Memory Performance:

The Effect of Dark Chocolate Content and Music Genre

Stats 101B: Lecture 1, Group 19

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1 Abstract

Americans currently face a global health crisis regarding memory. There is a growing population of people over the age of 65, and an increase in aging-related diseases such as dementia. Studies have found correlations between cocoa consumption and various measures of cognitive performance, including memory. Likewise, studies have found links between certain types of music and improved cognitive performance. To build on these findings, our study investigated whether dark chocolate cocoa content, music genre and their interaction had an effect on memory performance. Utilizing a randomized complete block design and analyzing with a two-way ANOVA with blocking, we found that music genre was the only statistically significant factor. Specifically, heavy metal music yielded a significantly longer change in time taken to perform a memory game. For further exploration, we could pivot our field of study to look at how music genre's effect on memory relates to its effect on mood, as well as investigate factors such as waiting time after consumption, age brackets and difficulty of the cognitive task.

2 Introduction

Memories are essential in shaping who we are and where we come from. We use memories to store information about our experiences and the world around us. Americans currently face a global health crisis regarding memory with a rapidly aging population and an increase in aging-related memory diseases (Santiago-Rodríguez, Estrada-Zaldívar, & Zaldívar-Uribe, 2018). This pressing issue of memory loss directly motivated us to further investigate and contribute to the plethora of research working towards a potential solution.

Humans have a combination of short-term memories and long-term memories that range anywhere from a couple of seconds to years. Memories can form in different ways. Declarative memory (explicit memory) is experienced consciously, while nondeclarative memory (implicit memory) is experienced unconsciously (Greshko). The brain creates memories through three stages. During the sensory register process, the brain takes in information from the surrounding environment through audiovisual cues. Short-term memory is used when the brain stores information to be repeated or manipulated, and long-term memory is used when the brain's neural wiring is changed. These brand new connections remain as long as they are used (Becker).

Many studies have begun to examine the effects of various factors, such as chocolate and music, on memory and memory loss. Research has shown a correlation between flavonoid consumption (chocolate being a rich source of flavonoids) and short- and long-term increased cognitive performance (Socci, V., Tempesta, D., Desideri, G., De Gennaro, L., & Ferrara, M., 2017). Cognitive effects of flavonols are especially pronounced in older populations, which is why we decided to block by age in our study (Socci, V., Tempesta, D., Desideri, G., De Gennaro, L., & Ferrara, M., 2017). With regard to the effect of music, research has found that it seems likely that the cognitive effects of music are related to the interplay between emotions/mood and cognitive performance. As a result, the effect of music on cognitive performance likely depends on the individual's enjoyment of the music (Schellenberg, E. G. & Hallam, S., 2005).

In this study, we examined the effects of dark chocolate content and genre of music, as well as their interaction, on memory performance. We used 4 levels of dark chocolate that varied in cocoa percentage (40%, 75%, 85%, and 99%) and 4 levels of music that varied in genre (classical, country, dance, and heavy metal). We blocked by age utilizing three levels that consisted of young (8-15 yrs), middle-aged (20-50 yrs), and elderly (65+ yrs) subjects. We chose these age ranges by accounting for the major cognitive growth young children experience in a short amount of time, the plateau most people experience once their brain is fully formed, and the cognitive loss people sometimes experience as their age increases. Through testing participants' memory via a matching pairs card game, our goal was to shed light on the cocoa concentration of dark chocolate, genre of music, and combination of these factors that resulted in the most improved memory ability. We hope the results of our study may contribute to the body of research surrounding the prominent public health issue of growing cognitive impairment.

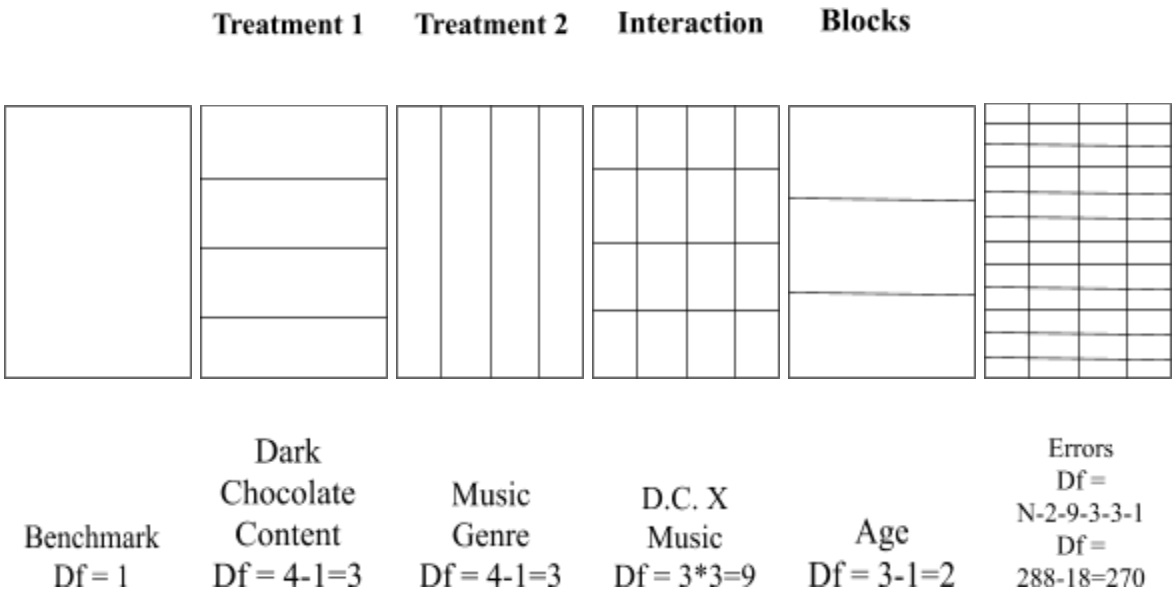
3 Data Analysis: Methods and Procedures

3.1 Design and Factors

Our study utilized a Randomized Complete Block Design (RCBD). The parameters for the design are as follows:

Response Variable	Memory Performance Change			
Treatment 1 (Dark Chocolate Cocoa Content)	40%	70%	85%	99%
Treatment 2 (Music Genre)	Classical	Country	Dance	Heavy Metal
Blocking Factor (Age)	8-15	20-50		65+

The factor diagram and corresponding degrees of freedom for our study are detailed below:



We chose to focus on dark chocolate cocoa content due to flavanols' known effect on memory retention and on music genre due to its hypothesized effect on memory improvement. To study the individual influence of dark chocolate, we utilized four varying concentrations of cocoa to see whether or not cocoa concentration was significant. We also followed up with four distinct music types to investigate the individual effect of music on memory. Combining the two treatment factors together (for a total of 16 possible combinations), we were able to see whether or not the interaction of dark chocolate and music was significant. Lastly, we blocked by age to account for the known variance in memory performance that exists between young, middle-aged, and elderly people.

3.2 Sample Size and Power

Figure 1: Initial Sample Size

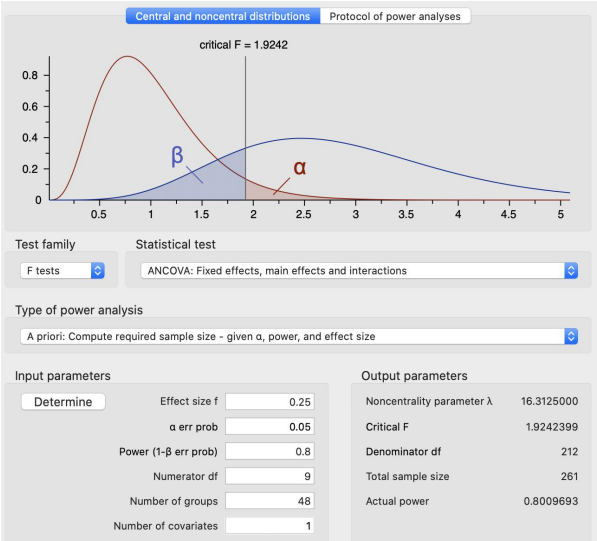
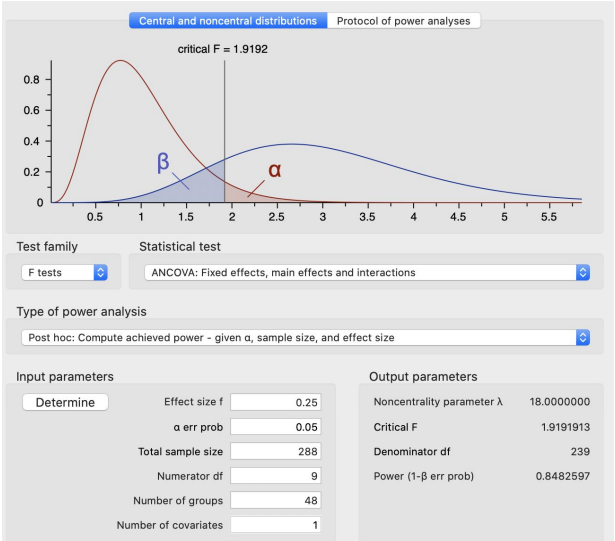


Figure 2: Updated Power



Choosing a medium effect size of 0.25 and power of 80%, GPower found that we would need a total sample size of 261 (see Figure 1). However, given that both treatment factors consisted of 4 levels, and our blocking factor consisted of 3 levels, we increased the sample size to 288 in order to obtain a balanced design. This way, each block included 96 subjects with six subjects receiving one of 16 treatment combinations. Using our larger sample size of 288 and working backwards in GPower, our updated power increased to about 85% (see Figure 2).

3.3 Participants

Per our earlier GPower calculations, our total sample size consisted of 288 subjects. In order to find our participants, we sampled from the three largest cities on the island: Macondo, Fairhaven, and Edwarton. Blocking by age, we selected 96 subjects from the 8-15, 20-50, and 65+ age groups. In order to properly randomize treatment assignment, we used the sample function in R to determine which treatment combination each subject received within their respective block.

3.4 Instruments and Data Collection

The response variable of memory performance change was measured by subtracting the time taken for the "Memory Game" pre-test from the time taken for the "Memory Game"

post-test. The Island's "Memory Game" records the time (in seconds) taken for a subject to sort 30 cards into matching pairs. Subjects chosen for the study consumed 50 grams of dark chocolate (of varying concentrations) and then waited 2 hours in order to allow for the chocolate to properly metabolize. The same subjects then listened to their assigned music genre for 10 minutes before completing the "Memory Game" a second time.

The specific data collection procedure is as follows:

1. Conduct "Memory Game" pre-test (secs) to establish baseline for participants' abilities.
2. Give each participant their assigned dark chocolate cocoa content (50g).
3. Wait 2 hours to allow for the chocolate to be metabolized.
4. Give each participant their assigned music genre, which they listen to for 10 minutes.
5. Immediately after, conduct "Memory Game" post-test (secs).
6. Compute memory performance change (response variable) by finding the difference between "Memory Game" pre-test time and "Memory Game" post-test time.

3.5 Overview of Statistical Tests and Graphics

We used R to complete the data analysis portion of this project. First, in an effort to visualize each factor before conducting the ANOVA test, we created scatterplots for Age Bracket, Dark Chocolate Content, and Music Genre vs. Memory Change. We also included an interaction plot for Dark Chocolate Content and Music Genre treatment factors. Then, we conducted an ANOVA test to see whether Dark Chocolate Content, Music Genre, and/or their interaction were actually significant factors. Moving forward, we conducted a post-hoc analysis using TukeyHSD to determine which specific level(s) of the significant factors were different. For further ease of visualization, we also included a stacked histogram for the factor that proved to be statistically significant. Lastly, we used the plot function to generate diagnostic plots and verify that our model was valid.

4 Results

4.1 Preliminary Graphical Exploration

Figure 3. Scatterplot of Age Bracket vs. Memory Change

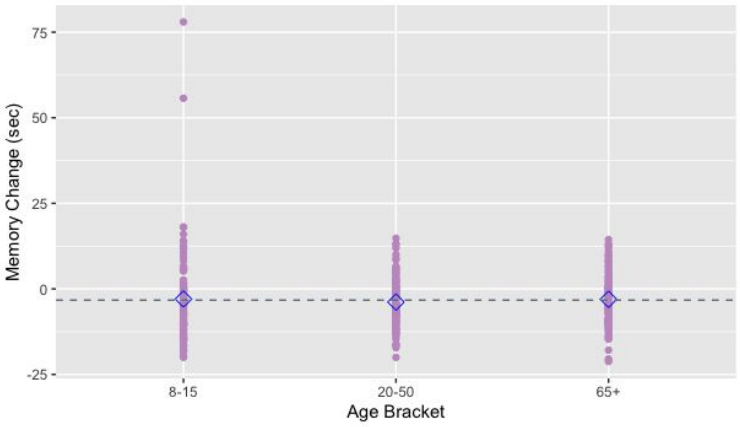


Figure 4. Scatterplot of Dark Chocolate Content vs. Memory Change

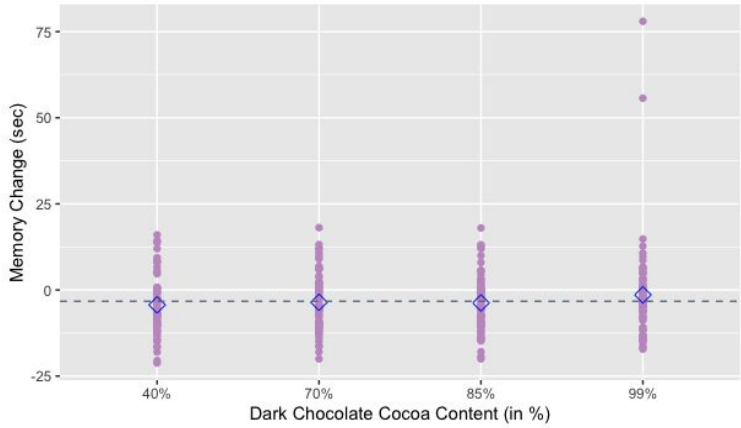


Figure 3. Scatterplot of Age Bracket vs. Memory Change. Figure 4. Scatterplot of Dark Chocolate Content vs. Memory Change. These scatterplots suggest that the age blocking factor and dark chocolate treatment factor are both not significant. The marginal mean memory changes for the different age brackets and dark chocolate cocoa contents are roughly equal to each other and the overall mean (denoted by the horizontal dotted line). Therefore, there are no suspected significant differences in memory change across the age brackets and dark chocolate treatments.

Figure 5. Scatterplot of Music Genre vs. Memory Change

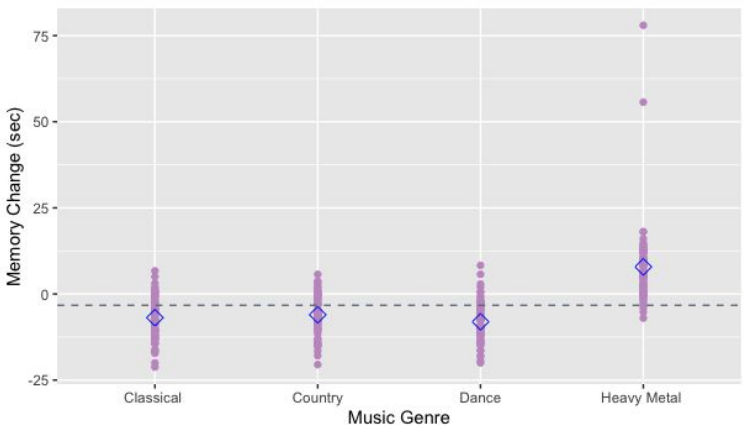


Figure 5. Scatterplot of Music Genre vs. Memory Change. In contrast to the two previous plots, this scatterplot suggests that the music genre treatment factor is significant. While the marginal mean memory changes for classical, country, and dance music are roughly equal to each other and the overall mean, the marginal mean for heavy metal

music is significantly higher than the other genres and the overall mean. Therefore, we conclude there are suspected significant differences in memory change across the different music genres.

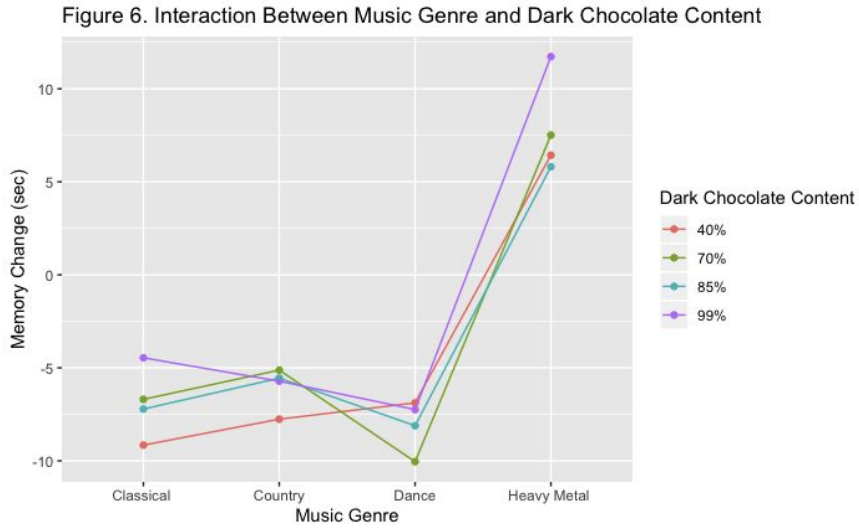


Figure 6. Interaction Plot of Dark Chocolate Content and Music Genre. This plot provides slight evidence of an interaction between dark chocolate content and music genre. Even though the four lines are roughly parallel with similar rates of change, the lines corresponding to 40% and 99% dark chocolate cocoa content (the pink and purple lines, respectively) appear to have slightly different rates of change throughout the classical, country and dance music genres. However, while this interaction plot may provide slight evidence of an interaction between dark chocolate content and music genre, our ANOVA test below (Table 1) indicated that this interaction was not enough to be significant.

4.2 ANOVA Analysis

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Dark.Chocolate.Content	3	354	118	1.956	0.121
Music.Genre	3	12089	4030	66.875	<2e-16
Age	2	47	23	0.388	0.678
Dark.Chocolate.Content:Music.Genre	9	414	46	0.764	0.65
Residuals	270	16270	60	-	-

Table 1: Two-way ANOVA test with one blocking factor. From the ANOVA table, we see that Music Genre was a significant design factor and that there is at least one music genre level that has a marginal average memory performance change that is different than another music genre level. Next, we observe that both the Dark Chocolate Content treatment factor and Age blocking factor were insignificant. We fail to reject the null hypothesis that all

dark chocolate content levels and all age levels have the same average memory performance change. Lastly, the interaction between Dark Chocolate Content and Music Genre was insignificant. Therefore, we don't have enough evidence to conclude that the effect of dark chocolate content on memory performance change differs depending on the values of the music genre and vice versa. These results reaffirm what we previously analyzed in our plots..

4.3 Tukey HSD Post-Hoc Investigations

	difference	lower	upper	p adj
Country - Classical	0.8430556	-2.501503	4.187614	0.9149195
Dance - Classical	-1.1888889	-4.533447	2.155669	0.7947634
Heavy Metal - Classical	14.7541667	11.409608	18.098725	0.0000000
Dance - Country	-2.0319444	-5.376503	1.312614	0.3972237
Heavy Metal - Country	13.9111111	10.566553	17.255669	0.0000000
Heavy Metal - Dance	15.9430556	12.598497	19.287614	0.0000000

Table 2: Tukey HSD Confidence Intervals.

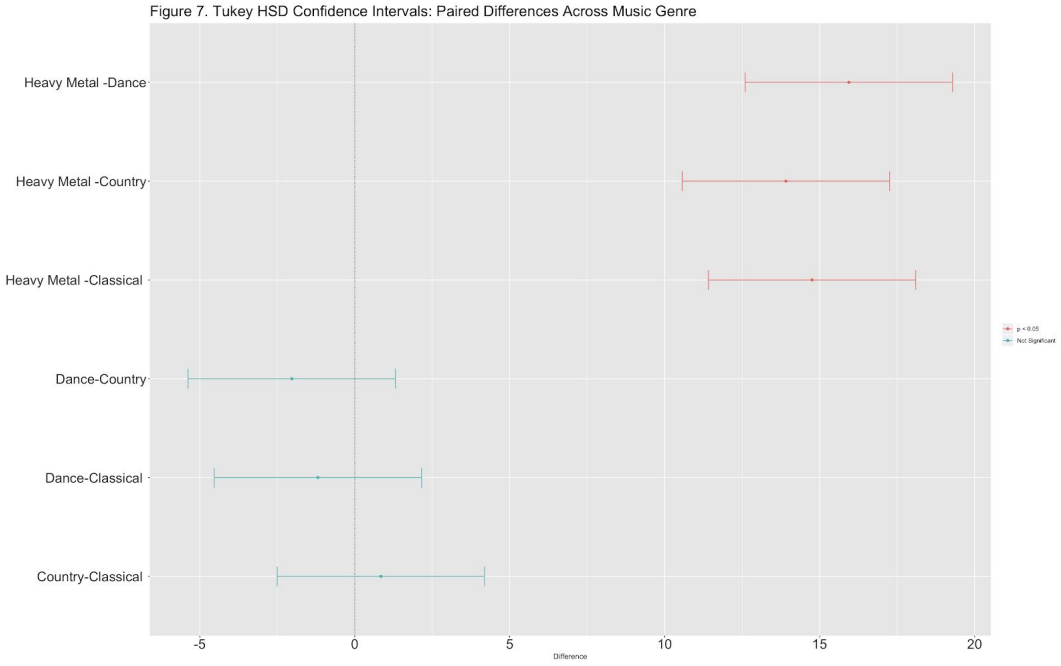


Figure 7: Plot of Tukey HSD Confidence Intervals. Because Music Genre was a significant treatment factor, we conducted post-hoc investigations using Tukey HSD. From the table and plot, we saw that there are three significant pairwise comparisons that don’t include 0 in their confidence intervals. These are between Heavy Metal and Classical, Heavy Metal and Country, and Heavy Metal and Dance. Since Classical, Country, and Dance are subtracted from Heavy Metal in each of these cases and the resulting confidence intervals were greater than 0,

Heavy Metal consistently correlated with increased "Memory Game" time and worsened memory performance. The three insignificant pairwise comparisons were between Dance, Country, and Classical music; there is no significant difference in marginal averages among these 3 music genres.

4.4 Statistical Plots

4.4.1 Music Genre Histogram

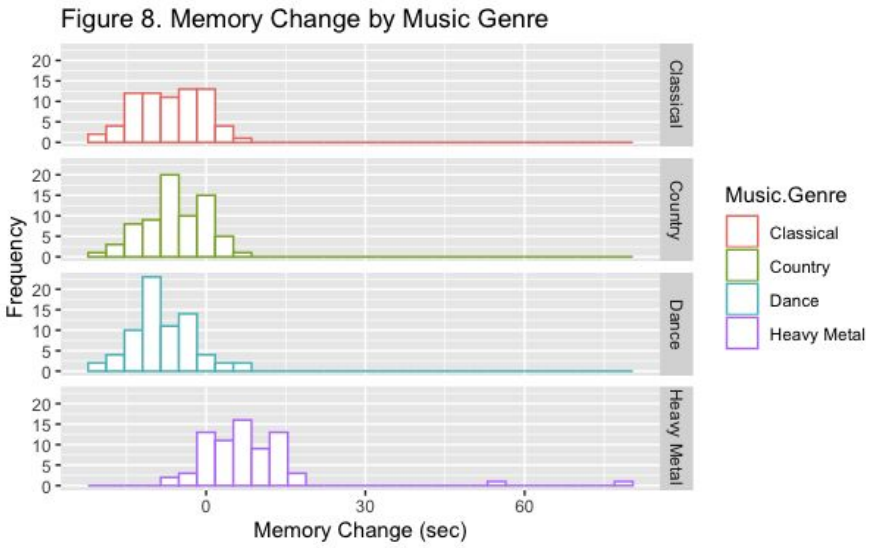


Figure 8. Histograms of Memory Change for Each Level of Music Genre. To better visualize the results from the post-hoc analysis, we plotted histograms for the 4 music genre levels. In this graph, Memory Change = 0 represents no change in memory game time from the pre-test to the post-test. We observe that Classical, Country, and Dance music have distributions mostly falling below 0 and on the negative side. This means that less time was required to complete the task in the post-test compared to the pre-test, and therefore the subjects in these 3 genres generally experienced memory improvement. In contrast, Heavy Metal had a majority of its distribution falling towards the positive side. This means that more time was required to complete the task in the post-test, and subjects experienced memory worsening.

4.4.2 Model Validity

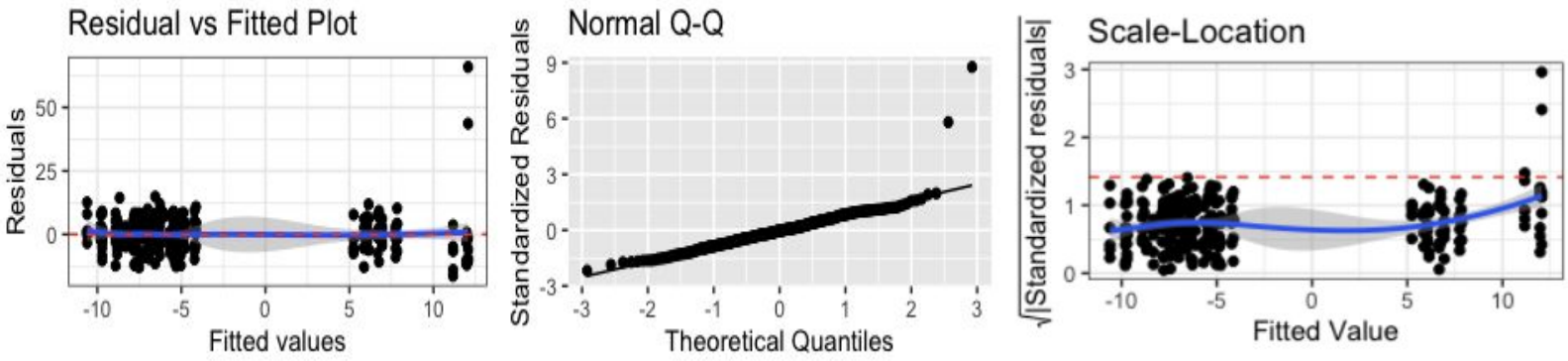


Figure 9: ANOVA Model Diagnostic Plots. The diagnostics plots above provide evidence that our model predicting memory change using dark chocolate content, music genre, and age is valid. First, the residual plot displays a random trend and no fan shape. This suggests the model is well fit to the data, the errors are random and independent, and there is constant variance throughout the model, all providing evidence of model validity. Next, there is a linear trend in the Normal QQ plot, which suggests the errors in this model are normally distributed and provides further evidence of model validity. Lastly, there is a random trend in the Scale-Location plot with a flat trend line, which suggests there is constant variance throughout the model and provides further evidence of model validity.

5 Discussion

The ANOVA tables for the data from our experiment indicate that, at a 5% level of significance, neither dark chocolate cocoa content nor the interaction between dark chocolate cocoa content and music genre were statistically significant. Age also was not significant, meaning it was not a very useful blocking factor, even though other studies have found the effects of dark chocolate flavanols on cognitive ability to be especially pronounced in older populations (Socci, V., Tempesta, D., Desideri, G., De Gennaro, L., & Ferrara, M., 2017).

Only one treatment factor, music genre, was associated with a statistically significant difference in memory game performance change. From Tukey post-hoc investigations, we saw no evidence that differences in memory game performance change (measured as time to complete post-music game - time to complete pre-music game) between classical and country, classical and dance, or country and dance were significant. The only significant paired differences in memory game performance change were between heavy metal and each other

genre (classical, country and dance). Each of these paired differences (heavy metal memory game performance change - other genre memory game performance change) is positive, indicating that heavy metal is associated with less improvement/greater worsening of memory game times than any other genre.

6 Conclusion

When looking to explain heavy metal's detrimental effect on memory performance, one possible area for further investigation is to find out how heavy metal affects people's emotional states, including the extent to which they enjoy it. Other studies have put forth the idea that the cognitive effects of music are related to the interplay between mood and cognitive performance (Schellenberg, E. G. & Hallam, S., 2005). In future iterations of this type of study, we hope to have discussions with participants to gather information about how they feel about the music they listen to in the study to see if there is any correlation between how participants say certain music makes them feel and how it affects their performance on the memory game or a similar memory task.

Several possible reasons for why dark chocolate cocoa content was not a significant treatment factor involve the cognitive load of the memory game task in our study and timing of the memory game task after cocoa consumption and cocoa dose. There is some evidence that tasks have to reach a certain level of cognitive demand in order to detect the effects of chocolate (Socci, V., Tempesta, D., Desideri, G., De Gennaro, L., & Ferrara, M., 2017). Different studies have also involved consuming varying amounts of cocoa and waiting varying amounts of time after consumption to perform the task a second time, with some studies even waiting weeks or months to examine the long-term effects of cocoa on cognitive performance, including memory (Socci, V., Tempesta, D., Desideri, G., De Gennaro, L., & Ferrara, M., 2017). Therefore, possible changes to make in future iterations of this study are to increase the cognitive demand of the memory task, increase the cocoa dose and increase the amount of time after cocoa consumption before completing the second task.

7 References

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