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1. Introduction

Whether it is the soft playing of Mozart sonatas in the car or the gentle humming of lullabies at bedtime, parents have long surrounded their children with music – and for good reason. Music has been widely acknowledged for its cognitive benefits by educators, psychologists, and neuroscientists. Numerous studies have shown that musical training can improve various aspects of cognitive functioning, including attention, working memory, and verbal intelligence (Schellenberg, 2005; Moreno et al., 2009; Roden et al., 2012). To be more precise, longitudinal evidence suggests that children who engage in structured music education tend to exhibit enhanced verbal and visual memory performance compared to peers without such exposure (Roden et al., 2014). While these findings display compelling evidence for the long-term benefits of active musical engagement, far less attention has been given to the cognitive effects of passive music listening, particularly its impact on memory retention.

Therefore, the present experiment seeks to address this gap by investigating how exposure to different genres of music affects short-term memory performance among elementary school children. In contrast to musical training, passive listening is a highly accessible and low-cost intervention that can be easily integrated into both classroom and home environments. Existing literature on background music and cognition has produced mixed findings, with some studies reporting how memory and concentration could be enhanced (Hallam, Price, & Katsarou, 2002), while others point out the existence of interference effects resulting from certain music genres, particularly with fast-paced or loud music (Perham & Currie, 2014). However, few of these studies have systematically compared the impacts of multiple music genres within a controlled experimental design targeting school-aged children.

In this study, we investigated the island of Bonne Santé, because the calculated average town hall wealth of $4,352,139 is lowest for Bonne Santé, as compared to $7,076,440.5 for Ironbard and $7,322,840 for Providence. The key assumption is that lower-income students often lack access to resources to enrich cognitive abilities, such as tutoring. Therefore, music serves as a cost-effective and scalable method of cognitive enhancement. The aim of this study is to examine the relationship between listening to music, specifically different genres of music, and memory performance, reflected by time taken of memory games, of elementary school students. We hypothesize that genres characterized by soothing and refined acoustic properties, such as classical music, may enhance memory performance, while genres marked by high auditory stimulation, such as heavy metal, may detract from it. Country music, with its moderate tempo and melodic familiarity, most likely has a neutral or intermediate effect.

Understanding how music genres influence short-term memory has practical relevance in both educational contexts. If certain genres of music boost memory performance, then music listening could serve as a scalable and accessible cognitive support tool in early education. In doing so, it bridges disciplinary gaps and provides actionable insights for parents, teachers, and policymakers alike.

2. Experimental Design

To examine the effect of music genre on memory retention, we employed a Randomized Complete Block Design, a statistical framework well-suited for isolating treatment effects while

controlling for known sources of variability. The effect model is $y_{ijk} = \mu + \alpha_i + \tau_j + \beta_k + \epsilon_{ijk}$, where i = 1, 2, j = 1, 2, 3, and k = 1, 2. To contextualize, the primary treatment factor here was the genre of music to which participants were exposed, with three levels: classical, country, and heavy metal. The response variable was operationalized as the difference in time (measured in seconds) taken to complete a standardized memory task before and after listening to music, thus capturing within-subject cognitive change attributable to the treatment.

Two nuisance factors – grade level and gender – were included as blocking variables. Grade level was divided into two strata: lower division (grades 1 to 3) and upper division (grades 4 to 6), reflecting development differences in memory capacity. This is supported by neurological studies where, accordingly, younger children typically exhibit shorter working memory spans and are more susceptible to attentional distraction, while older students often demonstrate increased cognitive resilience (Gathercole et al., 2004). Additionally, gender was included to account for potential differences in cognitive processing styles. That is, females and males may process verbal and spatial memory tasks differently and exhibit varying degrees of auditory sensitivity, as reported in developmental psychology literature (Halpern & LaMay, 2000). Blocking on these factors enhances the efficiency of the experiment by reducing within-group variability and enabling more precise estimation of the treatment effect.

The full factorial block structure resulted in 4 blocks (lower division boys, lower division girls, upper division boys, and upper division girls), with 3 treatment levels assigned within each block (classical, country, and heavy metal music). To determine how many students should be included in each block, we conducted a power analysis using k = 4 (3 treatment levels and 1 control group), f = 0.35, significance level = 0.05, and power = 0.8. The minimum number of students in each block is 24, and we used 36, which is far above the minimum. The total sample size is therefore 144 students across all treatment conditions.

Table 1

```
Balanced one-way analysis of variance power calculation

         k = 4
         n = 23.25
         f = 0.35
 sig.level = 0.05
     power = 0.8

NOTE: n is number in each group
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Sample size determined from power analysis

For the sample collection process, we employed a proportional stratified random sampling procedure in order to avoid selection bias. First, we identified all 12 elementary schools across the island of Bonne Santé and obtained the number of eligible students per location. Then, for each school, we randomly selected k students from a block (e.g. lower division boys), with k being allocated proportionally based on student population distribution across 12 schools. This process was repeated across all 12 schools and blocks until 36 students were gathered for each block. This sampling strategy ensured that the final sample was representative of the population distribution while maintaining randomization within blocks.

To isolate the true effect of music listening and control for any learning effects from repeated testing, we included an additional control group. Specifically, 12 control students were added per block to

raise the total sample size in each of the 4 blocks to 48 students, corresponding to 4 treatment levels. After obtaining consent, each student in the treatment groups underwent the following procedure: 1) completed a standardized memory game (pre-test), 2) listened to an assigned music genre for 10 minutes through headphones in a quiet room, and 3) repeated the memory game under identical conditions (post-test). In contrast, each student in the control group only underwent steps 1 and 3. With the experimental design and sample allocation in place, we proceed to analyze the data using ANOVA to determine whether different music genres significantly affect short-term memory performance in children.

3. Results and Interpretation

To test the effect of exposed music genre on the difference in memory task completion time, we fit an ANOVA model with the difference between task completion time as the response variable and music genre, gender, and grade division as the predictors.

The model showed that only music genre has a significant effect ($F_{3, 186} = 86.01$, $p < .001$) on the difference between completion time, while both gender ($F_{1, 186} = .004$, $p = .095$) and grade division ($F_{1, 186} = .019$, $p = .892$) have no significant effects (Table 1). This suggests that there is at least one treatment level in music genre that leads to a significantly different memory performance.

Table 2

```
             Df Sum Sq Mean Sq F value Pr(>F)
Music.Genre   3  13586    4529  85.600 <2e-16 ***
Gender        2      7       4   0.068  0.934
Division      1      0       0   0.001  0.978
Residuals   185   9787      53
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Summary of the ANOVA model

To investigate which specific levels of music genre have a significant effect, we conducted a Post-Hoc Tukey test on our model, which shows the following (Table 2): children in the control group performed significantly slower than both classical, country music groups and significantly faster than heavy metal music groups; children in the heavy metal group performed significantly slower than both classical and country music groups; and finally, children in classical and country music groups performed equally well.

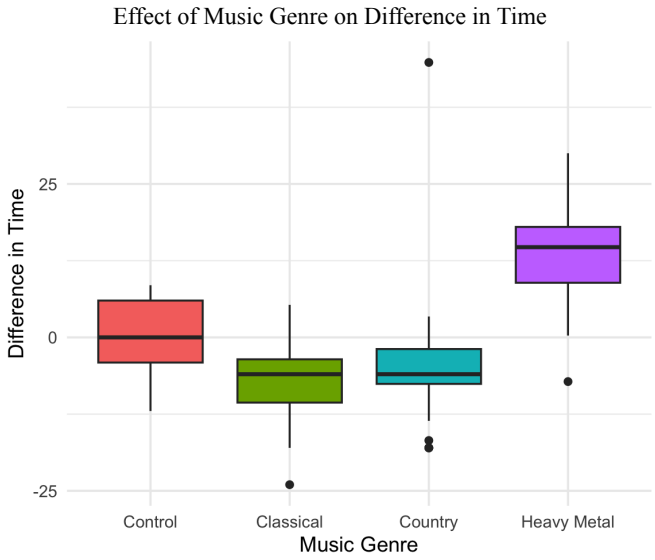
Table 3

```
$Music.Genre
                          diff        lwr       upr     p adj
Classical-Control     -7.308333 -11.148149 -3.468517 0.0000106
Country-Control       -5.060833  -8.900649 -1.221017 0.0042961
Heavy Metal-Control   14.316667  10.476851 18.156483 0.0000000
Country-Classical      2.247500  -1.592316  6.087316 0.4291680
Heavy Metal-Classical 21.625000  17.785184 25.464816 0.0000000
Heavy Metal-Country   19.377500  15.537684 23.217316 0.0000000
```

Post-Hoc Tukey Test on the mean of the differences in response time

These results, along with the bar plot that visualizes the difference in response time of each treatment group (Figure 1), suggest a few findings. First, merely doing the memory game two times does not have any effect on completion times, as there are no differences in response time between the two games in the control group ($M_{Control}$ = 0.183, $t(47)$ = 0.236, p = 0.814). This means that we can safely assume that the differences in completion time observed in other music groups are indeed caused by the music genres. With that in mind, we can then examine the effect of each music genre. Heavy metal music seems to slow down children's performance in completing the memory game post-exposure ($M_{Heavy\ Metal}$ = 14.5, $t(47)$ = 12.429, p < .001), and both Classical ($M_{Classical}$ = -7.13, $t(47)$ = -8.44, p < .001) and Country music ($M_{Country}$ = -4.88, $t(47)$ = -3.775, p < .00)1 seems to improve children's completion time post-exposure.

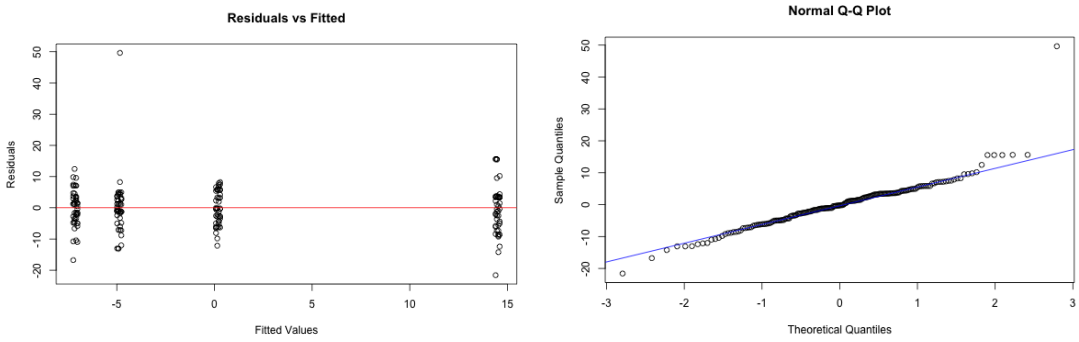
Figure 1



Barplot of the Effect of Exposed Music Genre on the Differences in Task Completion Time

In addition to the main analysis, we examined the residuals of our ANOVA model to check for model assumptions. The Residuals v.s. Fitted plot suggests that the residuals are randomly scattered around 0 and have constant variance, as they are not showing any discernible patterns. The Residual Normal Q-Q plot also suggests that the residuals are normally distributed since most of the points lie close to the straight line. Since our model assumptions hold, we can assume that our analysis above is valid.

Figure 2, 3



Residuals v.s. Fitted Values plot and Residual Normal Q-Q Plot

4. Discussion

Our study shows that passive music listening significantly affects short-term memory performance among elementary school children. Specifically, classical and country music improve memory performance, while heavy metal music worsens it. These effects were observed consistently and independently of gender or grade level, as neither of the blocking variables showed significant influence.

These results can be better understood by studying the musical characteristics of each genre. Classical music is often known for its harmonic structure and moderate tempo, which has been shown to enhance cognitive performance. Research found that classical music activated brain regions involved in memory retrieval, likely due to its soothing qualities (Angel et al., 2010). Similarly, music with moderate tempo and predictable melodies like country music can improve task performance by optimizing arousal levels (Thomas et al, 2001). In contrast, heavy metal music tends to be of high volume with fast tempo and unpredictable changes, and these characteristics have been associated with cognitive overload. Studies have shown that heavy metal music may interfere with complex task performance due to increased distraction (Nantais and Schellenberg, 1999) by provoking emotional intensity that can overwhelm listeners (Schäfer et al, 2013).

From an educational standpoint, our results suggest practical applications. Background music was found to improve verbal memory performance in children, especially among those with lower cognitive baselines (Bottiroli et al., 2014). Playing classical or country music and avoiding heavy metal music in the background during break or quiet study sessions at school could be a low-cost, scalable intervention to improve cognitive performance, particularly for under-resourced environments like Bonne Santé. These interventions could be impactful in bridging achievement gaps where access to other educational resources is limited. However, passive listening alone should not be the sole intervention. Cultivating a genuine interest and habit of listening may offer greater long-term benefits. Possible further interventions in schools include integrating classical and country music into the curriculum, making them a core part of music education, inviting musicians to perform and engage with students, fostering direct exposure and emotional connection to the music and establishing music clubs to encourage active participation and community-building through music.

However, one possible limitation of our study is that it only examines the immediate, short-term effects of music exposure. While the results are clear in this context, we cannot infer long-term memory impacts or possible consequences of repeated passive listening. Furthermore, although gender and grades were blocked, other individual differences, such as baseline cognitive ability and familiarity with the music genres, were not accounted for and may have influenced the results. All in all, this study adds to the growing evidence that music genre matters in cognitive environments as the musical structure, emotional tone, and tempo influence memory processes. By leveraging low-cost, passive interventions like background music, we may be able to better support learning in both traditional and under-resourced educational settings.

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