HIGH SCHOOL EDITION
Journal of Student Research

Volume 14 Issue 1 (2025)

Evaluating the Impact of Music with Different Tempos on Memory Recall Among High School Students

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ABSTRACT

Music is known to have effects on the brain. With the prevalence of music streaming services today, it is essential to investigate the potential relationship between music and cognitive performance. However, while the effect of classical music on the brain, the so-called Mozart Effect, remains arguable, the effect of music tempo on memory recall performance is poorly understood. In this study, we evaluated the impact of music with various tempos on the memory recall ability among a cohort of high school students. Participants were first exposed to music of varying tempos or silence for 10 minutes and then engaged in a memory recall task. Our results show there is a statistically significant difference in the effects on memory performance between fast-tempo music and slow-tempo music (or no music at all) ($p < 0.05$). Compared with slow-tempo music, fast-tempo music also largely increased the participant's arousal level ($p < 0.001$). Taken together, our results indicate that faster-tempo music tends to enhance the listener's memory recall ability.

Introduction

Music streaming services have become more prevalent today. With how easy it is to play music whilst completing other tasks, it is no surprise that people have started wondering about the relationship between music and studying. Many studies have been performed regarding the music genre and its effect on the mind. It is arguably recognized that classical music, especially Mozart, leads to increased cognitive performance (Lehmann et al., 2017). In one of their studies, Rausher, Ky, and Shaw (1993) found that listening to Mozart for 10 minutes had a short-term but direct effect on intelligence and absorption of information. In this study, students who listened to 10 minutes of Mozart before an assessment (So-called "Priming") performed better than those who sat in silence or listened to calming instructions before the assessment was given to them. However, others have doubted the validity of the Mozart Effect and instead put forward the Arousal-Mood Hypothesis (Husain et al., 2002). This hypothesis argues that what affects cognitive performance is the change in mood and arousal that results from listening to music. Arousal refers to the level of excitement or emotional intensity felt whilst experiencing something, and mood refers to the adjectives that describe feelings, such as *sad* or *happy*, which is often influenced by the key of the piece.

A common belief is that music with lyrics is too distracting when working on non-repetitive tasks, hence the idea that classical music is the best for studying. When investigating how music genre affects studying capabilities, classical music has been seen to be more beneficial in comparison to songs with lyrics, but there was not a significant difference between silence and listening to music (Bugter and Carden, 2012). However, Bugter and Carden questioned whether differences in tempo might have caused the difference in test performance instead. To pursue this premise, we investigated the potential impact of music tempo on memory recall performance in high school students, a population that are actively using music streaming services while studying. We hypothesized that participants exposed to fast-tempo music would demonstrate better memory recall abilities compared to those exposed to slow-tempo music or silence. In our study, participants (high school students) were randomly assigned to three groups: while the control group was exposed to no music (silence), another two groups were exposed to fast-tempo and slow-tempo Mozart for 10 minutes, respectively. Both fast-tempo and slow-tempo pieces were from Mozart's Piano Sonata No. 7 in C Major.

To evaluate their cognitive short-term ability, the participants then watched a video of words appearing in 1.5-second intervals and were asked recall as many words as possible in a minute after the video was over. Participants who listened to music were further asked to score themselves on a Self-Assessment Manikin (Lang, 1993) to quantitatively evaluate their arousal level. Our results showed that listening to fast-tempo music while studying significantly improved the participant's memory recall (in comparison with no music) while listening to low-tempo music had little impact. In addition, listening to fast-tempo music led to a higher level of arousal than listening to slow-tempo music.

Materials and Methods

Participants

The subjects were students from Dublin Coffman High School, Ohio. Students were recruited from free-period classrooms, the cafeteria, and study halls. Students were informed of the activities of the study and gave oral consent before participating. Participants were then randomly assigned to one of three groups (No Music, Slow Tempo Music, and Fast Tempo Music) using a random number generator. No personal or easily identifiable information was released or collected.

Assessment and Measurement

Participants assigned to the Fast music or Slow music groups were given Wireless *Bluedio* T-Monitor Turbine headphones and listened to music for ten minutes. The music volume was kept constant for all participants, at a volume of seven button presses up from zero. Those in the Fast Music group listened to the third movement of Mozart's Piano Sonata No. 7 in C Major. The Slow Music group listened to the second movement of the same piece. While the fast music was at a tempo of 210 beats per minute, the slow music was at a tempo of 50 beats per minute. During the listening phase, participants were allowed to move around or study as long as they didn't go on their phones. They were also asked not to interact with people during the entire listening phase. After the listening phase, participants went on to the testing phase. Students in the No Music group started in the testing phase.

During the testing phase, participants were shown a video that flashed fifteen words onto the screen in one-and-a-half-second intervals. After the video was over, they were given one minute to recall as many words as they could. They were encouraged to write down all the words that came to mind, even if these words might be incorrect. If the participant listened to music during the listening phase, they continued to listen to the same music during the testing phase.

After the one-minute recall period was over, participants were given a survey to record their grade, sex at birth, favorite music genre, study habits, and Self-Assessment Manikin (SAM) scoring on their arousal status (1, calm; 2, dull; 3, neutral; 4, wide-awake; 5, excited). (Bracken et al., 2000) The number of words they recalled correctly and the number of words they wrote down were also recorded. The maximum number of words they could get correct was 15.

Data Analyses

Due to the exploratory nature of this study, a sample size to achieve a predetermined power was not required. Data was first presented as descriptive statistics. In brief, categorical data was presented as count (n) and frequency (%); continuous variables were summarized as mean (standard deviation, SD) or median (range) where appropriate. Categorical data was compared using Chi-Square or Fisher's Exact Test, and continuous variables were compared using one-way ANOVA (analysis of variance) with Dunnett multiple comparison adjustment (the group without music was the control) or Student's t-test. Cohen's *d* value, the difference in means / composite standard deviation, was used to assess the impact of music on the memory recall ability as following: Cohen's $d < 0.2$, small or minor impact; Cohen's d between 0.2 and 0.8, moderate impact; Cohen's $d > 0.8$, strong impact. (Cohen 1992) Potential associations between the SAM score and the number of words written, between the SAM score and the number of words written correctly were investigated using Pearson's correlation analyses. All statistical tests were two-sided, and the significance level was 0.05. Microsoft Excel Analysis Toolpak (Add-In) was used in this study.

Results

Demographic Characteristics of Participants

In the current study, 42 high school students were tested to evaluate impact of music tempo on memory recall performance after exposure to fast-tempo music (n = 15), slow-tempo music (n =11), and silence (no music, n = 16) (Table 1). Most students were juniors (23/42, 54.8%) and seniors (11/42, 26.2%), while the numbers of students at 9th grade and 10th grade were 2 (4.8%) and 6 (14.3%), respectively. More female students than male students participated in this study (26/42, 61.9% *vs* 16/42, 38.1%), and 54.8% (23/42) of participants were currently learning an instrument or part of some other musical ensemble. Moreover, most participants listened to music during studying frequently (24, 57.1%) or occasionally (13/42, 31.0%), and only 11.9% students (5/42) did not. The favorite music genre of all participants was rather diverse, including Hip Hop, Pop, classical, indie, R & B, Rock, country, jazz, film soundtrack and instrumental music, and the top three choices were Pop (19/42, 45.2%), R & B (7/42, 16.7%), and Hip Hop (9.5%).

Table 1. Comparisons of demographic and cognitive characteristics among participants

Characteristics	**No music group (n = 16)**	**Slow music group (n = 11)**	**Fast music group (n = 15)**	***p* value***
Grade				0.40[a]
9th	2 (12.5%)	0 (0%)	0 (0%)	
10th	2 (12.5%)	0 (0%)	4 (26.7%)	
11th	8 (50%)	7 (63.6%)	8 (53.3%)	
12th	4 (25%)	4 (36.4%)	3 (20%)	
Sex at birth				0.32[a]
Female	12 (75%)	5 (45.5%)	9 (60%)	
Male	4 (25%)	6 (54.5%)	6 (40%)	
Favorite music genre				0.58[a]
Hip Hop	1 (6.3%)	2 (18.2%)	1 (6.7%)	
Pop	7 (43.8%)	4 (36.4%)	8 (53.3%)	
R & B	1 (6.3%)	3 (27.3%)	3 (20%)	
Classical	1 (6.3%)	1 (9.1%)	1 (6.7%)	
Other**	6 (37.5%)	1 (9.1%)	2 (13.3%)	
Listening to Music during studying				0.009[a]
No				
Yes	2 (12.5%)	3 (27.3%)	0 (0%)	
Sometimes	5 (31.3%)	7 (63.6%)	12 (80%)	
	9 (56.2%)	1 (9.1%)	3 (20%)	
Playing music instruments				0.85[a]
No	3 (18.8%)	4 (36.4%)	3 (20%)	
Yes	10 (62.5%)	5 (45.5%)	8 (53.3%)	

Used to but quit	3 (18.8%)	2 (18.2%)	4 (26.7%)	
Words written during test				0.009[b]
Mean (sd)	6.8 (2.0)	6.6 (2.1)	8.7 (1.7)	
Median (range)	7 (4, 11)	6 (4, 11)	9 (5, 11)	
Words correctly written during test				0.022[b]
Mean (sd)				
Median (range)	5.9 (1.8)	5.6 (2.2)	7.5 (1.6)	
	6 (3, 10)	6 (2, 9)	8 (4, 9)	
Correct word percentage (%)				0.69[b]
Mean (sd)	88.2 (12.6)	83.7 (17.7)	86.6 (10.4)	
Median (range)	86.6 (60, 100)	81.8 (50, 100)	88.9 (60, 100)	
SAM score				<0.001[c]
Mean (sd)		1.4 (0.7)	3.3 (1.2)	
Median (range)		1 (1, 3)	3 (1, 5)	

sd, standard deviation; range, from minimum to maximum.
*All statistical tests were two-sided, and the significance level was 0.05.
**Other included indie, rock, country, film soundtrack, jazz, and instrumental music.
[a]Fisher's exact test was used.
[b]One-way ANOVA (analysis of variance) was used.
[c]Unpaired Student's t test was used.

There are no statistically significant differences among these three testing groups in grade ($p = 0.4$), sex at birth ($p = 0.32$), favorite music genre (p =0 .58), and whether the participants were currently leaning an instrument or part of some other musical ensemble ($p = 0.85$). for the preference on listening to music during studying, there trended to be fewer students listening to music frequently during studying in the No Music group (5/16, 31.3%) than in the Slow Music group (7/11, 63.6%; $p = 0.13$) or in the Fast Music group (12/15, 80%; $p = 0.056$).

Evaluating the Memory Recall Ability

Among all participants (n = 42), the average number of words recalled (written down) in the testing was 7.4 (SD = 2.1) with a median of 7 (minimum = 4, maximum = 11). In comparison, the average number of words recalled correctly in the testing was 6.4 (SD = 2.0) with a median of 6 (minimum = 2, maximum = 10). As for the recall correctness, i.e. the percentage of correct words out of written words, the average percentage of correct words (out of recalled word) was 86.4% (SD = 13.2%) with a median of 87.5% (minimum = 50%, maximum = 100%).

As shown in Table 1, there is a statistically significant difference in the number of words written among these three groups ($p = .009$), and groupwise comparisons showed that the average number of words written in the Fast Musci group, 8.7 (SD = 1.7) was statistically significantly higher than the corresponding average number in the No Music group, 6.8 (standard deviation = 2.0) ($p = 0.013$) (Figure 1A). In contrast, the average number of words written in the Slow Music group, 6.6 (SD = 2.1), was almost identical to that in the No Music group ($p = 0.98$). Furthermore, the Cohen's d value of the change in the number of words written between the Fast Music group and the No Music group was 1.07, indicative of a strong impact of fast music on memory recall ability. In comparison, there is no impact of slow music on memory recall ability as evidenced by the Cohen's d value of 0.06 between the Slow Music group and the No Music group.

Similarly, there is a statistically significant difference in the number of correct words among these three groups ($p = 0.022$). As shown in Figure 1B, the average number of correct words in the Fast Music group, 7.5 (SD = 1.6) was bigger than the corresponding value in the No Music group, 5.9 (SD = 1.8) ($p = 0.041$), whereas the latter was comparable with the average number of correct words in the Slow Music group, 5.6 (SD = 2.3) ($p = 0.89$). the

Cohen's *d* values of the change in the number of words written between the Fast Music group and the No Music group, between the Slow Music group and the No Music group were 0.93 and 0.15, respectively, implying that fast music, not slow music, strongly impact the participant's memory recall ability.

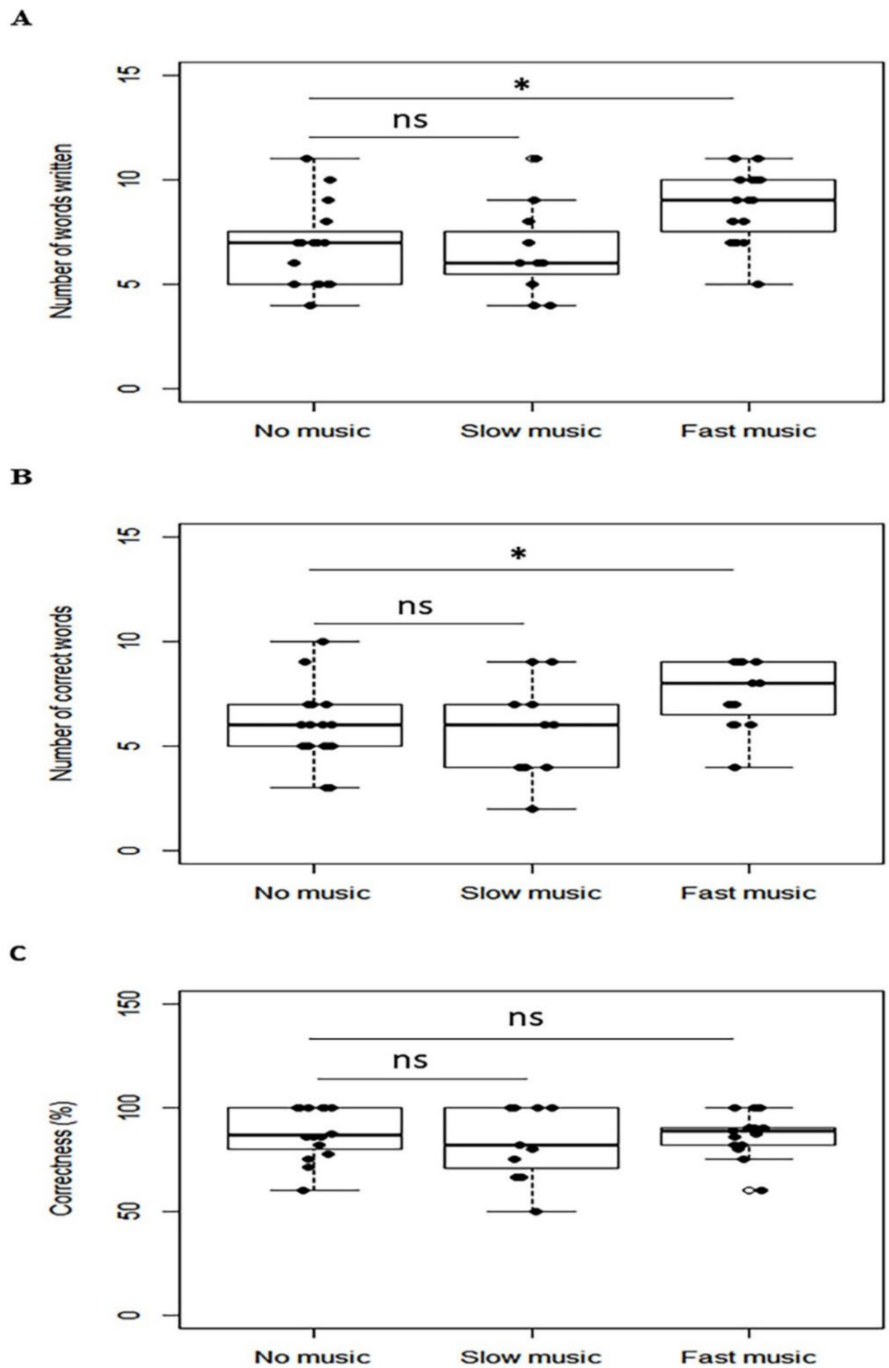

Figure 1. Box plot analyses of number of words written (A), number of words correct (B), and the percentage of correct words (C). Data were analyzed using one-way ANOVA followed by Dunnett's multiple comparisons. *, $p < 0.05$; ns, not significant.

We further compared the percentages of correct words out of written words among these three groups and found that there was no statistically significant difference among these groups ($p = 0.69$), suggesting that Fast music impact memory recall ability, not the accuracy of memory recall (Figure 1C).

In addition, we explored the potential associations between the participants' demographic characteristics (including grade, sex at birth, favorite music genre, and whether the participants were currently leaning an instrument or part of some other musical ensemble) and their memory recall ability. Our results showed that there was none of these demographic characteristics weas statistically significantly associated with the number of words written nor the number of correct words (all p values > 0.05).

Taken together, our results demonstrated that in comparison with low-tempo music or silence (no music), listening to high-tempo music while studying led to better performance in memory recall as evidenced by significant increases in the total number of words recalled and the number of words recalled correctly, supporting that fast-tempo music has positive impact on the listener's cognitive short-term ability.

Evaluating The Impact of Music on Arousal Rating

Lastly, we investigated the potential impacts of music tempo on the participants' arousal level. Only students in the Slow Music group (n = 11) and the Fast Musci group (n = 15) completed this evaluation, and the average SAM score of these 26 students was 2.5 (SD = 1.4) with a median of 2.5 (minimum = 1, maximum = 5) (Figure 2). Further analyses indicated that fast music statistically significantly increased the SAM score in comparison with slow music (average SAM score = 3.3, SD = 1.2 *vs* average SAM score = 1.4, SD = 0.7) ($p < 0.001$). The Cohen's d value of the change in SAM score between the Fast Music group and the Slow Music group was 1.86, indicating that fast music strongly impacts the arousal rating of participants in comparison with slow music. Interestingly, there was no statistically significant correlation between the SAM score and the number of words written (Pearson's correlation coefficient = -0.17, $p = 0.55$) nor between the SAM score and the number of correct words (Pearson's correlation coefficient = -0.08, $p = 0.78$) in the Fast Music group. Similarly, the Pearson's correlation coefficients between the SAM score and the number of words written, between the SAM score and the number of words correct in the Low Music group were -0.39 ($p = 0.24$) and -0.23 ($p = 0.49$), indicative of the absence of correlation in statistics.

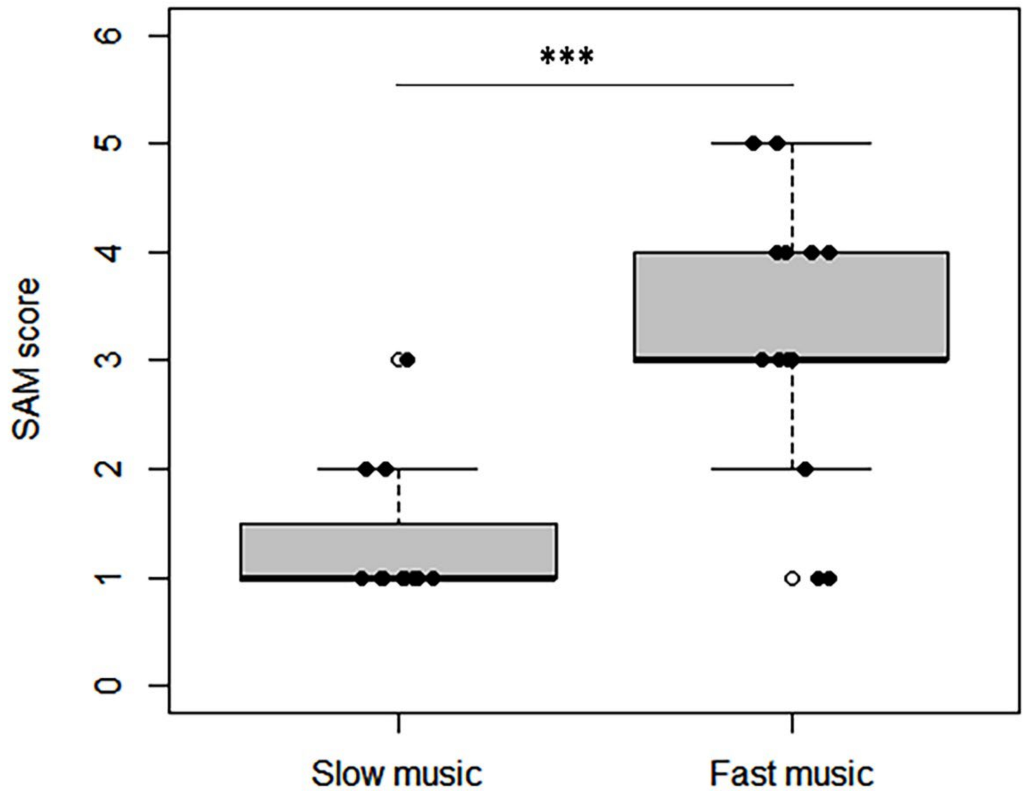

Figure 2. Box plot analyses of SAM score. Data were analyzed using unpaired Student's t test. ***, $p < 0.001$.

Discussion

Here we reported our pilot study to investigate the potential impact(s) of music tempo on the listener's cognitive short-term ability. Our results show that fast-tempo music, not slow-tempo music, considerably improve the listener's memory recall performance when listening to music during studying. Fast-tempo music leads to positive and strong impact on the listener's arousal level in comparison with low-tempo music. Overall, these findings support the idea that music tempo affects cognitive performance.

It has been reported that the brains of nonmusicians and musicians are vastly different. In fact, musicians may have reduced performance in language comprehension tasks when compared to non-musicians. In our study, over half of the participants (54.8%) were musicians (students who were currently learning an instrument or part of some other musical ensemble), and while distributed equally amongst the three groups, it may have been an underlying factor in memory recall performance. The 10-minute priming period was a standard set by Rausher, Ky, and Shaw (1993) in the Mozart Effect experiment. It remains unclear whether there would be significant benefits beyond the 10-minute period.

It is notable that the impact on the listener's performance was only observed with the selected high-tempo music, not the low-tempo music. While music varies largely in genre, tempo, length, and intensity, the listener's cognitive performance is believed to relate his/her physiological conditions, such as age, heart rate and arousal during testing. Hence, extensive studies in large populations are essential to evaluate the effect(s) of different characteristics of music on people's cognitive performance.

Limitations and Conclusions

There are limitations in the current study, First, the sample size of our study was small regarding the diversities in the demographic characteristics of high school students as well as in the genre of music. Second, our participants were limited to one school in an Ohio area, which may compromise the diversity of high school students in US. Third, it is optimal to use multiple methods to extensively assess a participant's memory recall ability and the arousal status. Nevertheless, our present study has provided novel insights into understanding the impact of music on the listener's cognitive ability, supporting further studies on the music impact on the brain in large populations of high school students. Findings from these studies would lead to optimizing academic environments and improving the students' performance in schools in US.

Acknowledgments

I would like to thank my advisor, Ms. Donna Parker at Coffman High School for her guidance provided to me in this research project.

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