

# Technical Report

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## 1 Abstract

Caffeine is an extremely popular stimuli used by people all over the world to enhance their performance. It has become somewhat of a modern staple to indulge in caffeinated beverages at the start of the day to help overcome the lethargy of the morning. Before major presentations, study sessions or tests, people will often indulge in a large dose of caffeine before beginning the task to boost productivity. The study explored various mental stimuli and if they have an impact on performance for cognitive tasks. Using random blocking on a simulated population, participants were given stimuli, such as cocaine or various kinds of energy drinks, and then asked to perform a memory card game. The results show that none of the tested treatments impacted memory card scores. In response, our findings suggest that stimulants such as caffeine and cocaine do not enhance cognitive performance, at least in the context of short-term memory tasks.

## 2 Introduction

Cocaine is a powerful stimulant that increases hyperactivity and alertness, among other effects. Despite being highly addictive and illegal, its euphoric effect and performance-enhancing properties have still kept it in use among individuals seeking heightened alertness and cognitive stimulation. In contrast, energy drinks contains legal stimulants that are often widely consumed for some of the similar benefits of cocaine: strengthening alertness and performance.

This study aims to analyze and compare the effects of cocaine the effects that both cocaine and energy drinks impact cognitive performance, particularly in memory related tasks. Additionally, we differentiated between sugar-free energy drinks and caffeine-free energy drinks to check which stimulant in energy drinks might be affecting the population differently. The data was gathered on random villages across the islands, reducing the bias different locations might provide. Furthermore, this research was done on people ranging from ages 18-65, ensuring our analysis is representative of a general population who may consume these substances. By evaluating memory retention scores across different treatment groups such as age, gender and education level, we compare how these two stimulants affect peoples memory.

- How does cocaine impact scores on mental cognition?
  - Null hypothesis: cocaine usage has no impact on the memory task score.
  - Alternative hypothesis: cocaine usage alters memory task score results.
- How does energy drink consumption impact scores on mental cognition?
  - Null hypothesis: Energy drink consumption has no impact on the memory task score.
  - Alternative hypothesis: Energy drink consumption usage alters memory task score results.
- How do the effects of cocaine compare to energy drinks on cognitive performance?
  - Null hypothesis: There is no difference between energy drinks and cocaine's memory test score.
  - Alternative hypothesis: There is a difference the two stimulants.

The paper is outlines as follows: section 3 details the experimental methodology, including participant selection, treatment assignments, and data collection procedures. Section 4 presents the analysis of cognitive performance across treatment groups. Section 5 discusses the results, highlighting key findings and their implications. Section 6 outlines limitations of the study and potential areas for future research. Section 7 is a conclusion summarizing our findings followed by section 8 which is the appendix of our code.

### 3 Methodology

The data was collected on individual Island accounts between February 21-23 during the day by Ana Elisa Lopez-Miranda, Diptanshu Chaudhari, Taleen Abraham, and Yuta Kondo. The experiment used Randomized-Block Design. The experimental units were the participants on the Islands (a simulated population). The experiment was a between-subjects design. Each participant underwent one of five treatments and performed a memory task to asses their memory performance. The quantitative response variable was the individual’s memory card score where participants were required to recall previously shown information after undergoing their treatment. The qualitative explanatory variables were the treatments administered to the participants. The treatments were cocaine insufflation 50 mg, energy drink 250 mL, energy drink caffeine-free 250 mL, energy drink sugar-free 250 mL, and the control group. 150 total observations were taken with 30 observations for each treatment. Within the 30 observations, 10 were from the first blocked age group, 10 from the second, and 10 from the third. Ana Elisa gave the control treatment to the people of the Gordes and the energy drink treatment to the people of Riludo Station and Bjurholm. Diptanshu gave the energy drink (sugar-free) treatment to the people of Helvig. Taleen gave the cocaine treatment to the people of Arcadia. Yuta gave the energy drink (caffeine-free) treatment to the people of Biruwa.

This experiment is hard to control. As such, the project relied heavily on blocking. Ages were blocked into the following groups: 18-24, 25-44, and 45-65. Gender, location, and education were also blocked. In the data sampling process, age was treated categorically in groups (18-24, 25-44, 45-65), but for the general linear model analysis, age was explicitly treated as a continuous quantitative nuisance variable to control for age-related variability. To ensure randomization, each team member was randomly assigned a treatment. Further, after creating a list of all the villages in the Islands, villages were systematically randomly sampled for each of the treatments. Within the villages, every person between the ages of 18-65 was enrolled into the experiment until there were at least ten participants in each age block. Ten participants were then randomly selected within their respective age blocks to ensure balanced design. The experiment was replicated 30 times per treatment.

### 4 Analysis

The summary statistics for the collected data are presented below:

	Min	Median	Max	Mean	SD	IQR
Value	18	32	65	36.21	14.57372	25.75

Table 1: Summary of Age

Table 1 indicates that, despite using a balanced design (50 samples per age group: 18–24, 25–44, 45–65), the median age is lower than the mean.

Table 2 and Figure 1 show that, for Treatment, the median was 9 out of 10, with a standard deviation of approximately 1.67, indicating that most participants received high scores.

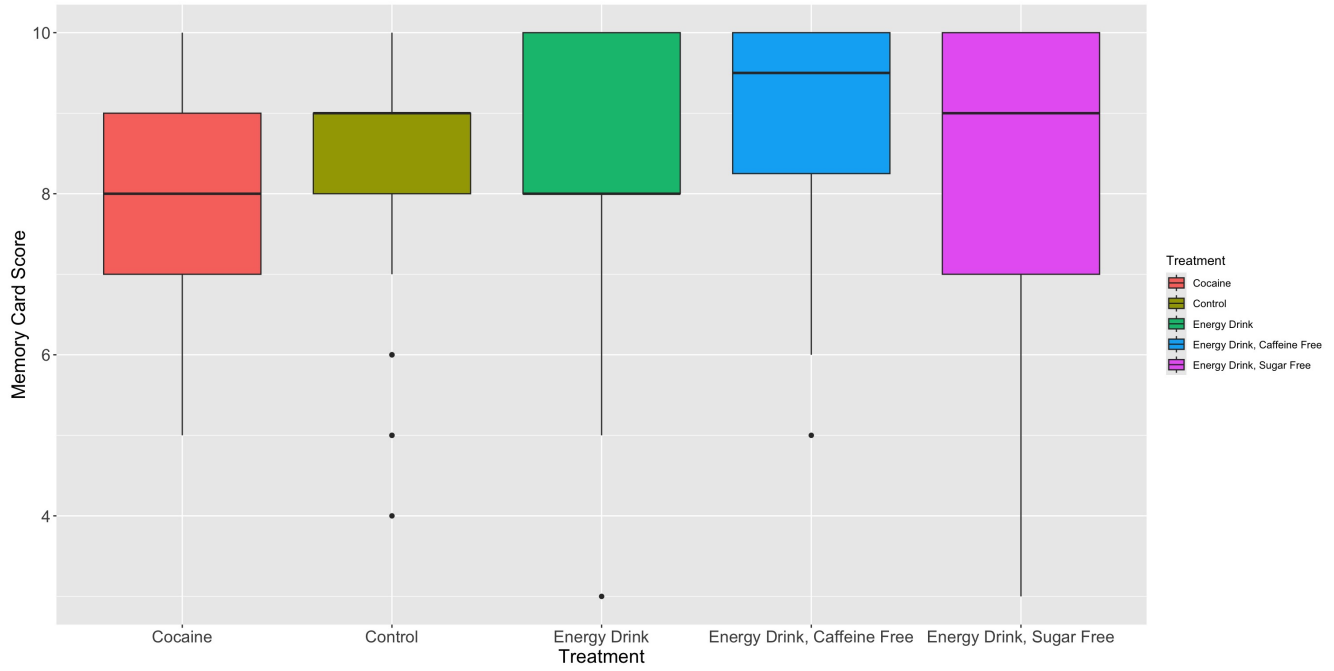


Figure 1: Memory Card Scores for Each Treatment

	Min	Median	Max	Mean	SD	IQR
Value	3	9	10	8.32	1.672197	2.75

Table 2: Summary of Card Score

Then, we used General Linear Model (GLM) to test our research questions. To conduct this, we checked the following assumptions:

1. Independence of samples
2. Normality of Residuals
3. Homogeneity of Variances

For (1) Independence of samples, this condition was satisfied because the data were collected independently.

For (2) Normality of Residuals, initially, the residuals did not satisfy normality. Therefore, we applied a Box-Cox transformation. After transformation, Figure 2's QQ plot shows minor deviations at large quantiles, but these deviations are acceptable. Hence, the normality assumption is satisfied.

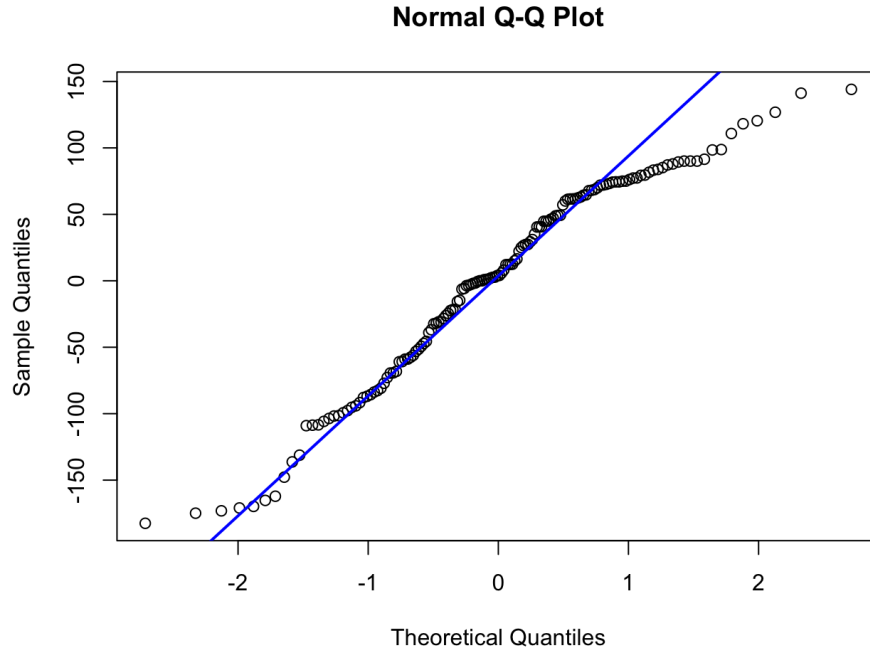


Figure 2: QQ plot of General Linear Model (GLM)

For (3) Homogeneity of variances, Figure 3 illustrates that the square root of standardized residuals versus fitted values plot is within the acceptable range, indicating that this condition is satisfied.

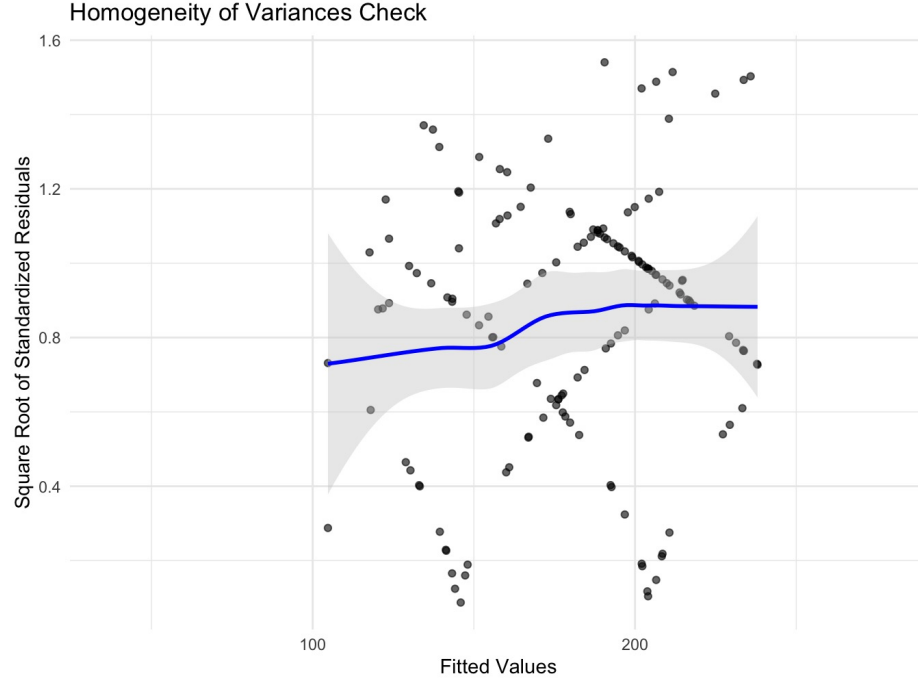


Figure 3: Homogeneity of Variance Plot

Thus, all assumptions for the general linear model are satisfied.

We used an additive model because our experiment used a randomized blocked design, which explicitly assumes no interactions between blocked covariates and treatments. The final model is as follows:

$$\begin{aligned}
y_{\text{alt},i} = & \beta_0(\text{reference: Control, Arcadia, Female, High School}) \\
& + \beta_1 I_{\{\text{Cocaine}_i=1\}} + \beta_2 I_{\{\text{Energy Drink}_i=1\}} \\
& + \beta_3 I_{\{\text{Energy Drink Caffeine Free}_i=1\}} + \beta_4 I_{\{\text{Energy Drink Sugar Free}_i=1\}} \\
& + \beta_5 \text{Age}_i + \beta_6 I_{\{\text{Bjurholm}_i=1\}} \\
& + \beta_7 I_{\{\text{Gender}_i=\text{Male}\}} \\
& + \beta_8 I_{\{\text{Education Level}_i=\text{No Degree}\}} \\
& + \beta_9 I_{\{\text{Education Level}_i=\text{University}\}} + \epsilon
\end{aligned}$$

where  $I$  is an indicator function such that:

$$I_{\{\text{Condition}\}} = \begin{cases} 1 & \text{if Condition is true} \\ 0 & \text{otherwise} \end{cases}$$

and  $\epsilon \sim N(0, \sigma^2)$ . Also, locations Gordes, Helvig, Riludo Station, and Biruwa are excluded due to singularities, and thus implicitly included in the intercept ( $\beta_0$ ).

The summary of coefficients and significance tests is shown below:

Table 3: Summary of coefficients and p-values for additive model

Variable	Estimate	Std. Error	t value	Pr(>  t )
(Intercept)	249.3990	23.1502	10.773	< 2e-16
Treatment: Cocaine	-22.2188	20.3963	-1.089	0.2779
Treatment: Energy Drink	-130.8311	80.4978	-1.625	0.1064
Treatment: Energy Drink, Caffeine Free	27.1466	20.5016	1.324	0.1876
Treatment: Energy Drink, Sugar Free	-5.2443	20.3833	-0.257	0.7973
Age	-2.1515	0.5093	-4.225	4.29e-05
Location: Bjurholm	137.1146	80.6606	1.700	0.0914
Gender: Male	0.1867	13.0630	0.014	0.9886
Education Level: No Degree	40.4770	80.7028	0.502	0.6168
Education Level: University	16.9906	14.9102	1.140	0.2564

Locations Biruwa, Gordes, Helvig, and Riludo Station were excluded from table due to singularities.

The result shows that the p values of all treatment factors are greater than 0.05, which means that we conclude that there are no significant effects for any of our treatments.

Although we are not interested, we observed a relationship between age and memory card score performance, since the p-value for age is less than 0.05.

## 5 Discussion

This study aimed to examine the effects of cocaine and energy drinks on cognitive performance using memory test scores. The results indicate that all treatments, including cocaine and standard energy drinks, did not significantly influence memory task scores, as none of them had significant p-values. We will now address each research question from the introduction.

### 1. How does cocaine impact scores on mental cognition?

- Table 3 showed that cocaine had an estimated coefficient of  $-22.22$  with a p-value of 0.2779. Since a p-value is greater than 0.05, cocaine did not have a statistically significant effect on memory recall compared to the control group. The box plot (Figure 1) further supports this, as the median memory card score for the cocaine group was around 9, similar to the control group. This suggests that cocaine did not significantly enhance or impair memory recall. While cocaine is known to increase alertness, these results imply that it does not necessarily improve structured memory recall tasks.

## 2. How does energy drink consumption impact scores on mental cognition?

- Table 3 shows that none of the energy drink variations had a statistically significant impact on memory recall. Regular energy drinks had an estimated coefficient of  $-130.83$  ( $p = 0.1064$ ) in the additive model, indicating no significant effect. Caffeine-free energy drinks had an estimated coefficient of  $27.14$  ( $p = 0.1876$ ), which is not statistically significant. Similarly, sugar-free energy drinks had coefficients of  $-5.24$  ( $p = 0.7973$ ), showing no significant difference from the control group. These results indicate that energy drink consumption does not impact scores on mental cognition, no matter the variation of the energy drink.

## 3. How do the effects of cocaine compare to energy drinks on cognitive performance?

- There was no significant difference between the cognitive performance of participants who consumed cocaine and those who consumed energy drinks. Table 3 indicates that all treatment p-values were above 0.05, meaning that neither cocaine nor any energy drink variation significantly impacted memory scores compared to the control group.

Additionally, the data showed a strong negative correlation between age and memory performance ( $p < 0.001$ ), with an estimated coefficient of  $-2.15$  (Table 3), which suggests that memory function declines with age. Gender ( $p = 0.9886$ ) and education level ( $p > 0.05$ ) did not play significant roles, indicating that memory recall performance was relatively consistent across these demographics.

## 6 Limitations

We failed to reject any of our null hypotheses. There are three possible factors that could explain why we failed to reject anything in our study: the under-representation of people with lower educational levels, the method used to analyze cognitive ability, and the dosage given to participants was not high enough for a short term study. Our dataset included only one participant who did not graduate high school. A larger sample of individuals with lower education levels may have led to more significant findings. Our participants not coming from varied educational backgrounds could have impacted how well it worked out. There are issues with the memory test as well, as more than half of the population got a score above 9. Thus, it was not a good measure of intelligence, or the impact of these stimulants. Finally, the dosage of cocaine or the caffeine and sugar content in energy drinks may not have been enough to produce measurable cognitive differences in a short-term study. That could explain why there was not enough variability in the scores.

In the future, we could include people across all education levels, ensuring that we have enough people in our dataset who lack a high school education. We also could reshape our study to test for factors outside of memory, such as IQ tests. Cognitive ability is not just limited to the person's memory, so a different test could have yielded better results for the group overall. Our study only examined the short-term effects of these substances. Both cocaine and energy drinks may have longer-term impacts on cognition that were not tested in our experiment. Checking with the users after a set time could return different results for our experiments. In the future, we plan to refine our methodology by including additional cognitive tests, and accounting for lifestyle factors. Testing long term affects of these substances could also reveal different information about how these substances affect a person.

## 7 Conclusions

This study examined the effects of cocaine and various energy drinks on cognitive performance, specifically memory recall. Our findings indicate that none of the tested treatments (cocaine, standard energy drinks, sugar-free energy drinks, and caffeine-free energy drinks) had a statistically significant impact on memory task scores. Additionally, we observed that age had a strong negative correlation with memory performance, while factors such as education level and gender did not significantly influence results. The lack of significant findings may be due to several limitations, including the cognitive test used, which may not have been sensitive enough to detect changes, which may not have been sufficient to produce measurable effects in a short-term study.

Future research may benefit from exploring different stimulants such as nicotine and Adderall alongside energy drinks and cocaine. Different substances might have different affects on the body, so it might be valuable to look at how these stimulants affect the body. Future studies might also look at how these stimulants affect different other aspects of our behavior, like processing speed or attention. Finally, future studies can investigate the impact of

these stimulants over longer periods of time, to see how these affect human behavior. Short term affects can widely differ in the long term, so checking how these stimulants affect people can be valuable.

## 8 Appendix

- ChatGPT link to generate latex code for the model: <https://chatgpt.com/share/67da3f90-e2f8-8007-838c-e9b7e45deac9> and <https://chatgpt.com/share/67ddc41e-b910-8007-8c73-7580e3a60a6b>
- ChatGPT link to generate latex code for tables: <https://chatgpt.com/share/67ddbd37-b3a8-8007-b5b0-537e42c7fe1d>
- ChatGPT link to fix grammar: <https://chatgpt.com/share/67da4ab0-0bdc-8007-af06-841c1847fe94>

Below is the R code used in Analysis:

```
df <- read.csv("island_data.csv")

library(MASS)

# Model before Box-Cox Transformation
initial_model <- lm(Memory.card.score ~ Treatment + Age + Location + Gender +
                    Education.Level, data = df)

initial_model$call$data <- df # Prevent bugs.

# Box-Cox transformation to determine lambda
boxcox_result <- boxcox(initial_model, lambda = seq(-2, 4, 0.1))
lambda <- boxcox_result$x[which.max(boxcox_result$y)]

# Transform the response variable
df$y_alt <- (df$Memory.card.score^lambda - 1) / lambda

# Additive Model
additive_model <- lm(y_alt ~ Treatment + Age + Location + Gender +
                    Education.Level, data = df)

# Q-Q Plot to check normality
qqnorm(residuals(additive_model))
qqline(residuals(additive_model), col = "blue", lwd = 2)

# Check homogeneity of variances
library(performance)
check_model(additive_model, check = "homogeneity")

library(ggplot2)

# Extract fitted values and standardized residuals
df_plot <- data.frame(
  Fitted = fitted(additive_model),
  Std_Residual = sqrt(abs(rstandard(additive_model)))
)

# Clearly plot with desired labels and gray confidence area
ggplot(df_plot, aes(x = Fitted, y = Std_Residual)) +
  geom_point(alpha = 0.6) +
  geom_smooth(se = TRUE, method = "loess", color = "blue", fill = "gray80") +
  labs(
    x = "Fitted-Values",
    y = "Square-Root-of-Standardized-Residuals",
    title = "Homogeneity-of-Variances-Check"
```

```
) +  
theme_minimal()
```

```
df$Location <- as.factor(df$Location)  
df$Gender <- as.factor(df$Gender)  
df$Education.Level <- as.factor(df$Education.Level)  
df$Treatment <- as.factor(df$Treatment)  
df$Treatment <- factor(df$Treatment, ordered = FALSE)  
df$Treatment <- relevel(df$Treatment, ref = "Control")  
levels(df$Treatment)
```

```
# Interaction Model (for unequal slopes) (not used in the report)  
interaction_model <- lm(y_alt ~ Treatment * Age + Location + Gender +  
                        Education.Level, data = df)  
summary(interaction_model)  
anova(interaction_model)
```

```
# Additive Model  
additive_model <- lm(y_alt ~ Treatment + Age + Location + Gender +  
                    Education.Level, data = df)  
summary(additive_model)  
anova(additive_model)
```

R code to generate plot:

```
#figure 1  
i_data = read.csv("island_data.csv", header = TRUE)  
library(ggplot2)  
  
ggplot(data = i_data, mapping = aes(x = Treatment, y = Memory.card.score,  
fill = Treatment)) +  
  geom_boxplot() +  
  labs(y="Memory-Card-Score") +  
  theme(axis.text.x = element_text(size = 14),  
        axis.text.y = element_text(size = 14),  
        axis.title.x = element_text(size = 16),  
        axis.title.y = element_text(size = 16))
```