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How Formal Music Training Affects Executive Functions in Middle School Band Students

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An Honors Thesis submitted in partial fulfillment of the requirements for Honors in The Fred and Dinah Gretsch School of Music.

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ABSTRACT

My thesis project explored the relationship between a formal music training experience and executive functions in a middle school band classroom. Executive functions are working memory, inhibition, and cognitive flexibility which allow us to gain and focus our attention on specific tasks. Participants in the study were two groups of middle school students: a sixth-grade class with no previous musical experience and an eighth-grade class with two years of band classes. I measured changes in students' overall success on cognitive tests over a two-month span to observe at what point music training begins to impact executive functions. I found significant improvements on all executive function tasks for both groups of participants. With that information, I believe that music instruction plays a significant role in cognitive development. With a larger sample size, I believe that these results would become much more apparent.

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How Formal Music Training Affects Executive Functions in Middle School Band Students

Whenever students engage in music practice and performance, they engage their minds in ways that require great cognitive control. Such cognitive processes can be categorized under the term “executive functions”. Executive functions (EF) are very impactful on the development of the minds of children of all ages. These functions are specifically important when student’s brains are the most susceptible to change (Holochwost, 2017). Executive functions as described by Diamond (2013) as “core skills critical for cognitive, social, and psychological development”. The three executive functions that I will be measuring in my research are working memory, inhibition, and cognitive flexibility. One of the subjects that may significantly enhance executive function is music, specifically formal music practice/training. In my research, I explore how executive functions may be impacted by a formal music education experience.

Executive functions are crucial in developing strong musicianship skills and maintaining a high level of performance. In a musical context, EFs relate to the skills that we use to understand complex musical concepts and translate them to performable actions. This is very important to me because I believe it is important as an educator to understand how our students learn best. By studying executive functions, I hope to gain knowledge about how students develop; I can use that information to be a more effective teacher. I specifically find executive functions interesting because of their relevance to music making.

Music educators strive to find new and innovative ways to teach students. However, without a better understanding of how music is related to brain function, teachers may never get the success out of their group that they so desire. In fact, music programs are often sacrificed for other subject areas because it seems too one-dimensional, but the skills developed in a music classroom may transfer to other subject areas as well. Most previous research has studied the effects of private lessons on executive function. However, this is limiting because private lessons are not accessible for all students. Therefore, I aim to make my research more accessible to students by measuring the effect of music training in a band class setting. The scope of my research is to explore the connection between music training and executive functions because the executive functions may support their other academic skills.

In this study, I will focus on the following three executive functions: (1) Working memory: the ability to hold information in mind while mentally manipulating that information (Diamond, 2013), (2) Inhibition: ability to override prepotent responses and direct one's attention, behavior, thoughts, and emotions to what is appropriate (Diamond, 2013), (3) Cognitive Flexibility: ability to adjust to changed demands, switch perspectives, and come up with alternative ways to succeed when not successful at first (Diamond, 2013). Researchers such as Schellenberg have found that music training and increased IQ may be related (2011), but they never confirmed the causation to be executive functions. The lack of clarity in Schellenberg's research, as well as in many similar studies has led to the formation of my research questions, as I hope to find a more direct correlation between music and executive functions in my research. .

Review of Literature

When identifying research studies that matched the criteria for my study, I first looked for studies that collected data from participants at an elementary school. The research studies I found varied significantly in terms of the participants who were tested. In total, the range of my studies tracked students aged 4-13 years old. However, for my research I will be focusing specifically on the studies which measured the development of executive functions in 4-7 year olds. This specific age range is most susceptible to brain development, and falls right in their zone of proximal development, as the brain is almost 90% developed by the age of 5 years old (Sriram, 2020). After identifying which studies matched well with my parameters, I noted the testing periods that other researchers have done and used that information to establish my own procedures. In terms of testing periods, the research studies I observed typically tested their participants on either a weekly or bi-weekly basis. In my research, I intend to modify this to have a pre-testing period and a post-testing period following two months of music training.

Working Memory

Working memory is the executive function that deals with how well we can hold information in our brain, and how we can manipulate that information to complete short cognitive tasks (Clark, 2018). Working memory is similar to a mental workspace for the small amounts of information that can be stored in the mind long enough to complete cognitive tasks. This is not to be confused with long-term memory which consists of all of the information saved in one's life. Working memory is important, as it gives students the opportunity to intake information and store it briefly in their minds. It also plays a key

role in decision-making and reasoning (Clark, 2018). In a musical context, working memory could involve maintaining information such as remembering the key signature to a piece and only playing notes in that key signature. Working memory can also be observed in a music setting as a way to switch attention between tasks, such as manipulating scale patterns or changing articulations when rehearsing repeated sections. It is also responsible for how we store and rehearse information.

To study working memory the researchers used various types of tests, the most common being the Digit Span Task. In this task, students are asked to either aurally or visually observe and repeat a set of numbers given from the experimenter. The digit set gets longer each time the student completes the exercise. Using the Digit Span Task, students are measured on how accurately they can replicate the digit list that was provided to them once that list is taken away. The more digits remembered, the greater the working memory capacity. Another common working memory task is the Block Design Task, in which students are shown a pattern of blocks and are asked to recreate it. This task measures accuracy of replication, much like the Digit Span Task, but also measures the variable of time by tracking how long it takes the student to recreate the block design.

In my review of the literature, I found that 7 of my 13 articles had a focus on working memory, with five of these solely focusing on working memory and the other two articles encompassing many different cognitive functions. The age of participants ranged from kindergarten to 12 years old, with a majority of the participants coming from the 6-12 year old age group. The most popular mode of testing working memory in my literature was the Digit Span Forward Task, and a similar task that utilized word lists

instead of digits. The Digit Span Forward Task could be found in four of my articles, with the word lists being used in two of them.

The studies I reviewed had inconsistencies that I aim to clarify through my research. Approximately one half of the literature found no significant trends between music training and executive functions in the participants. Rather, they attributed the connection between executive function and music solely to the participants developing new skills as they aged. To minimize this risk, my study will complete both phases of testing within just a few months of each other, thus limiting the variable of natural development and focusing solely on the impact of music on working memory.

Cognitive Flexibility

Cognitive flexibility is the executive function that enables us to selectively switch between cognitive processes and generate appropriate responses in response to a task (Moreno, 2011). Younger students that are still developing cognitive skills may be inadvertently practicing centration, or the act of focusing on one specific part of a task rather than the task as a whole (Piaget, 1968). Cognitive flexibility allows the student to manage many aspects of a problem and direct their attention to various parts of the task when needed. An aspect of cognitive flexibility known as cognitive shifting/transfer involves how one redirects attention from one stimulus to the next (Moreno, 2011). If this function is done unconsciously it is referred to as task switching.

There are two measurable types of cognitive transfer that we observe when collecting data, near-transfer and far-transfer (Dege, 2017; D'Souza et al., 2018; Schellenberg et al., 2011). Near-transfer involves the transfer of skills from the same domain, whereas far-transfer deals with the transfer of skills from an unrelated domain.

In a musical context, near-transfer occurs within the walls of the band classroom. Students may want to switch instruments within families. While these students may be learning a new instrument/skill, they can utilize the musical abilities they previously learned to develop new skills as well. Far-transfer happens when a skill learned in one area applies to other areas of the students' life. For example, a student may gain leadership skills by playing a solo in their band class which can transfer over to a sports team or school organization that they are a part of.

Cognitive flexibility is a major aspect within childhood development, as children around middle school age are asked to complete problems that are more complex than they were previously asked to do. In musical terms, cognitive flexibility is present when adapting to limitations of a certain musical group and when deciphering musical symbols and ideas. Cognitive transfer helps us to understand our role in a specific musical group at any given moment in a piece of music and adjust our approach quickly based on the various changing musical elements.

One of the most used tests to measure cognitive flexibility in the literature I studied is known as the Stroop Test (Holochwost, 2017). The Stroop Test is a cognitive test where participants are asked to name either a color that is written in word format, or the actual color that the font is. This task is used to measure how quickly participants can switch their focus between differentiating based on color and based on text. The Stroop Test measures both for speed and accuracy of completion of the exercise. In the literature I found relating to cognitive flexibility, four of the five studies used a version of the Stroop test to gather their data.

In my literature I have articles that are primarily focused on the study of cognitive flexibility. These articles typically focus on participants aged 4-9 years old, which is generally younger than the articles studying working memory. James (2020) included a few students that were 12 years old in her study, but the majority of the participants stayed in the range of 4-9 years old. The methods of testing varied significantly throughout the cognitive flexibility section of my literature. The method used the most often was the Stroop test, but other types of tests were used to measure different aspects of cognitive flexibility such as cognitive transfer. I will use one of these other methods to conduct my research, the Trail Making B Test.

Cognitive transfer deals more with the ability of students to translate skills used in one medium to another that differs. Two of my articles discussed how music training affects cognitive transfer. D'Souza (2018) showed significant trends between musical training and extra-musical concepts such as writing, poetry, and visual arts, all of which are forms of far-transfer. The Stroop Test was used in all four of the articles discussing cognitive flexibility and researchers showed trends between private instrumental musical training and an increased ability to decode and decipher information. Based on the information in these articles, I can conclude that in some contexts there are statistical correlations between music training and increased cognitive flexibility.

Inhibition

Inhibition is the executive function that deals with the ability to block out certain stimuli that do not pertain to the task at hand (Holochwost, 2017). This is important in an educational context because school music settings often deal with inhibiting previously learned behaviors. This may mean a concept was learned incorrectly, or the teacher is

adding to information already learned. In a musical aspect, this may be found when a performer inhibits playing a passage, note, or even rhythm incorrectly in favor of playing it correctly. The role of the teacher in inhibitory control is important, as they describe to students what information they already know and what needs to be restricted. Inhibition also affects the way we plan and progress. Without this cognitive skill we would not acknowledge unsuccessful attempts and could not restrict those behaviors to ensure a better outcome in the future. So in many ways, inhibition controls how we manage and direct our goals.

Similar to cognitive flexibility, the most common test used to measure inhibition is the Stroop Test (Holochwost, 2017). However, the relevant results differ between the two executive functions. When measuring cognitive flexibility the Stroop Test shows trends related to switching between tasks, but when measuring inhibition the Stroop Test shows how quickly students can focus on a specific stimulus when conflicting stimuli are present. In many of the articles I read, the Stroop Test was administered in an in-person format. However, for my research I will use an online testing tool to hopefully get more accurate results by eliminating user errors in terms of the time variable.

In my literature I found four articles addressing inhibition (Bugos, 2017; D'Souza et al., 2018; Frischen et al., 2019; Holochwost et al., 2017). The participants in these articles ranged in age from 4-12 years old. Inhibition was typically studied alongside cognitive flexibility. Within the five articles I found, most used the Stroop test to measure both cognitive flexibility and inhibition. However, the data being measured differed between the two executive functions. When testing inhibition, the data typically measured for cognitive flexibility rather than speed of completion. This was because

inhibition focuses more on the ability to overcome cognitive interference that occurs from the presence of both previously learned stimuli, and newly learned stimuli simultaneously. The results of the testing showed that students that had musical experience performed much better on the Stroop test than those that had no musical background (Holochwost, 2017). These results are consistent with the results found in the cognitive flexibility section of my literature review.

Overall, the literature I selected showed contrasting results regarding the impact of a formal music training program on the executive function of students. Many studies have found a correlation between these two areas but have not linked music as the causation. My primary hypothesis predicted that formal music training would increase executive function in middle school students. Secondarily I explored possible effects of the COVID-19 pandemic on students' cognitive development.

Method

Executive functions can be measured in many ways, but I chose activities that fit well into a private setting that could be measured over an extended period. My data was collected during two sessions, a pre-testing period in August and a post-testing period in early November. In the period of time between the pre-testing and post-testing trials students attended daily one hour band classes, excluding weekends. Each student completed the tasks individually with the proctor during the 10-minute testing period.

Participants

Participants were sixth and eighth graders at a local middle school in a rural area in Southeast Georgia. See Table 1 for participant demographics. I originally elected to study younger elementary students between grades kindergarten and second grade, but

later chose to shift to older children due to accessibility. The study included students who were currently enrolled in a band class at a public middle school. The students ranged in regard to their previous musical exposure, but all students received similar classroom instruction over the course of the study.

Measurement tools

My study was composed of three different cognitive tasks that measured the executive functions that I identified. The first executive function participants were tested on, working memory, was measured using the Digit Span Forward task. The second executive function, cognitive flexibility, was measured using the Trail Making B test (See Figure 1). The last executive function, inhibition, was measured using the Stroop Color and Word test (See Figure 2).

Figure 1: *Trail Making B Task*

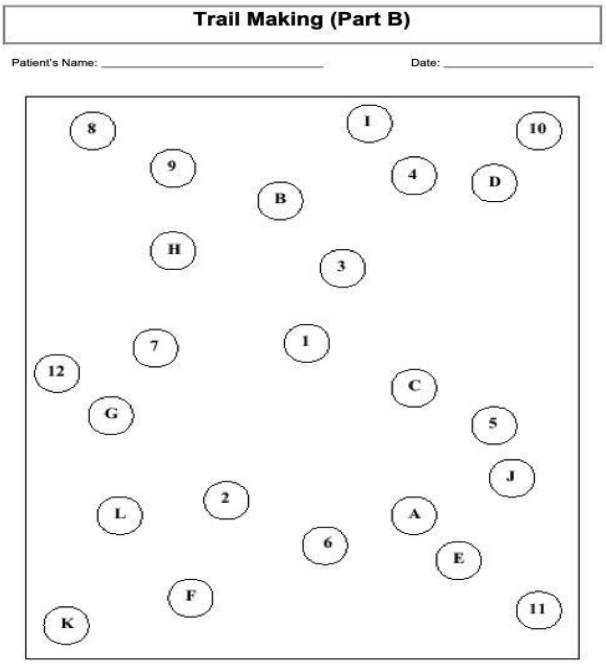
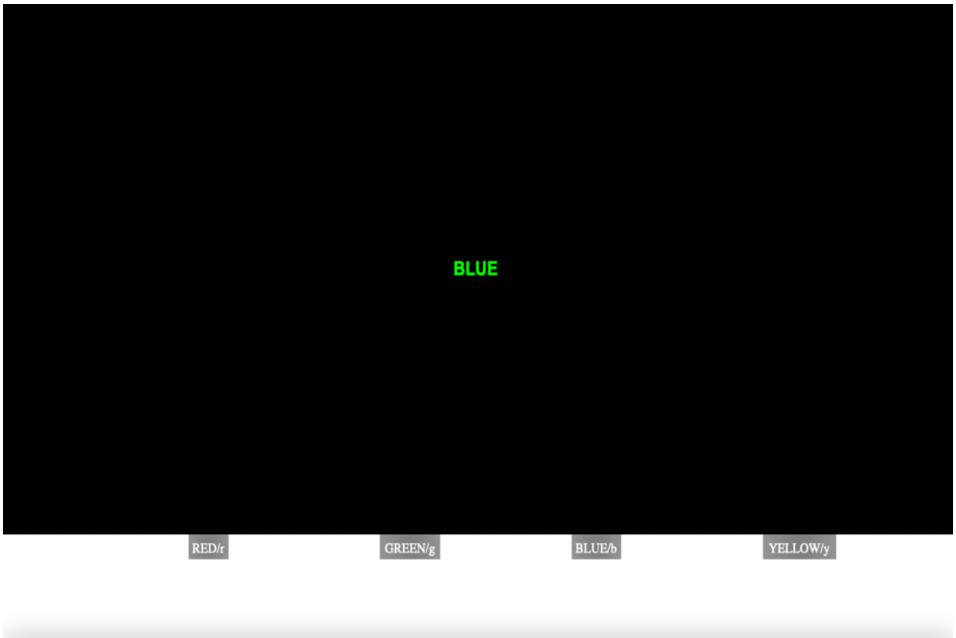


Figure 2: *Stroop Color and Word Test*



The third executive function I tested is working memory in which I used the Digit Span Forward task. The Digit Span Forward task has students listen to a recorded or spoken short list of numbers and repeat them back. This exercise is repeated until the student gets a number in the sequence incorrect. This task will be completed during the same 10 minute pre- and post-testing periods as the other task.

The second executive function I tested was cognitive flexibility in which I used the Trail Making B test. The Trail Making B test is printed on a piece of paper, where students are asked to draw a line connecting a sequence of letters and numbers. The test is measured on speed of completion. This measures cognitive flexibility by having the student rapidly switch their attention between a number list and a letter list. This task asks students to distinguish between the two contrasting stimuli, but also mentally assign pairs from two different lists together quickly.

The Stroop Color and Word test is what I used to measure inhibition. This test was administered electronically with written color names in colored fonts that did not match the text on the screen. The goal of this test was for the students to differentiate the color of the text from the word that was written. The goal of this test was to measure how quickly students could say the word while inhibiting the color they saw. This task was completed in two parts, one part being a congruent trial in which the colors seen match the word written, the other being an incongruent trial in which the colors seen do not match the word written. There was a 10-minute pre-testing period in early August 2022, and a similar 10-minute post-testing period in November 2022.

Analysis

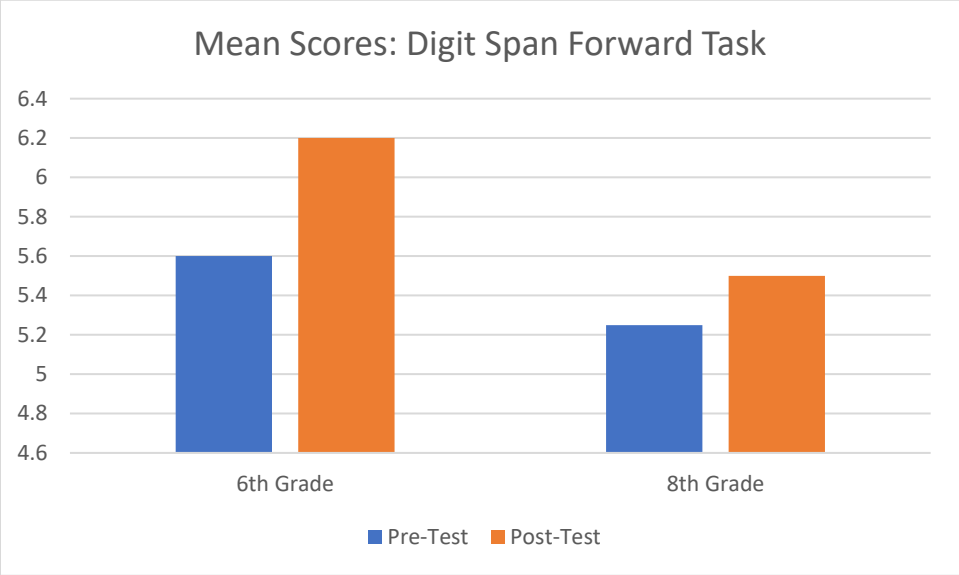
I used descriptive statistics to analyze the results of my study. When conducting my research I compared individual students' pre-test results to their post-test results, and I compared sixth-graders to eighth-graders. These results gave me an idea on how different ages responded to cognitive stimuli, and how music instruction affected different ages of learners differently.

Results

Working Memory

When examining the results of the working memory task I found that both groups of participants improved over the course of the study. The eighth-grade group improved by a total of .25 on their mean score, and the sixth-grade group improved by .6 on their mean score. In total, none of the students in either group got worse at the working memory task. Of the eighth-grade group 75% of them maintained their score and 25% improved on their score. Of the sixth-grade group 40% of them maintained their score and the remaining 60% improved on their score.

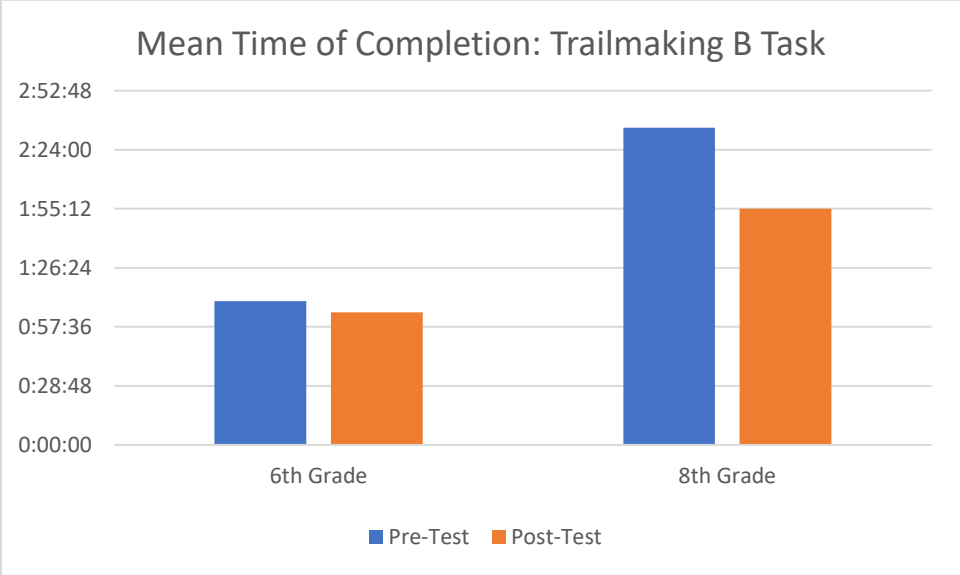
Figure 3: *Mean Scores: Digit Span Forward Task*



Cognitive Flexibility

Similarly to the working memory task, the results of the cognitive flexibility task showed improvements from both groups of participants. All of the students in the eighth-grade group showed an improvement from their pre-test times. This resulted in a much steeper mean decrease in time of completion for the eighth-grade group compared to the sixth-grade group that scored relatively similar to how they did during the pre-testing period. Though the improvement was much less extreme, 60% of the participants in the sixth-grade group showed improvement from their pre-test times.

Figure 4: *Mean Time of Completion: Trail Making B Task*



Inhibition

Table 1: *Mean Time of Completion (ms): Stroop Test*

	6th Grade Congruent	6th Grade Incongruent	8th Grade Congruent	8th Grade Incongruent
Pre-Test	1218.63	2319.25	1325.48	1947.93
Post-Test	1276.56	2416.99	1304.69	1890.69

As stated previously, the Stroop Test measures two variables. The first of these variables is time of completion, which shows us how quickly the students inhibited the information and completed the task. The table above shows the mean time of completion in milliseconds (ms). The sixth-grade group completed both the congruent and incongruent trials at a slower mean time than the eighth grade group. However, the eighth-grade group improved on their mean times from pre-test in both trials.

Table 2: *Mean Scores, Accuracy: Stroop Test*

	6th Grade Congruent	6th Grade Incongruent	8th Grade Congruent	8th Grade Incongruent
Pre-Test	.94	.78	1	.975
Post-Test	1	.90	1	.95

The other variable measured using the Stroop Test was accuracy. While the time variable shows us how quickly students can process information, this variable showed us how well they were inhibiting the information presented to them by selecting the correct answers. In Table 2, the sixth-grade group had improved accuracy when comparing the incongruent pre-test and post-test data. The eighth-grade group remained relatively consistent and accurate at both trials.

Discussion

The primary purpose of this study was to explore how executive functions were affected by involvement in a classroom band program. Secondarily, my study explored the possibility that the COVID-19 pandemic may have affected student's executive functions during the transition from elementary to middle school. Participants were asked to complete three cognitive tasks each measuring a different executive function. I used the information from these results to compare pre-testing results to post-testing results to track for growth. This growth could show a correlation between band classroom instruction and improved executive functions.

When examining the results of my study in regard to my primary hypothesis I found an overall improvement in executive function from pre-test to post-test in both groups of participants. However, the results differed significantly in terms of how each

executive function was impacted by music instruction. Because of this, I believe that students at different stages of development may show increased aptitude at one or many of the executive functions compared to those at a different stage of their developmental process.

The working memory task was designed to investigate how well students could maintain information in their brain for a short period of time. I saw an overall improvement on the mean scores for both groups of participants from the first testing period to the second. Because this task is measured solely on accuracy, I can hypothesize that the instruction they received between pre-test and post-test improved their working memory executive function. However, because participants are students from a public school and they were exposed to stimuli from other classes during this time, we cannot justify that band instruction was the only factor on cognitive maturity. These results are similar to those found by Dege (2017), which showed an improved verbal memory in students that received a formal music training, which she accredited to their increased verbal rehearsal mechanism.

The Trailmaking B Task measured cognitive flexibility and tracked how quickly students could cognitively switch between a number list and a letter list. The results of this task were very similar to that of the working memory task. Both groups showed improvement from pre-test to post-test. The eighth-grade group had a much more drastic improvement between trials, showing an almost 40 second mean improvement on their times. The sixth-grade group also improved, but their scores were more consistent between testing times. Moreno (2011) found that cognitive flexibility was explored on

more of a far-transfer level. My research aimed to provide clarity to how music training might affect cognitive flexibility in more of a near-transfer effect.

The Stroop Test was used to measure inhibition. It tracked two variables, the speed at which the participant completed the task and how accurately their responses were. The findings for this task were more complex than those of the other two tasks. In both other executive function tasks, both groups of participants improved from the first trial to the second. However, on the Stroop Test the eighth-grade group improved on their speed of completion whereas the sixth-grade group got worse. In regard to accuracy the eighth-grade group maintained their scores from the initial trial, and the sixth-grade group improved on their scores significantly. With this result I hypothesize that the participants in the sixth-grade group learned that if they went slightly slower on the task that they could get more of the answers correct.

My study consisted of a pre-testing phase, two months of instruction, and a post-testing phase. During the three months of instruction students were exposed to similar classroom music instruction daily. However, during this time they also took other educational classes and electives, so it is hard to pinpoint if music was the direct cause of increased executive functions. In future research, studies may need to be modified to determine if music training was the sole factor in cognitive maturity, or if other factors influenced the data as well.

My secondary purpose was developed after the pre-testing trials in which I found results showing superior cognitive abilities in the sixth-grade group before treatment compared to the eighth-grade students. I believe that these results may be because of the COVID-19 pandemic. The eighth-grade group was transitioning from elementary to

middle school during the pandemic, and so decreased executive functions could be the result. I believe that further exploration of this topic could prove fruitful.

Implications for Music Education

The findings from my study could have lasting implications for the music education profession. First, I want to acknowledge that playing an instrument and participating in a school band are fun activities. However, our music classes are often sacrificed at the expense of other school programs. I hope to show through my findings that music is beneficial beyond amusement and pleasure. Rather it is an engaging task that can help students develop key cognitive skills that they can use in other areas of their lives. Second, I hope to provide the parents of students that are of a developmental age with some ideas on how to better understand the developmental process. My research shows that certain stimuli may improve executive functions in the brain. I hope that with further research, parents can work alongside their students to find classes that may help their students to develop at an appropriate rate. Lastly, I hope that with as a result of my research students can better understand the importance of learning a specialized skill and take the initiative to practice these skills for the betterment of their own cognitive abilities.

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APPENDIX A: Digit Span Forward Test

Instructions to the Experimenter

You should have in front of you a sheet headed Lists for Digit Span Determination. You will see that lists are arranged in sets, those in each set being of the same length, the lists becoming progressively longer as you work down the page. In each set, there are nine lists, but that is to allow for the possibility of interruptions. The subject will receive only six lists for the actual determination of span.

Say to the subject that you are going to read them lists of digits, and that they are to try to repeat the digits **in the order in which they were read out**. If the subject seems unclear about what is required, go through an example, say, the list: 4, 7, 1. Read the digits in an even tone, at approximately the rate of **one digit per second**.

The subject should be tested on six lists, starting with length 2. Read out the digits at the rate of one digit per second. In the space provided, put a tick if the subject repeats the list correctly, and a cross if they do not. If the subject gets at least five out of the six lists correct, proceed to the lists in the next set. Continue this procedure until the subject gets two lists from the set wrong. At the bottom of the page, enter the subject's Digit Span as the **maximum length of the lists of which the subject recalled at least 5/6 correctly.**

List	Result (√ or ×)	List	Result (√ or ×)	List	Result (√ or ×)
For Span = 2					
83		54		27	
28		37		91	
68		96		87	
For Span = 3					
829		687		871	
132		356		251	
152		637		915	
For Span = 4					
6241		1372		5316	
2359		7392		4815	
7132		6539		1872	
For Span = 5					
84132		85293		79514	
62143		91635		82691	
97438		16592		75468	
For Span = 6					
587261		492617		148239	
261384		247681		423896	
632147		429735		641357	
For Span = 7					
2941378		6297865		1897562	
1285394		8243167		3185624	
8693735		3945782		2473961	
For Span = 8					
65148279		28653197		85729136	
18472913		65792381		76591243	
42785921		74529638		76921358	
For Span = 9					
679174382		239874615		539748216	
746231958		867934612		513985267	
398724615		794831265		231986734	
For Span = 10					
4982176453		2853967624		2914984357	
5731298426		9781734826		6983285149	
8182397465		8491287637		6391727362	