Caffeine and Cognition: Assessing the Impact of Caffeine on Attention and Energy Levels Across Age Groups on the Island

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1 Abstract

Approximately 85% of the United States population reports consuming at least one caffeinated beverage daily, with 49% specifically consuming coffee. The U.S. Food and Drug Administration indicates that the maximum safe daily caffeine intake for adults is 400 milligrams, equivalent to about four cups of coffee, although the average daily consumption is approximately 150 milligrams. Given the significant proportion of Americans consuming caffeine, particularly coffee, it raises the question of whether caffeine genuinely enhances attention accuracy, as it is known to increase brain activity and promote a sense of focus and attentiveness. We aim to investigate the significant effects of coffee on attention. Our study focuses on the attention level scores of islanders, employing a Randomized Complete Block Design to determine whether the type of beverage (coffee, decaffeinated coffee, or water) and the quantity consumed (250 ml or 500 ml) influence attentiveness. These results could impact the way we associate our attention levels to caffeine and if we really need caffeine in order to be significantly more attentive.

2 Introduction

With a high proportion of Americans consuming substantial amounts of caffeine daily, our study seeks to assess the effectiveness of caffeine. A central nervous system stimulant, caffeine is present in various substances, including coffee beans, tea leaves, and synthetic forms. Among these, beverages are the most common type of caffeine consumption. An 8-ounce cup of coffee typically contains between 95-200 mg of caffeine, while a 12-ounce can of soda provides 35-45 mg, and an 8-ounce cup of tea offers 14-60 mg. Caffeine's stimulating effects are widely acknowledged, often resulting in increased energy and alertness among consumers. Given its widespread use, understanding the precise impact of caffeine on cognitive functions such as attention is of considerable interest both scientifically and socially.

The impact of caffeine consumption varies considerably based on individual preferences and physiological responses. For some, an intake of 200 mg of caffeine represents a typical daily amount, while for others, this level can lead to overstimulating and adverse effects such as intense shaking. These variations portray the need for a detailed examination of how caffeine affects attention and cognitive performance across different individuals. Factors such as genetic makeup, tolerance levels, and concurrent dietary habits can influence how caffeine is metabolized and its subsequent effects on the body. Therefore, our study aims to capture these diverse responses to provide a nuanced understanding of caffeine's role in enhancing or impairing attention.

Our study was motivated by our experiences as students relying on caffeine to enhance study endurance and exam performance. Recognizing the prevalence of caffeine use in academic settings, we aimed to investigate its impact on attention levels, which we frequently associate with our own caffeine consumption. Through this research, we seek to provide a comprehensive analysis of the relationship between caffeine intake and attention scores, contributing to a better understanding of how this common stimulant affects cognitive function. By conducting controlled experiments and utilizing the attention tests from the Island, we aim to draw conclusions that can both inform academic strategies and general lifestyle choices related to caffeine consumption.

3 Methods

3.1 Participants

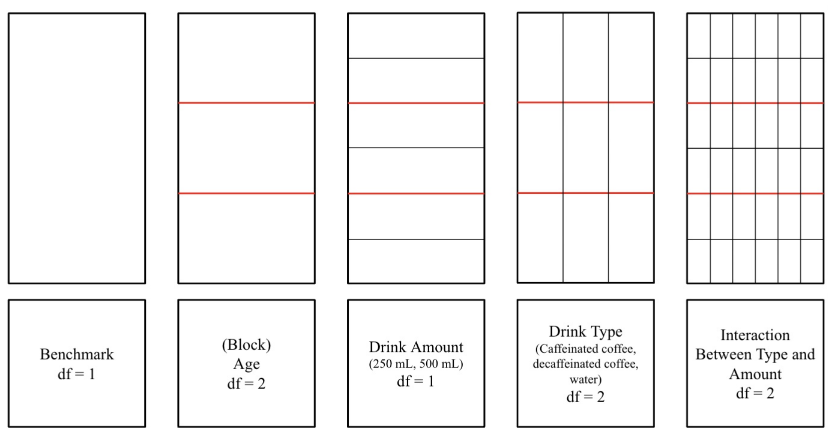
The participants in our study were islanders. To minimize noise in our study, we sampled islanders exclusively from "Providence". Starting in the city "Akkeshi", we noted the number of houses and used R to randomly generate house numbers until we had 54 islanders in each of our age blocks. Then we again used R to randomly assign islanders in each age block to a number 1 - 6, representing different treatment combinations.

3.2 Design

We used a Two-Way Randomized Block Design for our study as pictured below:

Response Variable	Attention Test Score		
Treatment 1 (Amount)	250 mL	500 mL	
Treatment 2 (Type)	Caffeinated Coffee	Decaffeinated Coffee	Water
Blocking (Age)	18 – 38 years	39 – 58 years	59+ years

Our factor diagram is pictured below:



3.3 Procedure

Step 1: Find 54 islanders that consented to take part in our study in each age block (18 - 38 years, 39 - 58 years, 59+ years).

Step 2: Administer the baseline attention test to all 162 participants and note the scores for each islander.

Step 3: Randomly assign participants within each age block to one of the six treatment combinations (250 mL of caffeinated coffee, 500 mL of caffeinated coffee, 250 mL of decaffeinated coffee, 500 mL of decaffeinated coffee, 250 mL of water, and 500 mL of water).

Step 4: Administer each of the islanders' respective assigned treatment combinations.

Step 5: For each islander, after 30 minutes since they finished consuming their assigned beverage(s), readminister the attention test and note their score again.

Step 6: Calculate the paired difference of each islander's attention test scores (post intervention score - baseline attention score) – this is our response variable.

Step 7: Use split-plot ANOVA and mixed-effects models to analyze the effects, controlling for baseline levels and individual differences.

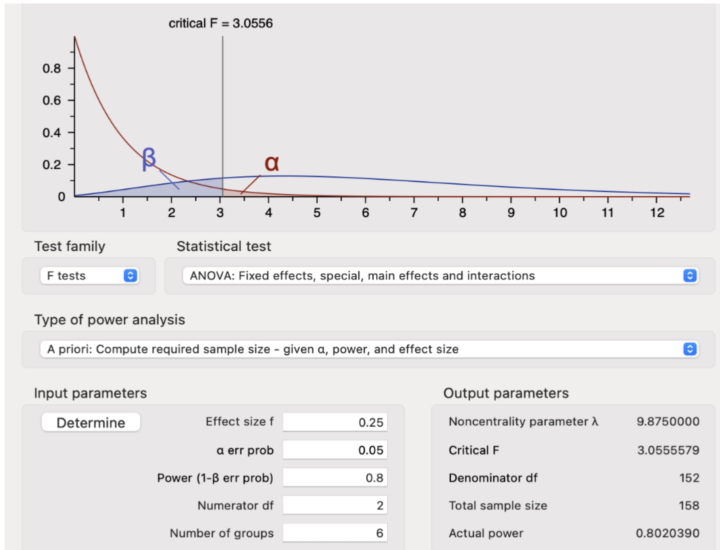
4 Data Analysis

4.1 Type of Statistical Analysis

We conducted an ANOVA test using R on the collected data. F-testing was applied within treatments and blocks to determine if there were significant differences in attention scores between our groups and to determine if there was any interaction between the amount and type of drink. We included water as a drink type to serve as a control group, as it is non-caffeinated and does not contain coffee.

4.2 Sample Size Determination

We used the default G*Power settings to determine our sample size. This specified a power of 0.8, meaning there is an 80% probability of correctly rejecting a false null hypothesis. This also set an alpha level of 0.05, indicat-



ing a 5% probability of falsely rejecting the null hypothesis. Finally, it also set the effect size to 0.25, representing a small to medium difference between groups. We then set our numerator degrees of freedom to 2, calculated as (number of different drink amounts - 1) $\times$ (number of different drink types - 1) = (2 - 1) $\times$ (3 - 1) = 2. Additionally, we had 6 groups for our 6 different treatment combinations.

4.3 ANOVA Analysis

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
type	2	16.4	8.191	0.404	0.669
amount	1	2.7	2.722	0.134	0.715
age_factor	2	62.3	31.136	1.535	0.219
type:amount	2	20.1	10.056	0.496	0.610
type:age_factor	4	33.4	8.340	0.411	0.800
amount:age_factor	2	18.4	9.185	0.453	0.637
type:amount:age_factor	4	40.5	10.130	0.499	0.736
Residuals	144	2921.3	20.287		

4.4 R-squared Calculations

Total Sum of Squares (TSS)

The Total Sum of Squares (TSS) is calculated as the sum of all the sums of squares from the ANOVA table:

$$\text{TSS} = 16.4 + 2.7 + 62.3 + 20.1 + 33.4 + 18.4 + 40.5 + 2921.3 = 3115.1$$

R-squared (R^2)

The R-squared value (R^2) is calculated using the formula:

$$R^2 = 1 - \frac{\text{RSS}}{\text{TSS}}$$

Where RSS is the Residual Sum of Squares:

$$R^2 = 1 - \frac{2921.3}{3115.1} \approx 0.062$$

Adjusted R-squared ($\bar{R}^2$)

The Adjusted R-squared ($\bar{R}^2$) adjusts the R^2 for the number of predictors in the model. It is calculated using the formula:

$$\bar{R}^2 = 1 - \left(\frac{(1 - R^2) \times (n - 1)}{n - p - 1} \right)$$

Where n is the number of observations (162) and p is the number of predictors (12):

$$\bar{R}^2 = 1 - \left(\frac{(1 - 0.062) \times (162 - 1)}{162 - 12 - 1} \right) \approx 0.012$$

Conclusions

The ANOVA analysis was conducted to evaluate the effects of the type and amount of coffee on attention scores, taking into account the interaction with age groups. The results can be summarized as follows:

- **Type of Coffee:** The ANOVA results show no significant effect of the type of coffee (caffeinated, decaffeinated, or water) on the difference in attention scores ($F(2,\ 150) = 0.404$, $p = 0.669$). This indicates that the type of beverage consumed does not significantly influence changes in attention scores.

- **Amount of Coffee:** Similarly, the amount of coffee (250 ml vs. 500 ml) did not have a significant effect on the attention scores ($F(1,\ 150) = 0.134$, $p = 0.715$). This suggests that the volume of beverage intake does not significantly impact attention.

- **Age Group:** The interaction between age and other factors (type and amount of coffee) was also not significant. This is reflected in the F values for age ($F(2,\ 150) = 1.535$, $p = 0.219$) and interactions like type and amount ($F(4,\ 150) = 0.411$, $p = 0.800$; $F(2,\ 150) = 0.496$, $p = 0.610$). Therefore, age groups did not significantly influence how the type and amount of coffee affected attention.

- **Overall Model Fit:** The low R^2 and adjusted R^2 values indicate that the model explains only a small fraction of the variability in attention scores. Specifically, the R^2 value of approximately 0.062 suggests that only 6.2% of the variability is accounted for by the model, and the adjusted R^2 of about 0.012 indicates minimal improvement after adjusting for the number of predictors.

In summary, the type and amount of coffee, as well as their interactions with age, do not significantly affect attention scores in this study.

5 Plot Results

5.1 Residual Diagnostics

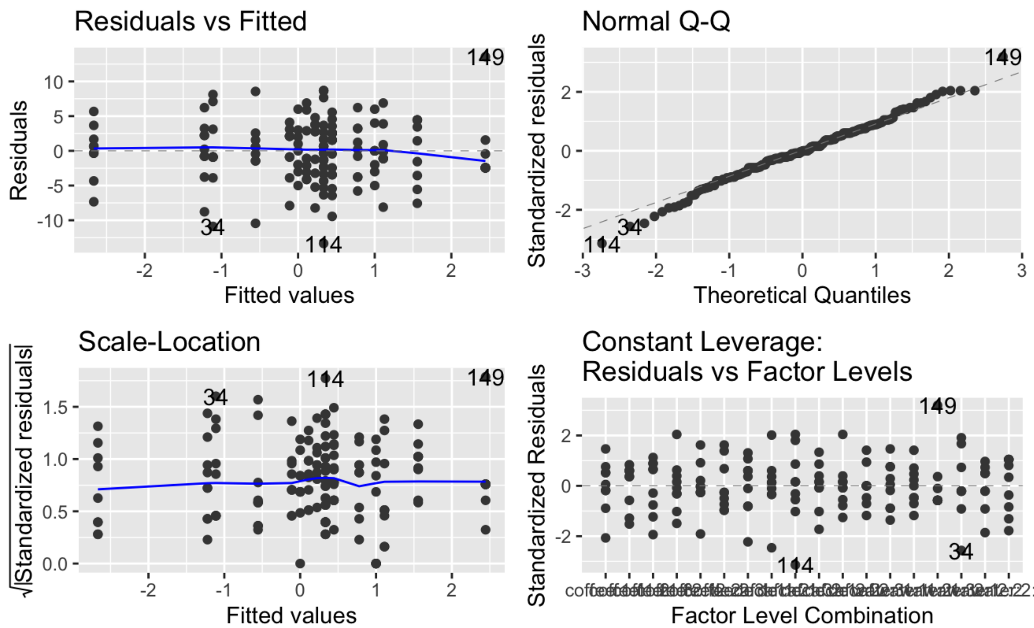


Figure 1: **Diagnostic Plots for ANOVA Model:** The plots provide a detailed assessment of the ANOVA model assumptions. The *Residuals vs Fitted* plot (top left) checks for homoscedasticity and reveals no clear patterns, indicating that the residuals are randomly scattered and thus the model fits well. The *Normal Q-Q* plot (top right) assesses the normality of the residuals, showing that they closely follow a normal distribution. The *Scale-Location* plot (bottom left) checks for constant variance across fitted values, confirming that the spread of residuals is consistent. The *Residuals vs Factor Levels* plot (bottom right) examines the influence of factor levels on residuals, indicating no significant impact of the factor levels on residuals. These plots collectively affirm that the model assumptions are satisfied, supporting the validity of the ANOVA analysis conducted on the effects of coffee type and amount on attention scores.

5.2 Interaction Plot Analysis

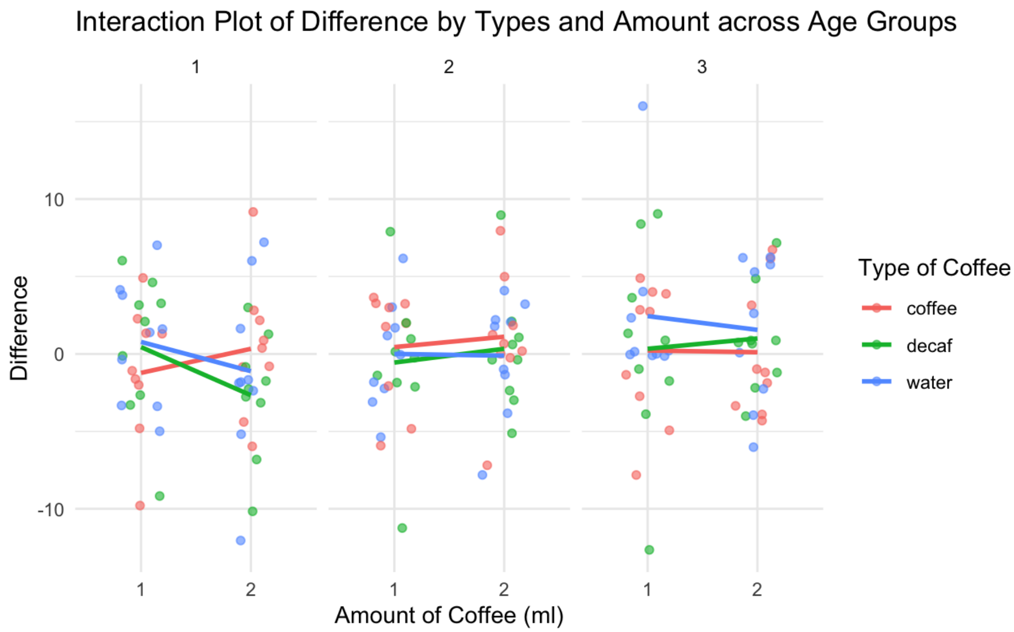


Figure 2: **Interaction Plot of Difference in Attention Scores by Types and Amount of Coffee across Age Groups:** This plot visualizes the interaction between the type of coffee (caffeinated, decaffeinated, water) and the amount of coffee (250 ml, 500 ml) across three age groups. The y-axis represents the difference in attention scores (postscore - prescore), while the x-axis categorizes the amount of coffee. The lines represent different types of coffee.

Overall Pattern: The differences in scores are generally centered around zero, indicating that there is no drastic change in attention scores after coffee consumption across different groups. This visual inspection aligns with the results of the ANOVA. Thus, we conclude that the intervention of different coffee types and amounts does not significantly impact attention scores.

5.3 Box Plot Analysis

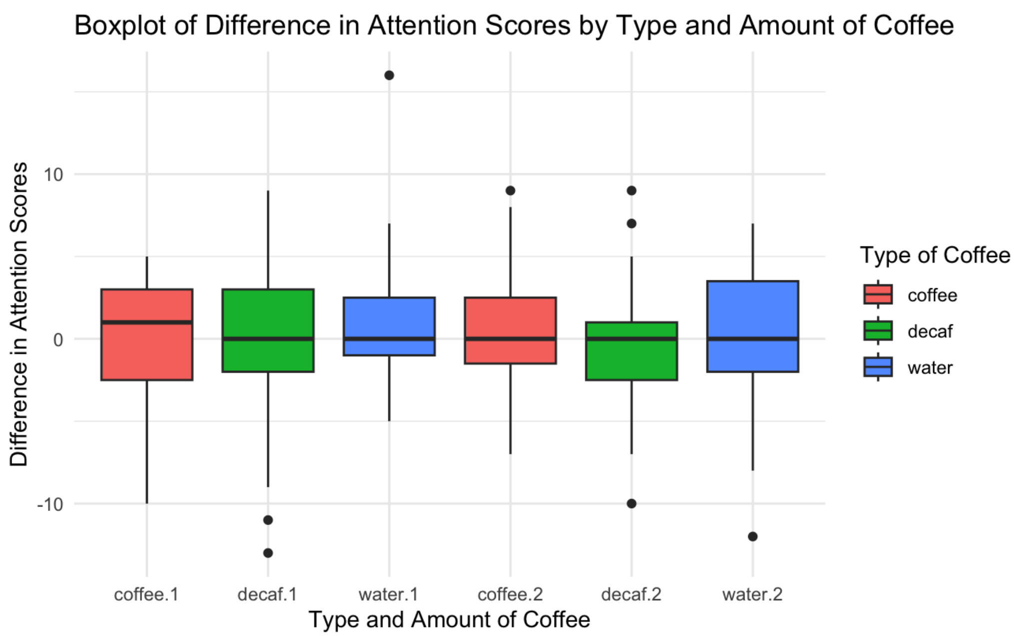


Figure 3: Boxplot of Difference in Attention Scores by Type and Amount

Analysis

- **General Distribution:** The median lines for all combinations are centered around zero, indicating no significant effect of coffee type and amount on attention scores. The interquartile ranges (IQR) are fairly consistent, showing similar variability across groups.

- **Comparison by Type and Amount:**

  - **Coffee (Red):** Both amounts (250 ml and 500 ml) have medians around zero. The data spread is similar, with no significant outliers, suggesting a consistent impact on attention scores.

  - **Decaf (Green):** Medians for decaf at both amounts are near zero. The IQR is larger for decaf.1, indicating more variability.

There are some outliers, but they do not significantly affect the overall pattern.

  - **Water (Blue):** Water.1 has a median close to zero with a similar spread to other groups. Water.2 shows a slightly higher median and more variability, with several high outliers, indicating a more varied response to higher water consumption.

Overall Pattern: The boxplot analysis aligns with the ANOVA results. The consistency in medians and overlapping ranges suggest these factors do not produce meaningful differences in attention scores.

6 Discussion and Conclusion

This research aimed to investigate the effects of different types and amounts of coffee on attention scores across various age groups. The experiment involved administering pre-tests and post-tests to participants who consumed either caffeinated coffee, decaffeinated coffee, or water in two different quantities (250 ml and 500 ml). The key objective was to determine whether these interventions had any significant impact on attention levels, as measured by the difference between post-test and pre-test scores.

6.1 Summary of Findings

Our analysis used ANOVA to evaluate the main effects and interactions of coffee type and amount on attention scores, with blocking by age to control for age-related differences. The ANOVA results revealed no significant main effects or interactions for the type and amount of coffee on attention scores. The p-values for all tested effects were well above the conventional significance threshold of 0.05, indicating that any observed differences in attention scores are likely due to random variation rather than the interventions.

6.2 Visual Insights from Interaction and Boxplots

The interaction plot and boxplot further supported these findings:

- The **interaction plot** demonstrated that the differences in attention scores across the age groups were minimal and did not significantly change based on the type or amount of coffee consumed. The lines representing different groups remained mostly flat and intersected, suggesting no clear pattern of interaction effects.
- The **boxplot** revealed that the distribution of attention score differences for each type and amount of coffee was centered around zero, with overlapping interquartile ranges. This overlap indicates that the variations in attention scores are not statistically significant across the different treatment conditions.

6.3 Interpretation and Implications

These results suggest that neither the type nor the amount of coffee has a substantial effect on attention scores within the context of this study. This finding aligns with the notion that, for the general population, moderate consumption of coffee (caffeinated or decaffeinated) and water does not significantly alter attention performance. From a practical perspective, these findings imply that individuals looking to improve attention and cognitive performance may not benefit from adjusting their coffee intake, at least not in the moderate quantities and contexts tested in this study. Additionally, age did not significantly modify the effects of coffee and water on attention, suggesting that the consumption habits of these beverages have a consistent impact (or lack thereof) across different age groups.

6.4 Limitations and Future Research Directions

While the current study provides valuable insights, it is not without limitations. The following considerations should be addressed in future research:

- **Sample Size and Diversity:** The study included a relatively small and specific sample size (all of our samples were collected from the Providence Island, and only sampling between 6-9 AM). Future studies should aim to include a larger and more diverse sample to improve the generalizability of the findings.
- **Control of External Variables:** Although we controlled for age, other factors such as individual tolerance to caffeine, baseline cognitive performance, and diet were not controlled. Future research could benefit from a more comprehensive approach to controlling or accounting for these variables.
- **Extended Consumption and Testing Periods:** The effects of coffee and other beverages might vary with prolonged consumption and testing periods. Future studies could explore long-term consumption effects and include multiple post-test intervals to capture more nuanced changes in attention.

6.5 Concluding Remarks

In conclusion, this study highlights that moderate consumption of caffeinated and decaffeinated coffee, as well as water, does not significantly impact attention scores across different age groups. These findings contribute to the understanding of dietary influences on cognitive performance and suggest stability in attention performance irrespective of moderate coffee consumption. Future research should expand on these findings by exploring additional variables and contexts to further elucidate the relationship between beverage consumption and cognitive function.

7 References

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