Effects of Music Training on Auditory Memory

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Abstract

A multitude of studies have examined the effects of music expertise on cognitive development. In the present study, the effects of music training on auditory working memory was conducted on 50 high school students (ages 14-18) in the United States. A set of 25 students had been enrolled in a music training program for at least 5 years, while the other set had received no music training. The auditory working memory was measured via the Forward and Backward Digit Span Test and results revealed superior performance in the musician group compared to the nonmusician group. Therefore, it was concluded that music training exerts a major influence on the development of auditory working memory.

Keywords: Auditory memory, working memory, music training, intelligence, cognitive

Introduction and Literature Review

The field of research concerning the effects of receiving music training on cognitive function has been thoroughly investigated all around the world. A multitude of researchers have examined the effects of music training in young children, adults, and older populations, in which the majority of experiments have focused on mental functioning. A myriad of studies focused not only on the effects of music training on music-related stimuli such as the ability to detect mistuned notes, but also on general cognitive processes. Since the late 1900s, the effects of music experience on brain function, specifically with working memory, have been increasingly investigated. Working memory is defined as the retention of limited amounts of information that can be held temporarily; there are two types — auditory and visual spatial working memory (Lehnert et al., 2006). For the purpose of narrowing the scope of this research paper, only one will be addressed—auditory memory.

To date, there has been controversy over whether or not music helps with auditory memory. Bastiaan Boh, a researcher with a PhD in psychology conducted a study on the effects of long-term musical training on auditory processing patterns in adults and found that musicians consistently expressed an enhancement of the ability, compared to nonmusicians (Boh et al., 2011). However, contrary to Boh's study, Nadine Helmbold, a researcher at the University of Goettingen, found no difference in the capability of auditory memory in adults with musical training and those without (Helmbold et al., 2005).

Investigating the effects of music on auditory memory is a continuing inquiry and despite doing extensive research in this field, the existence of studies that examined the effects of music training on teenagers were far too little. Plenty of studies were conducted on adults and young children, but teenagers seem to be excluded from this conversation, thus exposing the gap. In one of many examples, the pattern of omission can be seen in a clinical research led by Alexandra Parbery-Clark, as she recruited only adult participants from ages 19 to 31 (Parbery-Clark, 2009). On the other hand, a similar research conducted by Takako Fujioka, an associate professor at Stanford University, focused her research on a younger age group that ranged from 4 to 6 years of age (Fujioka, 2006). As a researcher, it is important to realize that trends that have occurred in adults or children does not mean that the same patterns will be prevalent in teenagers. For that reason, the following question was raised: To what extent does the enrollment in a formal music education program impact auditory memory in teenagers ages 14-18?

A key aspect of this field of inquiry is how music training plays a role in the brain's ability to process auditory information. During the music-learning process, sound is analyzed and the pitch is adjusted accordingly, facilitating their auditory processing in the brain by the high demands of listening-attentiveness, leading to a superior auditory memory compared to the average person. Furthermore, neurophysiological notions have stimulated research in this area. Larry Vandervurt found that music training alters the brain by recruiting the prefrontal cortex to the temporal structure, enhancing the retrieval of auricular information and thus working memory (Vandervurt, 2015). Similarly, Sylvain Moreno, an assistant professor in the Department of Psychology at the University of Toronto, established that music training demonstrated brain plasticity because it completely reorganized the functional capacity of the brains of children who played instruments compared to those who did not (Moreno et al., 2009), supporting the idea that music training can exert a major influence on the structure of the cerebrum and thus its function.

The assessment of auditory memory and its correlation with higher-level cognitive abilities has implications to academic success, as revealed in a study led by Carolos dos Santos-Luiz. He found that students learning music performed better in language and science classes, compared to students who did not learn music (Santos-Luiz, 2016). Similarly, psychologists also believe that auditory memory plays a valuable role in the acquisition of literary skills, especially since the lack of auricular ability is correlated with literacy difficulties, such as developmental dyslexia (Gathercole, 2004). These studies suggest that individuals with music instruction may be more likely to be academically successful compared to their peers, further highlighting the importance of improving auditory memory from a younger age through music training.

The present research aims to address the question, “To what extent does the enrollment in a formal music education program impact auditory memory in teenagers ages 14-18?”. The experiment will be carried out using Timo Denk’s Online Digit Span Test, which consists of two sections: the Forward and Backward Digit Span Test. It requires the participant to successfully recite a sequence of numbers presented, with increasingly longer sequences being tested. Although superficially very similar tasks, the simpler forward digit span test requires auditory memory and attention, while the backward digit span test additionally tests cognitive control. I hypothesize that due to constant training of the brain’s auditory processes, musicians will outperform their nonmusician counterparts in the forward and backward digit span test. To test the hypothesis, 25 teenage musicians and 25 teenage nonmusicians will take the online digit span tests and their scores will be used to determine whether music instruction has an effect on the auditory working memory. The importance of this research lies in the fact that children and teenagers may benefit tremendously if there is a correlation between receiving music education and having a superior auditory memory, as it not only correlates with greater cognitive abilities, but also higher academic achievement.

Methods

Setting

The location of the experiment was conducted at the [redacted] Public Library because libraries are an academic-centered establishment and are quiet in nature. Study rooms were booked in advance to provide a space with very minimal distractions which is optimal for participants, as it allows them to perform at their full potential. Librarians were also present to supervise the study. Additionally, this setting was selected based on convenience, as it was located only 400 feet away from [redacted] High School. This proximity allowed for the ease of students to travel to and from the destinations before and after school.

Study Population

From December 10th, 2022, to February 15th, 2023, 50 participants ages 14-18 were recruited from [redacted] High School, in which 25 have been enrolled in a formal music education program for at least 5 years and another set of 25 participants who have not. The criteria to be included in the “musicians” group was that the participant had to be playing their instrument through a formal musician education program, which is a type of formal instruction given by professionals that are specialized in that particular instrument, for at least 5 years. The requirement to be included in the “Nonmusicians" group was that students could not be currently enrolled in a music education program and they could not have had more than one year of formal musical training prior to the date of the study. Students who did not fit into this criteria were excluded from the experiment.

Recruitment Strategy

For the recruitment of musicians, orchestra and band students were invited to participate in the study and recruitment posters were posted in core-academic classrooms—English, Science, and History—to recruit other musicians that were not involved in the school's performing arts. For the recruitment of nonmusicians, posters were posted in the classrooms of core subjects—English, Science, and History—with the permission of the teachers. This method of recruitment was successful, as the goal of recruiting 50 participants and testing their auditory memory was achieved in less than 2 months.

Ethics

The experiment's design was approved by the high school Ethics Review Committee to ensure that appropriate ethical standards were met. For the subjects, consent forms must have been signed by the participants and their legal guardians before proceeding with testing. This ensures individuals received a thorough understanding about what this research was focused on and had a decision about whether or not they wanted to participate. Additionally, participants had the option of dropping out of the study at any time during the duration of the experiment.

Study Design

A quantitative research design was adopted to produce statistics for the purpose of being able to draw conclusions and justify the findings, which are essential for providing data that can be easily communicated to the audience.

Agnes Chan, who holds a doctoral degree in clinical neuropsychology, studied the effects of music training on adults and assessed their auditory memory using a word-based test (Chan, 1998). As a student, the qualifications for administering this word auditory memory test was not met, so it was determined that an online platform would be used that doesn't require a formal administrator.

After searching the web, it was ultimately decided that the data for this study would be collected using Timo Denk's Online Digit Span Test, in which approval to use the instrument was granted by the creator, Timo Denk. The use of this tool allows for a uniform experience for the participants, as the test is carried out through digital means. This way, results can be obtained in a precise, reliable manner, thus producing dependable results without altering participants' performance due to a flaw in the methodological process.

Procedure

Testing took place in one of the study rooms at [redacted] Public Library, which provided a testing experience with minimal distractions, which were booked ahead of time.

Participants were asked a series of questions about their name, age, and number of years of formal music training, if applicable. This information was then recorded on a digital data log, except their names, which were recorded on a separate document with restricted access in order to secure their personal information.

Next, a set of instructions were read aloud:

"You will be taking two Online Digit Span Tests: one forward recitation and one backward recitation. In the forward recitation, you will hear a sequence of numbers and will be required to recite the numbers back in the correct sequence, with increasingly longer sequences being tested. In the backward recitation, you will hear a sequence of numbers and will be required to recite the digits in the reverse sequence, with increasingly longer sequences being tested. You are not allowed to ask for the numbers to be repeated again. The test ends when you fail to recite the sequence correctly. Your score is based on the highest number of sequences you were able to recite with no mistakes."

The testing began after setting up Timo Denk's Online Digit Span Test. The setting was set to the Forward Digit Span test at a rate of 1000 milliseconds per digit, with a starting sequence of 2. The participant was reminded that the first test was going to be the forward digit span test.

After clicking on the start button, the computer recited the digits and the participants recalled them back, as the researcher typed in the recalled sequence into the computer. If the sequence was correctly recalled, then the participant moves onto a longer sequence, but if it was incorrect, their testing for the forward digit span ends. The scores were based on the maximum number of digits they were able to recite correctly, which were then recorded on the data log.

After the administration of the forward digit span test, the backward digit span test began. The participants were reminded that the backward digit span test would be carried out next. The researcher changed the settings to the Backward Digit Span test, but still maintained the 1000 milliseconds per digit, with a starting sequence of 2. After clicking on the start button, the computer recited a sequence and the participants recalled them in the reverse order. After the participants achieved their capacity of the sequence they could recall, their scores were recorded on the data log.

Generally, with the data obtained from the participants, unpaired t scores are calculated to compare the means of the two groups using the following formula:

$$t = \frac{(x_1 - x_2)}{\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}}$$

X_1= Average Musician score
X_2= Average Nonmusician score
S_1= Standard Deviation of Musician scores
S_2= Standard Deviation of Nonmusician scores

Then, the t scores would be translated to p-values using the t-score table in order to see how the groups compared with each other.

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073

However, in order to avoid calculation errors and to obtain a more precise p-value, the Statistical Analysis Tool from Google Sheets was utilized. This was done by entering the raw data, which were the test scores, into two columns based on whether that score came from a musician or nonmusician. Then, the raw data was converted into a p-value by executing the following steps: First, click on Insert and find Function. Next, click on Statistical and find T-TEST. Click on T-TEST and the p-value would be outputted.

F25 fx 8

	A	B	C
1	Musicians	Nonmusicians	
2	7	9	
3	8	7	
4	6	9	
5	8	8	
6	8	8	
7	9	6	
8	11	8	
9	10	7	
10	7	7	
11	8	8	
12	9	7	
13	5	6	
14	8	6	
15	6	9	
16	7	8	
17	8	7	
18	8	9	
19	8	8	
20	10	6	
21	9	7	
22	8	6	
23	8	7	
24	9	7	
25	7	8	
26	7	5	
27		0.03579826193	

This calculation of the p value would numerically determine whether or not the difference in scores between the musician and nonmusician group is statistically significant. The significance level was based on a 0.05 level, meaning that only a value equal to or less than 0.05 indicated that the observed outcome would be strongly unlikely under the null hypothesis. In other words, the contrast in test scores for the musicians and nonmusicians group will only be significant if the p-value from the data sets came out to be less than 0.05.

Results

The purpose of the experiment was to answer the following question: To what extent does the enrollment in a formal music education program impact auditory memory in teenagers between the ages of 14-18? Participants of the study were divided into two groups—musicians

and nonmusicians—and Timo Denk's Online Digit Span Test was administered which consisted of two parts: Forward Digit Span Test and Backward Digit Span Test. The score was determined by the maximum number of digits the participant could recall in the correct sequence.

Unlike other studies, which focused on adult participants, the mean age of both groups of participants in the present study was 16.56 years old. The musicians' minimum and maximum duration of music training was 5 years and 13 years, respectively, while the mean was 7.4 years (Standard Deviation: 2.06). As a result of the age gap, the length of music training for musician subjects was lower compared to other studies (11.5 years-Jakobson et al., 2008; 23.0 years-Rodrigues et al., 2014; 17.3 years-Anaya et al., 2017).

In line with a similar study conducted by Susanne Brandler, in which she found music training has beneficial effects on auditory memory, the results of the Forward Digit Span Test for this experiment, as shown in Table 1, revealed musicians scored significantly higher than their nonmusician counterparts (Brandler et al., 2003).

Table 1 **Forward DST**	Mean Score	Standard Deviation	Significance
Musicians	7.96	1.34	p=0.036
Nonmusicians	7.04	1.11	

Description: Table 2 depicts the musicians and nonmusicians' mean score and standard deviation for the Forward Digit Span Test, along with the statistical significance, which is based on a significance level of 0.05.

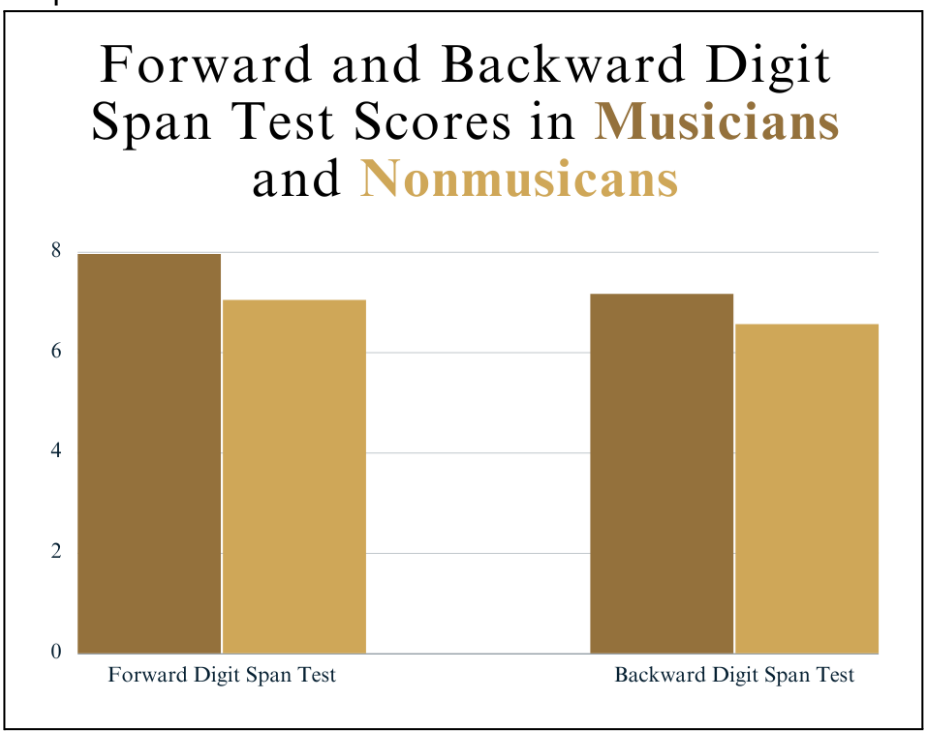
Interestingly, most studies did not report a significant difference between musicians and nonmusicians when it came to the scores of the Backward Digit Span Test. For example, Francesca Talamini, who investigated the working memory in musicians and nonmusicians by using the Backward Digit Span Test, discovered participants with music training scored equivalent to those without music training, suggesting that the capacity of the central executive memory is similar between the test subjects (Talamini et al., 2016). However, in contrast to Talamini's study, musicians in this study outperformed nonmusicians significantly (p=0.021) in the administration of the Backward Digit Span Test (See table 2), implying the need for more research in order to confirm the accuracy of the results.

Table 2 **Backward DST**	Mean Score	Standard Deviation	Significance
Musicians	7.16	0.99	p=0.021
Nonmusicians	6.56	1.04	

Description: Table 3 depicts the musicians and nonmusicians' mean score and standard deviation for the Backward Digit Span Test, along with the statistical significance, which is based on a significance level of 0.05.

The present study confirmed the findings about the impact of receiving music training on auditory memory in teenagers, and thus helped to fill a gap in the field of research, as there had not been previous studies that focused on youth ages 14-18. The data presented findings that were both in line and contrary to previous research, indicating limitations within the studies were present, such as having a small sample size, which runs a greater risk of false positives and negatives, as it is unrepresentative of the whole population.

Graph 1



Description: Graph 1 shows the comparison of the mean score for the Forward and Backward Digit Span Test in musicians and nonmusicians.

Discussion

The current study was designed to determine the effect of music training on auditory memory in teenagers by using Timo Denk's Online Digit Span Test. Results revealed that there is indeed a correlation between receiving music training and scores in auditory memory. The most important clinically relevant findings were the significant contrast between scores in the forward and backward digit span test when comparing musicians and nonmusicians. The results were unanticipated because no studies found statistical significance (based on a significance level of 0.05) in both tests; the majority found statistical significance in only one of the two tests.

Previous studies presented mixed results, as some found major contrast in the forward digit span test (e.g. Hansen et al., 2013; Arco, 2019; Saarikivi et al., 2019), while others in the backward digit span test (e.g. Talamini et al., 2016; Ding et al., 2018; Guo et al., 2018). Interestingly, although the current experiment found a strong correlation between enrollment in a music education program and scores in the forward and backward digit span test, no outside studies found statistical significance in both tests. In around half of the studies, researchers were able to obtain statistically significant findings that supported the idea that musically trained

individuals score higher on only the forward Digit Span Test. One particular study conducted by Nicole Arco found strong evidence supporting the current finding that music trained people outperformed their untrained peers in the forward digit span test (Arco, 2019). Arco found the p-value for the forward digit span test to be 0.012 on a 0.05 significance scale, but did not find statistical significance for the backward digit span test. On the other hand, a similar study led by Yue Ding found no notable difference in performance of the forward tonal span test between musicians and nonmusicians, but found a significant discrepancy on the scores in the backward tonal span test (Ding et al., 2018).

Although prior findings have been inconsistent with each other, the present research confirms the association between receiving music training and the development of auditory processing skills. The explanation of the results could be attributed to the music-learning process, in which sound is analyzed and the pitch is adjusted accordingly, facilitating their auditory processing in the brain by the high demands of listening-attentiveness, leading to a superior auditory memory compared to the average person.

Musicians constantly use their working memory, which includes both visual and auditory memory, when they read sheet music, memorize pieces, learn to play by ear, and play in an orchestra. Especially when learning to play by ear, the brain is functioning at full capacity. Not only does the action rely on the individual's capability to store auditory information, but also to retain the music and then reproduce it, shedding light on how music stimulates the brain's processes. Additionally, in ensemble playing, not only do musicians have to listen to themselves, but also to others and be able to respond to those changes. The ability to segregate the stream of sound produced by oneself and others require high demands of attentiveness to what is being heard. Therefore, it is feasible to conclude that music training can exert a major influence on the maintenance of auditory memory, which may impact performance in working memory tasks, specifically the Digit Span Test.

The contrasting findings when comparing the current study to prior ones suggest that more research is needed to conclude the accuracy of the results. However, the combination of findings has important implications for developing auditory memory, which helps individuals by enhancing their critical listening, thinking, and comprehension skills (Saarikivi, et al., 2019). It is especially an important skill to develop because auditory memory plays a major role in the ability to carry out instructions. Therefore, strategies to improve Auditory Processing Disorder (APD), a disability characterized by weakness in auditory memory, might include being enrolled in a music education program. Dr. Tanja Linnavalli claims music training has the ability to strengthen the basic brain mechanisms that can contribute to not only improvement in auditory working memory, but also phonemic awareness and the understanding of language (Linnavalli et al., 2018). Currently, hundreds of thousands of children struggle with APD, but if future research could elucidate the correlation between the enrollment in a music education program and improvement in auditory memory in people with APD, those struggling with the disorder can gain benefit socially and academically.

Conclusion and Limitations

The objective of the present research was to determine whether music training has an effect on auditory memory by administering Timo Denk's Digit Span Test. Although data gathered from the study proved that there is indeed a correlation, contrasting findings when comparing the current study to prior ones suggest that more research is needed to conclude the accuracy of the results.

A limitation of the current study could include not having a baseline score prior to receiving music training. For example, these two groups may have had pre-existing differences, instead of developing the contrasts as a consequence of being enrolled in a music education program. For example, a piece of literature suggested that children who engage in music lessons already begin with having differences from those who are not interested in taking lessons (Schellenberg, 2015). Such examples include children with greater phonological awareness that would drive them to enroll in music classes. However, further research is needed to fully grasp the relationship between how pre-existing variables contribute to auditory memory ability. The choice of not measuring baseline scores (scores before receiving music training) was taken to minimize the length of the experiment because longitudinal studies have higher risk of participants that drop out.

Additionally, having an insufficient sample size (50 participants) could inaccurately represent the population as a whole, so caution should be applied when the results are extrapolated. Nonetheless, data from the current study is key information that advances the field of the research, but looking forward, further attempts could prove beneficial to literature in order to elucidate the correlation between receiving formal music training and auditory memory ability.

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