The Effect of Caffeine and Music Genre on Heart Rate

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Abstract

Studies have shown that listening to music can profoundly impact an individual's health by affecting anxiety, blood pressure, and, most notably, heart rate. These effects vary depending on the genre of music, with most studies focusing on the impact of classical music on pulse rate. Classical music has been shown to reduce heart rate by creating a peaceful environment that allows individuals to relax.[4] However, fewer studies have been conducted on the effects of energetic or loud music, such as heavy metal. Our experiment aimed to investigate the effects of these two music genres.

Listening to music is a fundamental component of young adults' lives. Similarly, caffeine consumption is increasingly prevalent in young adults' diets. According to a study conducted by the NIH, 86% of adults aged 18 to 30 years old consumed caffeine regularly, with 64% specifically drinking coffee.[2] Therefore, our study focused on these two important factors, music and caffeine, in the lives of adults aged 18 to 30 years old.

To study these questions, we designed a randomized basic factorial with two factors. We sampled 168 participants aged 18 to 30 on Providence island and randomly placed each participant in one of 6 treatment groups. Our analysis revealed a significant main effect for both music genre and caffeine consumption on heart rate. However, the interaction between these two factors did not significantly affect heart rate.

I. Introduction

According to a study published by IEEE, classical music tends to lower heart rate more effectively than music individuals are familiar with.[4] However, further research on the relationship between various music genres and heart rate is still needed.

The effects of caffeine on heart rate have been widely studied, however much of the findings are contradictory. In a study led by researcher Periti, caffeine consumption was shown to improve focus and reduce anxiety.[5] This in turn allowed for a reduction in pulse rate. Conversely, a study published the following year indicated that caffeine ingestion increased tension, therefore raising heart rate.[3] This clear divergence in results prompted us to include caffeine consumption within our study to better understand its relationship with heart rate.

Furthermore, caffeine affects individuals differently based on a variety of factors. For example, it has been shown that Asian and African individuals metabolize caffeine at slower rates than Caucasians.[7] Additionally, young adults aged 18 to 30 metabolize caffeine at two-thirds the speed of those aged 65 to 70 years old.[6] This indicates that our study must control certain factors, such as geographic location and age, to isolate the effects of caffeine on heart rate. Lastly, a variety of studies have shown that those that metabolize caffeine quickly have peak caffeine concentrations fifteen minutes after ingestion.[1]

Based on existing research, we hypothesize that classical music will reduce the heart rate of our participants. Alternatively, we believe heavy metal music will increase heart rate. We have utilized the research regarding caffeine to hold age and location of participants constant. Due to conflicting findings from previous research, we cannot form a definitive initial hypothesis regarding caffeine's impact on heart rate.

II. Methods and Procedures

i. Participants

Participants for this study were selected from Providence island. We held the island constant in order to minimize variation in caffeine metabolization due to ethnic differences. The target demographic included individuals aged 18-30 years. A total of 168 participants were selected using a multistage sampling method to ensure diverse representation across the island.

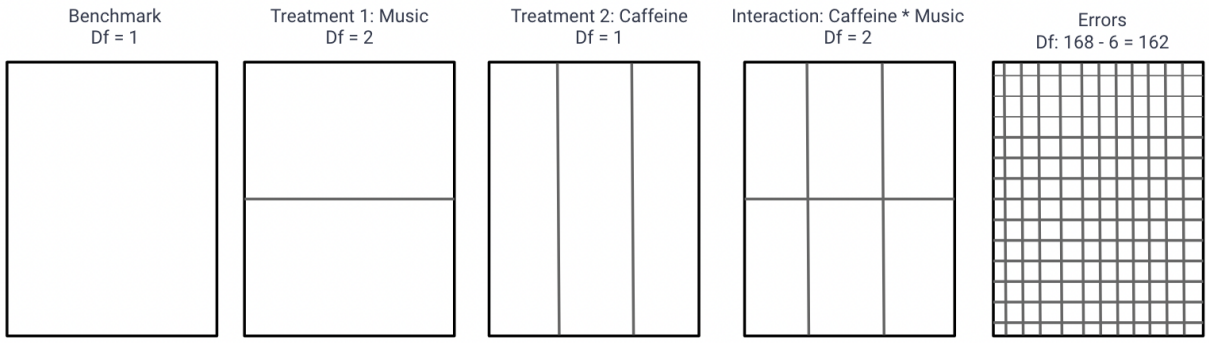
Selection Process:
1. First Stage: A city on Providence island was randomly selected.

2. Second Stage: A house within the selected city was randomly chosen.
3. Third Stage: A person within the selected house, fitting the age criteria (18-30 years), was randomly chosen.
This selection process was repeated until 168 participants were obtained. The randomization steps were conducted using the sample() function in R to ensure unbiased selection.

ii. Design

The study was conducted as a randomized basic factorial design with two factors. The experiment was a single blind study with paired samples, as we recorded each observation's heart rate prior to treatment and after treatment. There were an equal number of participants in each treatment group, making this a balanced experimental design. The following chart displays the different factors used within the study:

Variable of Interest	Change in Heart Rate
Treatment 1: Music	None/Control (0); 10 Minutes of Classical (1); 10 Minutes of Heavy Metal (2)
Treatment 2: Caffeine	250 ML Decaf Coffee (0); 250 ML Coffee (1)



The above chart is the factor design with degrees of freedom for the experiment. We chose to look at classical due to the prior research that has been conducted regarding this genre of music. We added heavy metal music as it is distinctly different from classical, and therefore will allow us to study a different style of music's effect on heart rate. Additionally, to study caffeine we focused on coffee as the majority of caffeine consumption for young adults is derived from coffee. We utilized these two factors, as well as their interaction, within our experiment and studied their effect on heart rate.

iii. Instruments

Two types of coffee were used as stimuli:
- Decaffeinated Coffee (0): 250 mL
- Caffeinated Coffee (1): 250 mL

The dependent variable was the change in heart rate (HR_after - HR_before), measured using a standard heart rate monitor.

Participants were exposed to different music genres during the experiment:
- No Music (0)
- Classical Music (1)
- Heavy Metal (2)

The experiment was conducted in a controlled environment that simulated typical island activities to maintain ecological validity. Participants engaged in routine activities available on the island, ensuring the results

would be generalizable to real-life settings on Providence Island. This controlled yet realistic environment helped in observing the naturalistic effects of caffeine and music on heart rate.

iv. Procedure

1. Baseline Measurement:

- Each participant's initial heart rate (HR_before) was measured and recorded.

2. Intervention Assignment:

- Participants were randomly assigned to one of the two caffeine groups: decaffeinated (0) or caffeinated (1).
- Each participant consumed 250 mL of their assigned type of coffee.

3. Music Exposure:

- After consuming the coffee, participants were randomly assigned to one of the three music genres: no music (0), classical music (1), or heavy metal (2).
- Participants either listened to the assigned music genre or experienced no music for a period of ten minutes.

4. Post-Intervention Measurement:

- After the ten-minute interval, participants' heart rates (HR_after) were measured again.

5. Calculation of Heart Rate Change:

- The change in heart rate was calculated as the difference between the post-intervention and pre-intervention heart rate measurements (HR_after - HR_before).

Randomization of participants to different experimental conditions (caffeine type and music genre) was performed using R to ensure unbiased assignment. The sample() function was employed to generate random selections for the city, house, and individual participant, as well as for assigning participants to the experimental conditions.

III. Data Analysis

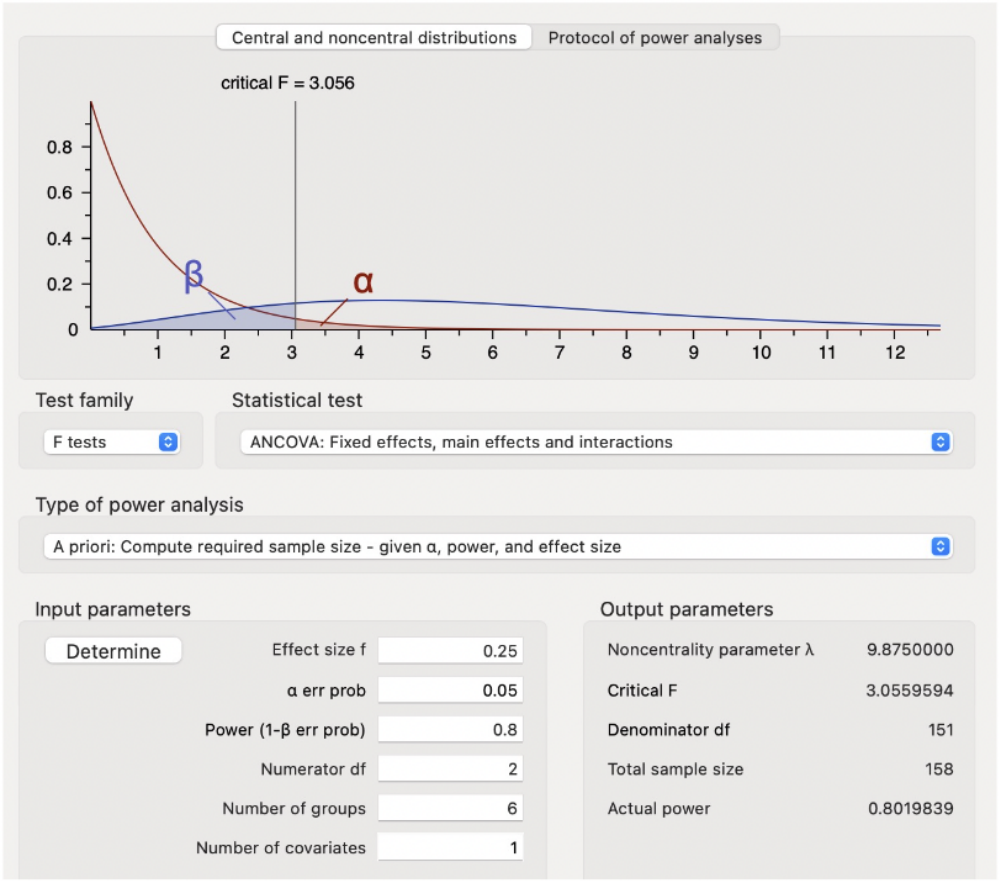
i. Type of Statistical Analysis

The data was collected manually using Excel and then loaded into R for data analysis. We will use a two way Analysis of Variance (ANOVA) with two factors and an interaction term to test whether or not caffeine impacts heart rate, music impacts heart rate, and whether their interaction impacts heart rate. The ANOVA analysis employs the F-Statistic to calculate the ratio between sum of squared errors for the treatment factor and the sum of squared errors for the residuals, ultimately determining whether or not the variation in the model is explained by the predictive factor. Given a factor is significant, we will conduct post-Hoc analysis using Tukey's HSD to determine which levels of the factor are impacting the response variable.

The factors considered in the R analysis are "caffeine" and "music", with the following treatment groups: (decaf - no music) (caf - no music) (decaf - classical) (caf - classical) (decaf - heavy metal) (caf - heavy metal). The treatment group (decaf - no music) acts as the baseline or "control" group to compare results to.

ii. Sample Size Determination

A power analysis was conducted using GPower to determine the appropriate sample size. The following parameters were used:
- Power (1-β): 80%
- Alpha (α): 0.05
- Effect Size (f): 0.25



The analysis indicated that a sample size of 158 would be required to detect a medium effect size. In order to have the same number of subjects for each group, we rounded the sample size up to 168 participants.

IV. Results

i. ANOVA Analysis

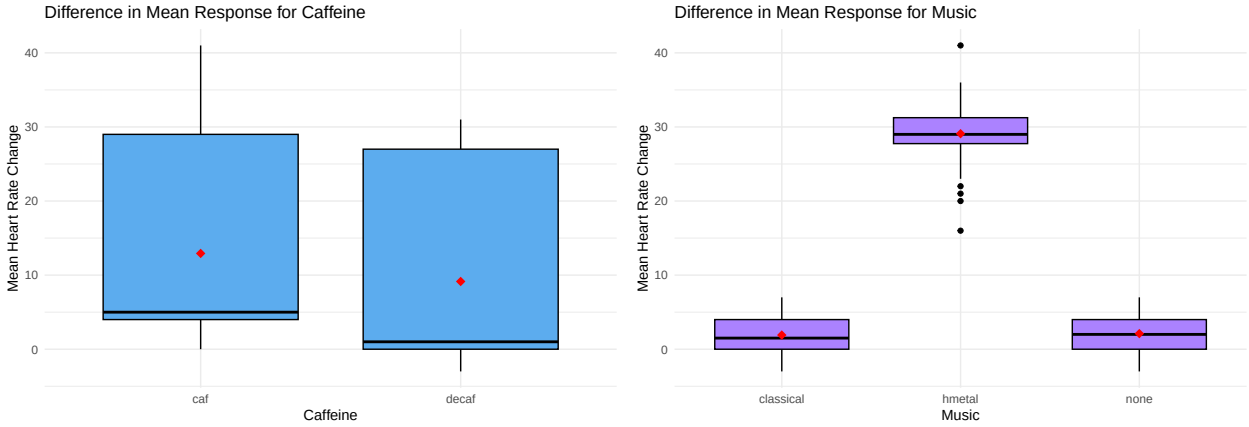
```
## Analysis of Variance Table
##
## Response: diff
##                                Df  Sum Sq Mean Sq   F value Pr(>F)
## factor(caffeine)                1   601.9   601.9  100.0201 <2e-16 ***
## factor(music)                   2 27379.3 13689.7 2274.7564 <2e-16 ***
## factor(caffeine):factor(music)  2    11.6     5.8    0.9644 0.3834
## Residuals                     162   974.9     6.0
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The p-value for the F-statistic for the "caffeine" factor is close to zero, indicating that caffeine has a statistically significant affect on heart rate. The p-value for the "music" factor is also close to zero, indicating that listening to music also has a significant effect on heart rate. The interaction between caffeine and music has a p-value of 0.3834, which is above the critical value 0.05, indicating that the interaction between these two variables does not significantly impact heart rate.

Thus, we reject the null hypothesis and conclude that 1) caffeine has an effect on heart rate, and 2) music has an effect on heart rate. We fail to reject the null hypothesis that interaction impacts heart rate given the high p-value.

ii. Main Effect Plots

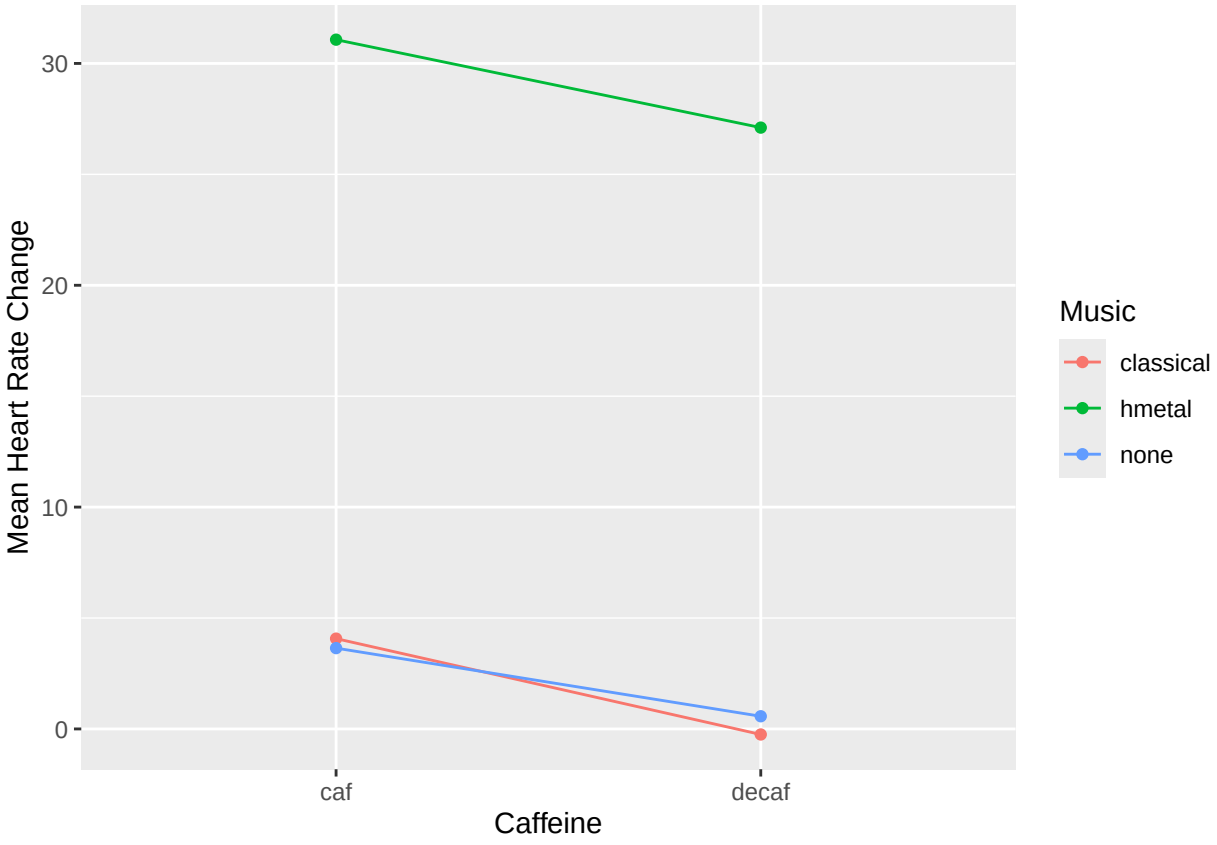
To determine which levels of the caffeine and music factors are significant, we first analyze the main effect plots to visually inspect differences in the response for different factor levels.



The box plot for Caffeine shows a slight difference in the mean change of heart rate between its two levels, suggesting a noticeable difference in means. With a p-value from the ANOVA analysis for caffeine less than 0.05 and considering there are only two caffeine levels, this reinforces the finding that caffeine indeed influences the change in heart rate.

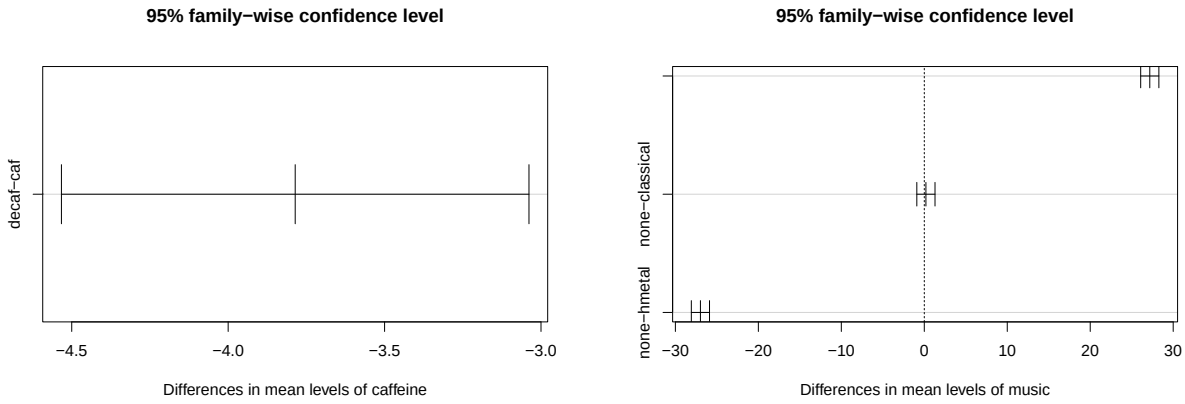
The box plot for Music shows a large difference in the mean change of heart rate between heavy metal and classical music as well as no music, indicating that the heavy metal level is very significant. The difference between classical music and no music appears to be marginal, though could still be statistically significant.

iii. Interaction Plot



The lines in the interaction plot are nearly parallel, indicating that the mean heart rate change for each music treatment level does not differ between the two levels of caffeine. In other words, there doesn't appear to be an interaction between the two factors.

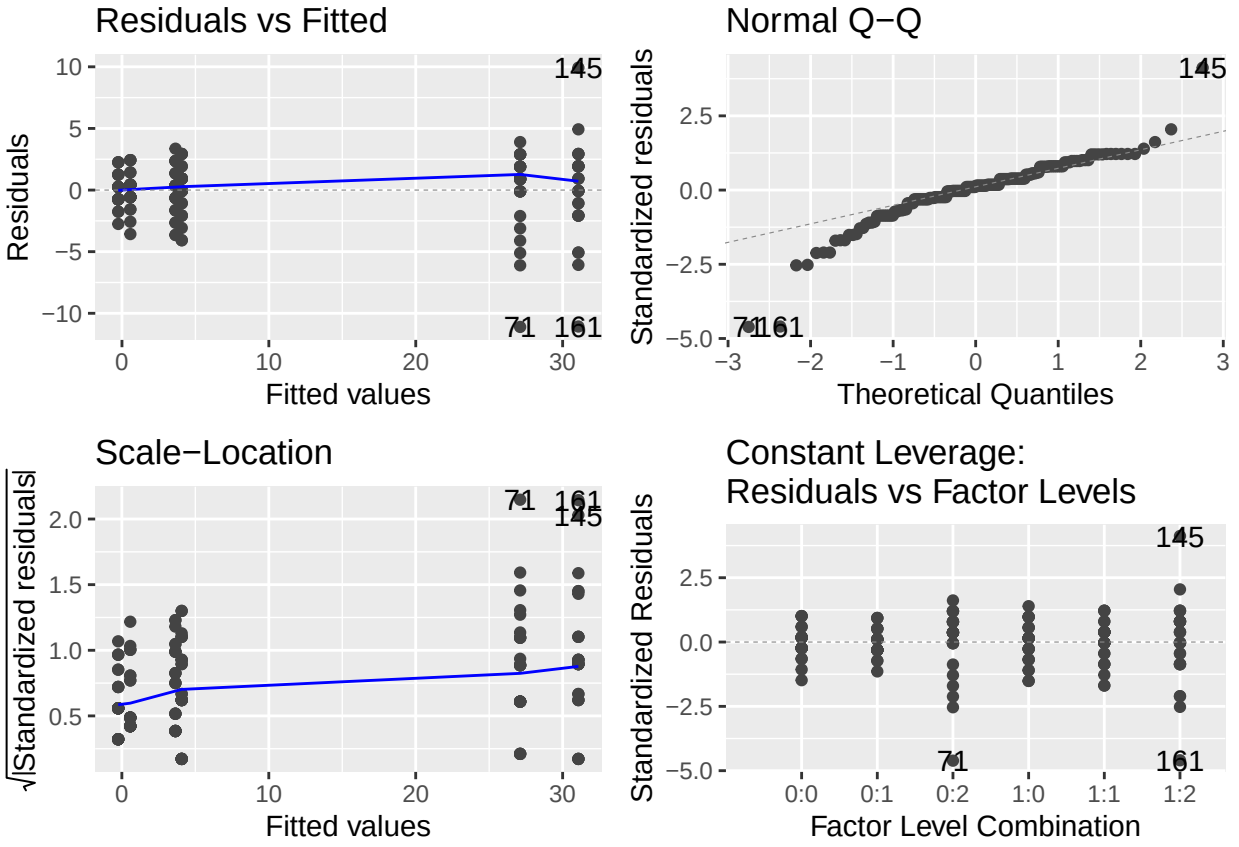
iv. Tukey's Honestly Significant Differences



The Tukey plot shows us the interaction between all the possible combinations for the levels of each factor, in our experiment it shows the different levels of music and caffeine. It gives us more information about which differences in means between the levels are significant. As shown by the Tukey plot we can see that

for Music the interaction between no music (0) and classical music (1) has no significant difference while the interaction between no music (0) and heavy metal music (2) and the interaction between classical music (1) and heavy metal music (2) have significant differences since 0 is not included in the 95% family-wise confidence interval. When looking at caffeine we only looked at the interaction between caffeine and no caffeine and there is a significant difference since 0 is not in the 95% family-wise confidence interval.

v. Model Assumptions



In order to check if model assumptions are met we looked at the residual plots for the model. The blue line in the Residuals vs Fitted plot is relatively horizontal and follows the 0 horizontal line which indicates that the residuals are centered around 0. However when looking closer there is a lack of random scatter which implies there may not be constant variance of the error term. The Normal QQ plato shows slight heavy tails but general normality of the error term. There aren't any apparent outliers in the Fitted Values vs Standardized Residuals plot. Additionally there are no apparent outliers in the constant leverage plot. Overall we can conclude that the normality assumptions are met and the model is adequate.

vi. Model Validity with R-Squared

The multiple R-squared for the model is 0.9663, and the adjusted R-squared is 0.9653. This means that around 96% of the variation in heart rate change is explained by caffeine, music, and their interaction. The high R-squared value indicates that the model is a good fit for the data and validates our conclusions.

V. Conclusion

The study found a significant main effect of caffeine on heart rate with caffeinated coffee increasing heart rate compared to decaffeinated coffee. The study also found a significant main effect of music genre on heart rate, with heavy metal music increasing heart rate and classical music decreasing heart rate compared to no music. There was no significant interaction effect between caffeine and music genre on heart rate. These results align with previous research suggesting that caffeine increases heart rate and relaxing music can potentially lower heart rate.

An extension of this experiment can test if time plays a factor by investigating whether the effects on heart rate differ if participants were exposed to music for a longer or shorter duration. Additionally we can investigate if different sources of caffeine were used (e.g. energy drinks, caffeine pills) instead of coffee. Another possible investigation area would be looking into other types of music genres (e.g. rock, pop, electronic) affect heart rate in comparison to classical and heavy metal music. One block factor we can introduce to a future research experiment is blocking sex and seeing how that affects the study's outcome.

VI. References

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