Music and Memory

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1 Introduction

We are interested in examining whether a link exists between music listening and memory retention, specifically, whether listening to classical music can be used as a tool for improving memory retention. Past studies have demonstrated multiple cognitive benefits of classical music listening which we would like to investigate further.

As students, we are constantly seeking effective study techniques, and learning new study strategies is important to our academic success. Additionally, this research could contribute to educational strategies, offering a simple method to improve school learning outcomes. The intersection of psychology, education, and music presents an intriguing area of study, motivating us to explore how a simple everyday activity like listening to music might impact cognitive performance. Through our Latin-Square experimental design we anticipate finding a correlation between listening to classical music and memory retention. We hope this will contribute valuable insights into the cognitive effects of music with applications for individual study habits, as well as school curricula.

All data was sourced from the virtual population on the Island Project created by Dr. Bulmer from the University of Queensland to assist in experimental design, epidemiology, and statistical reasoning. The population consists of three virtual islands: Ironbard, Providence, and Bonne Santé each of which were initially inhabited by survivors of a shipwreck 352 years in the past. Over time the populations have developed into the diverse community of forty thousand islanders in twenty-seven villages.

The paper is organized as follows: Section 2 explains the design we used to implement our experiment; Section 3 presents our experimental results and analysis; and Section 4 covers our conclusions and any potential limitations of the experimental design.

2 Methods

We selected a Latin-Square design for our experiment with minutes of music listened to as our treatment. We began by selecting four cities: Shinobi and Akkeshi from Providence Island, Vaiku from Bonne Sante Island, and Vardo from Ironbard Island. We then began gathering data from each city's associated school, selecting two students from each of grades 9 through 12 through use of a random number generator. We obtained consent from each student's guardian before conducting the experiment and selected a replacement student at random if consent was denied. Otherwise, if the guardian consented, we conducted the treatment as follows: the students would play a memory game (located under the Mental Tasks tab) in which they would have to find pairs that match each other within thirty cards. We recorded their initial time to complete the test in seconds. We then made the students sit (located under the Environment tab) and then listen to classical music (under the Music tab) for a combined total of thirty minutes. Both sitting and listening to music were done in ten-minute intervals resulting in four possible treatment combinations as shown in Figure 1 with treatments chosen by the Latin-Square assignment. As an example, a randomly selected ninth-grade student from Vaiku School would sit for 20 minutes and then listen to classical music for ten minutes. After receiving their prescribed treatment, the students played the memory game a second time. We were thus able to obtain the difference between initial and final attempts.

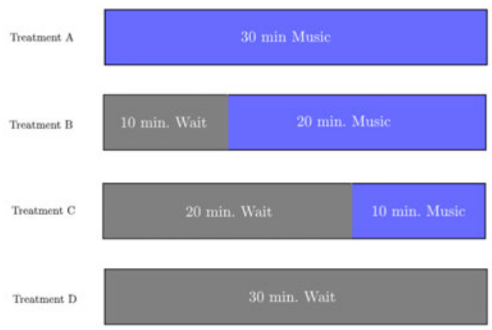

Fig. 1 Illustrated Treatments

The quality of one's memory retention can be impacted by many factors, including age and health, both of which affect certain cognitive abilities. Thus, proper blocking of multiple factors is crucial if we wish to minimize the observed error. With our choice of Latin-Square design we were able to simultaneously block by age group and city of residence. Our four treatments of classical music listening were then A = 30 minutes, B = 20 minutes, C = 10 minutes, and D = 0 minutes resulting in the design illustrated in Table 1.

	Grade 9	Grade 10	Grade 11	Grade 12
Shinobi	A	B	C	D
Akeshi	B	C	D	A
Vaiku	C	D	A	B
Vardo	D	A	B	C

Table 1 Latin-Square Design

We chose to run this experiment with two replicates, with two students being randomly selected for each block, so we would have a sample size of 32 students. We decided to consider only high school students in our experiment to simplify the data collection process. If we wanted to block by age alternative designs would require us to observe a large group of people and take only those who fit into the blocking scheme. Our approach allowed us to know each age group beforehand and thus we saved a significant amount of time in the data acquisition stage. We thus would be able to apply our results to the population of high school student on the three islands. Additionally, we chose to conduct our second replicate with the same treatments as the first block. This was done to decrease the rate of errors during the experiment, as keeping track of multiple treatment and block levels for 32 students proved difficult.

We concluded that having 32 students as our sample size would be ideal as this entails a sufficient amount of students to represent the overall population of high school students across the islands. Running power calculations, we found that a single-replicate design would have an effect size of about 0.97 at a power of 0.8. We considered this rather high, as we anticipated the effect of music listening to be rather small. Running the test for a design with an additional replicated indicated an associated effect size of about 0.63 with a power of 0.8, much closer to an ideal value and easy to implement thanks to the time-saving measures discussed above.

3 Results

Factor	Df	Sum Sq	MSE	F value	Pr(>F)
Music	3	988	329	6.95	0.002
City	3	225	75.0		
Grade	3	94	31.3		
Residuals	22	1042	47.4		

Table 2 ANOVA Results.

At a significance level of $\alpha = 0.05$ we find that the music treatment, with a p-value of 0.002, is significant. Thus, we have evidence reject the null hypothesis that music has no effect on the results of the memory game. We additionally find based on their associated errors that the chosen blocks do an acceptable job of accounting for the remaining error, but do not appear crucial to the design.

Checking our model assumptions, the normal Q-Q Plot in Figure 2 shows the outliers roughly following a straight line, with a few points away in the bottom left. This indicates that our dataset follows a normal distribution with a small right skew. Additionally, the Residuals vs. Fitted Plot in Figure 3 indicates no apparent relationship between the fitted value and residual value, and we say that the distribution of the residuals is

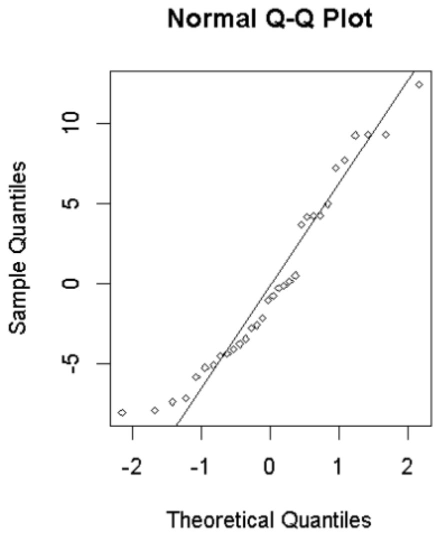

Fig. 2 Approximately normally distributed Q-Q plot.

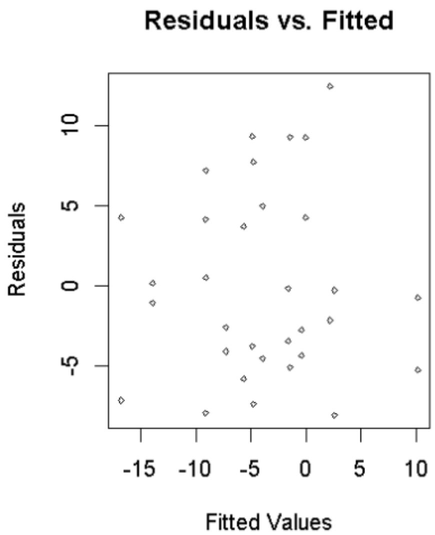

Fig. 3 Homoskedastic residuals/fitted values plot.

homoskedastic. We may thus conclude that our model assumptions are valid.

The box-plots here display the distribution of the data received from the difference in how fast a student finishes the memory game before and after listening to classical music. There is one box-plot for each treatment level, or the intervals of classical minutes we gave to each student to listen to. The main takeaways are the medians from each box-plot and the range of the second and third quartiles. When the students listened to classical

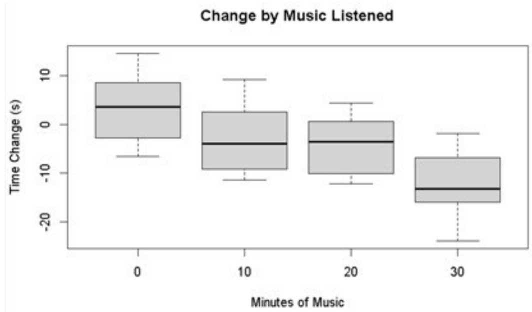

Fig. 4 Music with measured change in memory game performance.

music for 0 minutes, we see that they did about 5 seconds worse in the memory game on average than playing the game before listening to classical music. For 10 minutes, the students did about 5 seconds better. For 20 minutes, about 3 seconds better. And for 30 minutes, about 12 seconds better. As we can see, it appears that classical music did benefit the students' memory retention though the effect is only noticeably large between the highest and lowest levels.

Finally, we conducted a Tukey's HSD test to see which levels contribute most to the significance observed in the ANOVA test. In analyzing the results we find that the only significant difference at the $\alpha = 0.05$ level is observed between the highest and lowest treatment level. We additionally observe large but not significant differences between the 0 and 20, 10 and 30, and 20 and 30 treatment levels.

	Diff.	Lwr.	Upr.	p Adj.
10-0	-6.288	-15.845	3.270	0.288
20-0	-7.613	-17.170	1.945	0.151
30-0	-15.613	-25.170	-6.055	0.000873
20-10	-1.325	-10.882	8.232	0.980
30-10	-9.325	-18.882	0.232	0.058
30-20	-8.000	-17.557	1.557	0.123

Table 3 Tukey's HSD results.

4 Conclusion

Overall, our experiment provides clear evidence that listening to classical music does improve memory retention among high school students. The measured p-value of 0.002 from the ANOVA test and the adjusted p-value of 0.00087 from the

Tukey HSD test both support this claim, specifically for the difference between 30 minutes of listening and 30 minutes of waiting.

Classical music has been found through multiple studies to lead to overall improved cognitive performance in a result dubbed the "Mozart Effect." It has been known to stimulate areas of the brain such as the hippocampus, which is in charge of critical regions such as memory formation and retrieval. In an article of a similar experiment to our own researchers found that listening to classical music improves the performance of episodic memory when compared with both white noise and silence[1]. Thus, the results of our simulated experiment seem reasonable to those of real-world experiments.

Despite our statistically significant result we may consider future improvement to our experimental design. Firstly, we may consider an alternative control treatment. We chose waiting for ten minutes as a control as it appears as a good measure of "doing nothing." However, it may be that asking our participants to wait for a significant amount of time in boredom actually hindered their mental performance. Thus, it is possible that performance in the memory game after *any* activity would have improved performance. Additionally, waiting is a rather uncommon task to perform while studying, which is our most applicable use-case. For future experiments we should consider comparing music listening to alternative activity like light reading, watching an episode of television, or listening to an audio book.

References

[1] Sara Bottiroli, R.R.T.V. Alessia Rosi, Cavallini, E.: The cognitive effects of listening to background music on older adults: processing speed improves with upbeat music, while memory seems to benefit from both upbeat and downbeat music. National Library of Medicine (2014)