proverbio et al., 2018). However, it was also shown that agitating music had an overall detrimental effect on performance indicating that type of music listened to does in fact play a part in how performance will be affected (Proverbio et al., 2018).

Figure 3: How music affects mathematical skills



Brain Imaging Technologies

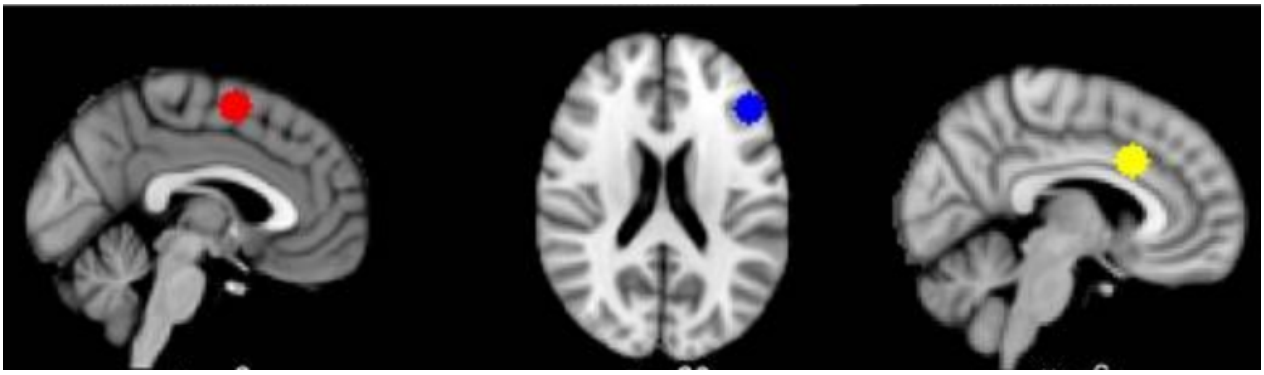
One way that is effective to measure the structural and activity changes in the brain is by way of brain imaging technologies. Brain imaging technologies such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) are common and effective ways of measuring the physiological changes in the brain due to a stimulus. Many studies conducted so far only use one brain imaging technology to measure the biological changes in the brain, however, using more than one brain imaging technology would be useful in determining more than one biological aspect that has changed when musical training has been introduced unto the participant's lifestyle (Sachs, Kaplan, Der Sarkissian, & Habibi, 2017, Nan et al., 2018, James et al., 2017).

Functional magnetic resonance imaging is a technology that measures both brain activity and structural composition of the brain. Proverbio et al. (2018) showed that fMRI technology could uncover which areas of the brain were being activated and how they change when learning music, specifically the dopamine reward system was shown to be activated. This type of imaging has not been used a lot in trying to reveal if mathematical skills can be improved with musical training. Sachs et al. (2017) claims that fMRI imaging may have the following implications for research: "Neuroimaging may additionally help clarify the link between music training and executive functions by illuminating structural and functional differences in the brain that may not be captured by behavioral assessments alone" as functional and structural differences cannot be visually seen by test scores on a sheet of paper.

Sachs and his team used fMRI to qualitatively measure the changes in cognitive ability from musical training (Sachs et al., 2017). One of the major findings in this study was that they were able to confirm previous results localizing cognitive functions to certain areas of the brain

as shown by the colored dots on the brain images shown below (Sachs et al., 2017). Using fMRI technology would enable this research to localize where musical training and mathematical training affect the brain and if these regions overlap to gain a more holistic view on how musical training affects mathematical skills, creates more brain-like images, and will show matter changes in the brain better as shown in figure 4.

Figure 4: An example of images produced by fMRI technology

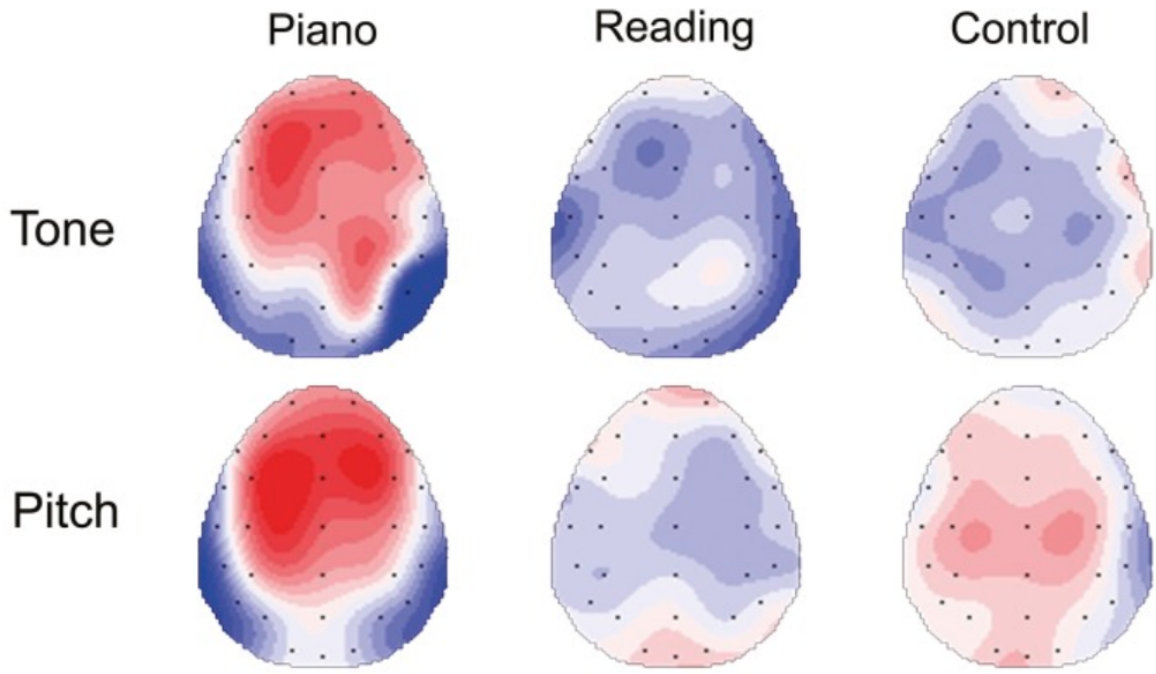


Sachs et al. (2017)

Electroencephalography technology has been in use for a long time since it can be used while participants are active, measures activity, and hints at structural changes in the brain. The reason why this study would use both fMRI and EEG technology is because EEG technology is better at determining actvity through electrical impulses while fMRI can determine activity via blood flow and electrical impulse. EEG is also more inexpensive than using fMRI but does leave out imaging and different topographic maps of the brain that can be used to construct a more well-rounded view of how musical training affects mathematical skills. Also, it is very hard to construct a good electroencephalography kit from the materials readily available to researchers. A study conducted by Lau, Gwin, & Ferris (2012) showed that for research purposes EEGs should be conducted with a minimum of 35 electrodes placed on the head to measure activity. However, it is improbable to attain such equipment easily and without it costing as much as an fMRI (Lau et al., 2012).

EEG technology in this study will be used with 16 electrodes which is less than half of 35 electrodes, however from previous research, these electrodes can be strategically placed where music impacts the brain to see if those who have not practiced music have similar changes in those regions of the brain as those exposed to musical training (James et al. 2017). Studies have shown that EEG activity measures can measure distinct changes in perception based on activity sensitivity in music specific areas of the brain (Nan et al., 2018). These perception changes measured how good students were at detecting changes in tones between lexical (speech) and musical ranges, since this has been established, there is a possibility that musical training improves error detection and/or problem-solving ability (Nan et al., 2018; James et al., 2017). Figure 5 shows how the results of EEG testing can be organized into topographic maps illustrating where more brain activity is occurring by measuring the membrane potential across the scalp from the electrode readings.

Figure 5: Example of topographic maps created by EEG



Nan et al. (2018)

Proverbio et al. (2018) also utilized EEG technology to quantify how much brain activity increased when completing mathematical tests with music in the background versus silence in the background. Overall the EEG was useful to them by showing that some types of music are better for completing mathematical tasks as other types can cause overstimulation of the brain yielding negative results (Proverbio et al., 2018). EEG technology will allow for better topographic maps of the brain to be constructed and will help with utilizing less EEG electrodes to produce high quality results.

The study conducted by James et al. (2017) used both of these brain imaging technologies to create a well-rounded and detailed view of the brain and how functions can be localized. The fMRI technology measures the blood-oxygen levels in the brain to determine which parts of the brain are more active than others and the EEG technology measures the membrane potential across the brain from multiple areas of the brain (James et al., 2017). These technologies coupled together created a holistic review of where functions in the brain are localized such as error detection to the anterior cingulate cortex and the sound to meaning mapping to the middle temporal gyrus (James et al., 2017). The use of both of these technologies was to reinforce the results found so that they were due to actual structural and activity changes in the brain and not just due to chance. Using both technologies subsequently in future study can also be used to reinforce findings for activity and structure changes as both technologies are known for doing this.

Mathematical Skill Assesments

This study would be incomplete if mathematical skills were not actively tested so that there would be a cognitive assessment of mathematical performance with and without musical training. Hallam and Holmes (2017) conducted a study where children received musical training

with a focus on rhythmic skills as this skill is one of the more math heavy concepts of music. Their study did not include any for of brain imaging technology assessment but they did administer a European test called the SAT to determine the change in mathematical skills of their participants (Hallam & Holmes, 2017). The purpose of using such cognitive assessments would make it easier to have visual representations of data and would yield results on how changes in the brain or lack thereof would have on actual performances during mathematics exams. These results could then be analyzed with descriptive and inferential statistics which is hard to do with data collected from EEG and fMRI testing.

The measurement of cognitive mathematical ability and mathematical performance will be assessed by using the Wechsler Individual Achievement Test II: Abbreviated (WIAT-II) and specifically the Numerical Operations subset of the test (NO). This test has been selected as it has been a popular choice of mathematical skill assessment in recent years. The WIAT-II has helped researchers assess mathematical skills such as number discrimination, rote counting, solving simple equations, rational numbers, geometry, and simple algebra which should be within the skill range of high school students (Wu et al., 2017; Geary, Nicholas, Li, & Sun 2017). A study conducted by Li & Geary (2017) also uses the NO subtest of the WIAT-II and reported that this test is suitable for children and young adolescents from grades 5 to 9 according to the American scale of grade progression. It is no mystery that most studies conducted to date have use some form of written test to try and quantify mathematical ability, however the WIAT-II NO subtest will be useful for the target population of this study and has been recently tested and proven to accurately assess mathematical skills in the target population (Wu et al., 2017; Geary et al., 2017; Li & Geary, 2017).

Using Vocal Training

The musical training described in many of the studies used in this paper do not specify the type of musical training they utilize. Some reviews are in support of saying learning instrumental music is better than other types of musical training however this cannot be proven as there are many studies that do not disclose what musical training they are using (Francois et al., 2015). Since type of musical training is not specified it is also unclear of what musical instrument is being used. The costs associated with buying and maintaining musical instruments can also add up. Beginning musicians are more likely to damage their instruments as they are unsure of how to handle them properly or tune them properly. Furthermore, improper storage of instruments can also lead to the degradation of the instrument and make it easier to break. There have been studies that have utilized piano training but it is very hard to get so many good quality keyboards or pianos in a public school so every student can practice at once (Nan et al., 2018).

The type of vocal training that will be utilized throughout the study will be vocal training. As explained in Elbert (2012) and Holmes & Hallam (2017) vocal training is as effective as instrumental training and is significantly more cost effective. There are no costs associated with maintaining instruments when it comes to vocal training as there are no instruments needed. In the school the study will take place, they pay to have their piano tuned by themselves so there will be no cost in this study for upkeeping instruments if anything were to happen to them. The sheet music for vocal groups will be provided by the school where this study will take place as well. In a study conducted by Gomez Gallego & Gomez Garcia (2017) showed that vocal training is also an effective therapy and also has positive effects emotionally on the brain. As discussed in the introduction, the stimulation of the neurotransmitters that produce positive

effects on the brain also increase neuroplasticity, allows for better functional connectivity, and stimulates the storage of memories in the brain (Gomez Gallego & Gomez Garcia, 2017). Vocal training will also have less near transfer effects with motor skills since trainees' arms and fingers are not required for vocal training. The far transfer effects of the vocal training may come about faster since the near transfer effects will be established faster.

Plan

This study will take place at West Morris Central High School (WMCHS) in Chester, New Jersey. This school has been chosen because not all children are asked to be in musical participation programs when they are young and have the option of declining to learn a musical instrument. At the school 32 participants will be selected all participants will be incoming freshman who have had preferably either no prior musical training or very limited musical instruction either in elementary or middle school. This will provide clear baseline readings of mathematical skill and brain activity and composition of adolescents who have not had any musical training.

The principle, Timothy Rymer, and the choral director, Mark Stingle, have granted permission for the study to take place at WMCHS and to utilize the choral facilities, music, and free classrooms the school currently has available after the scholastic day ends. Two teachers will be hired in order to conduct the study, a vocal music teacher and a mathematics teacher. The 32 participants will be split into two groups of 16 students each, an experimental and control group. The control group will meet with the mathematics teacher after school every day for an hour and the experimental group will meet with the music teacher after school every day for an hour. The mathematics teacher's group will focus on helping students with their current mathematics class material and homework, if the students understand and have completed their in-class assignments and homework, they will be given supplementary worksheets to ensure they are engaged in doing mathematical processes for the hour they have after school. For the vocal students on the other hand, the music teacher will first assign them vocal parts as the music will be choral and after this they will begin learning songs until the instructor finds that the group has learned the pieces well enough to move on to new ones. These lessons will not take place when the school has a half-day or is on vacation.

Once before the school year begins, all 32 participants will be bussed to Yale University to have fMRIs of their brain taken before they begin the musical training or mathematical tutoring to have a baseline. While in Connecticut, students will be lodged at a nearby hotel and EEGs will be taken with the participants not scheduled to have an fMRI that day. Two EEGs will be conducted, one will be conducted as the student is at rest and one will be conducted as the student takes a short exam on the material they will learn this academic year. Overall, we will spend no more than 3 days at this location and will return to Chester before the scholastic year starts. At the end of the year the same procedure will be carried out to see how much physiological changes the participant's brains underwent and the change in the activity of the brains as disclosed by the EEG results to their resting states or mathematical cognition state. Students will also take the WIAT-II NO subtest without EEG or fMRI technology to asses cognitively their understanding and processing of mathematics has changes over the course of the study.

The school days of students in this study will be extended an hour. The students will report to school during its normal opening time and then when their last class ends, those in the vocal training group will report to the choral room and those in the mathematical group will report to the library. Their respective teachers will be in their classrooms so that instruction can begin. The classes will begin at 2:45 and run to 3:45 every day after school. The vocal teacher will warm the students up for about 10 minutes and then they will begin learning simple choral music at first and then moving on to more advanced pieces throughout the school year. As for the mathematics group, they will begin with asking the teacher about anything they find confusing in their math classes and will be able to ask for homework help and then halfway through the session students will be given a worksheet that emphasizes specific skills tested on the WIAT-II. To evaluate the students mathematical progress throughout the year, the NO test will be given four times, once at the end of each marking period. Students will be given the full hour they would receive after school for training to complete the test, if the students finish early they will be allowed to leave early.

This study could potentially be conducted over multiple years which would give rise to more data to be analyzed. This would also allow for more instructional time for the students which would allow for more data on how longer-term musical training affects the brain and mathematics abilities. This could yield better results because it is known that musical trainings impact on the brain cannot be seen for at least a year after the start of the training and the study will only encompass the months the students are in school. The data from this study and an extended study could also be compared to resting state measures of musicians brains to see if they are developing in the same patterns or if they are developing and have overlapping changes with other changed skills from musical training. For the results from the mathematical group, these findings will help localize the function of mathematical skills to one or more parts of the brain and will help distinguish if these changes are the same or similar to what musical trainings effects on the brain are. If the two trainings present the same effects, then it would show that musical programs are not just an “extra” expense but can actually help children with their studies in a fun and more engaging way.

Budget

The cost of this study has been planned so that it is cost efficient with respect to also obtaining much needed detailed results. The bulk of the cost of this research will be reimbursing the vocal instructor and the mathematics instructor for their time they will put into the study. Graduate students from the Rutgers University will be employed and reimbursed accordingly. These graduate students will not be paid much because they will not provide office hours to the students at WMCHS and will only be teaching for five hours a week. Four graduate students will be employed, two for musical training and two for mathematical training, the reason two will be employed is because if the main instructor falls ill, there will be a substitute and these instructors will teach every other week. These students will be paid a stipend of $15,141 each to compensate for their instructional expertise and transportation as this really is not a full time or part time job. The next biggest expense of the budget is the fMRI testing which comes to be $29,232 which is the cost of using a fMRI machine for research at Yale University for 12 hours a day with an analyst to help decode results from the fMRI analysis. Since Yale University is in New Haven, Connecticut, the students from Chester will be transported to Connecticut via school bus and will be lodged in a hotel for three days. The purpose of having the children there is to utilize the

fMRI machine at Yale and to thank them for being in the study by giving them an extra day to explore the city with the researchers, this totals to $8,424 for the hotel costs and $271.15 for the cost of the school bus rental.

Table 1: Costs associated with each part of the proposed research plan

Employment Costs	$60,564.00
fMRI	$29,232.00
Lodging	$8,424.90
Computer	$2,799.00
EEG Headset	$999.99
EEG Software	$949.99
Transportation	$271.15
Dry electrodes	$29.99
Batteries	$21.80
Total Cost	$103,292.82

The rest of the budget has been devoted to purchasing and upgrading an EEG set to help measure the specific changes in the brain this study intends to find. The most expensive item that is needed for the EEG results and to keep the data from the rest of the tests administered to the students, this will be an Apple personal computer which is the brand of computer for which the EEG software from the manufacturer has optimized the software for. The computer costs $2,799 and will be of great use throughout the study. The EEG headset and software will be purchased from OpenBCI which is the retailer that will give the most number of electrodes (16) in a headset without ordering the quote from the site, the cost of the headset is $999.99 and the software is $949.99. Extra dry electrodes will be purchased in case some of the electrodes wear out, experience corrosion, and create a higher density EEG which will cost $29.99 for a pack of 30. Finally, batteries and their respective chargers will be purchased to recharge the EEG headset and make it functional as it will not operate without batteries, the batteries and their charges will cost $21.80 for two of each product recommended for use with the set by OpenBCI. Table 2 shows the budget broken down into a tabular form.

Discussion

The goal of this study to be conducted at WMCHS is to establish a better biological relationship between musical training and mathematical skills by way of brain changes. These results will provide a better and more modern understanding of how musical programs do affect performance and the brain which will hopefully lead to a decline in the overshadowing of musical programs in public schools now. This study has been carefully formulated so that there are multiple ways to successfully accomplish what this study is set out to do. These models of success will correctly map and image the brain so there will be a holistic view of what happens to the brain as mathematical skills and as musical skills are gained by the students.

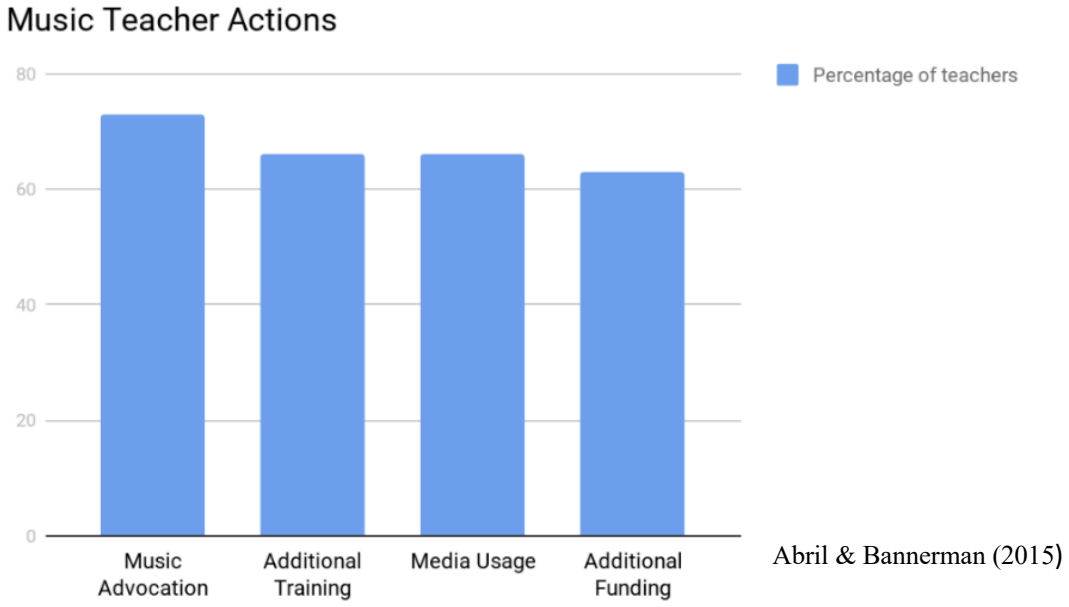
The only possible errors that could be present in this study are the small sample size and the number of electrodes on the EEG cap (Lau et al., 2012). The small sample size of this study means that there are less results to analyze which could then lead to skewed results based on the

small sample taken. This would make the results harder to generalize to the population of all high school students as such a small sample is selected and subsequently examined. Another possible issue is that the EEG that will be purchased for this study could not be high enough density as it has been shown that at least 35 electrodes should be placed on the scalp to get a good reading of the electrical potentials across the brain (Lau et al., 2012). However, this could be solved by adding additional electrodes to the headset or re-orienting the electrodes and taking two EEGs to get an overall view of the participant's brain activity.

Now more than ever, public and private high schools are facing budget and time cuts to their musical programs. The main reason for the decline of these programs in schools is because of the lack of research on how musical training improves more than just one aspect of academic performance. If there was more research showing that there is a relationship between mathematics and music, whether it be positive or negative, it would showcase how there is more to musical training than just benefiting language skills because the grounds school boards have for rejecting musical training programs is weak. Even if subsequent research shows that yes only language skills are improved by musical training this will justify the school board's actions in cutting the musical programs from their schools.

A survey study conducted by Abril & Bannerman (2015) showed that there were beginning to be problems of schools keeping their musical programs intact. The figure below shows what over half of the teachers asked in this review what they had to do outside of the classroom to make their musical programs better. 73% of teachers said that they had to pair up with the other music teachers in the district to promote their musical programs as their schools would not as they are trying to minimize these programs, so they can put less money and effort into them (Abril & Bannerman, 2015). Even though this is the smallest bar on the figure, it has also been shown that 63% of music instructors must pursue additional funding through outside forces to make their music programs beneficial to students.

Figure 6: Representation of how music teachers support their own programs



Abril & Bannerman (2015)

Another study conducted by Rajan in 2017 showed that there was a contradictory relationship between what superintendents of schools were saying about their musical programs and what actions they took to preserve these programs. At the beginning of the survey, these superintendents were quick to say that yes musical training is necessary for schools to employ, however when it came to put in time and money into these programs these authorities claimed that they could not do such things as it would be too much to spend on a "luxury" activity (Rajan, 2017). This then leads to the communities wanting a decline in musical programs as they are as educated on the subject as their superintendents, therefore providing more research on these programs will provide better rational to justify these cuts or to reduce these cuts.

Table 2: School Board Executive's Thoughts on School Music Programs

Music education is necessary in school	97%
Music education is supported in school	93%
Music education is supported by community	72%

Rajan (2017)

Hopefully this study will provide school board members to stop marginalizing their music programs by showing that there is a relationship between mathematics, music and the brain both performance wise and biologically. It is of the utmost importance that the relationship between musical training, mathematics, and the brain be established because the lack of research on this topic is minimal and more research would support the idea that musical training is worth keeping in schools. This research should show school board members that more than just language skills are impacted by musical training and that by improving the overall structure of their student's brains they will subsequently be able to do other cognitive tasks which include academic subjects.

Finally, this will better establish the relationship between musical training, mathematical skills and the brain. Even if there turns out there is no positive relationship between mathematics and musical training there will be less ambiguity about how these skills are related and what musical training really does improve in the brain. Therefore, more studies can also be created to confirm the results obtained from this study. For every topic in cognitive psychology and neuropsychology there needs to be a first research study to encourage other researchers to investigate topics they previously had not studied before. Brain imaging technology use early on with this investigation will yield better results of how the brain changes in response to musical training and how these changes affect mathematical skills more accurately. Musical training and mathematical abilities may be related, but until more research is established on this topic, it will forever be unknown.

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