Island Study to Observe the Exclusive and Combined Effects of Caffeine and Alcohol on Comprehension

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1 Abstract

In the modern world, the consumption of caffeine is at an all-time high. Frequent stops to get some coffee to keep the day going are common among many people across America, especially the youth. From studies published previously, it is evident that caffeine is known to alter or possibly improve some cognitive abilities, such as memory. The study we focused on in our experiment was to see whether the consumption of caffeine would alter a person's comprehension abilities. Moreover, not only were we interested in seeing the effects of caffeine alone on comprehension, but also whether it has the effect to dilute the effects of alcohol and further help a person's comprehension abilities. We were especially interested in seeing if the caffeine content in coffee as a stimulant could balance out the depressant properties of alcohol.

2 Introduction

According to a recent study, over 49% of Americans reported consuming coffee on a daily basis (Loftfield). Having numerous Starbucks coffee shops within a one mile radius certainly doesn't aid in decreasing caffeine consumption either. According to literature studied in class, it is evident that caffeine certainly does aid in memory retention. Our group wanted to experiment on the islanders and hypothesize whether caffeine aids in a person's comprehension abilities. As students, we also fall into the cycle of constant caffeine consumption to stay awake and finish up on some homework, so it was only compelling to see whether coffee actually helps us in accomplishing our tasks.

It is also known that the consumption of alcohol impairs a person's abilities to not only operate machinery, make rational decisions, maintain attention on a subject, but it is also known to cause trouble in learning. Consequently, we expect alcohol to impair the islanders' comprehension abilities, but we are more interested in seeing the combined effects of alcohol and coffee. Therefore, the two questions we wished to analyze is whether coffee increases comprehension abilities and whether the combined effect of alcohol and coffee have a "balancing out" effect in terms of a person's comprehension abilities.

3 Data Collection

3.1 Participants

The data was collected on 3 groups of 96 islanders, totalling up to 288 islanders. The three groups consist of people within the age group of 21-40, 41-60, 61-100, respectively. The islanders in each group were randomly selected using the method specified later.

3.2 Design

The design used in this experiment was complete randomized block design. Our main goal was to find out how coffee and alcohol affect the comprehension ability of a person. Age could play an important role in the comprehension capability, and thus it was used as a block factor.

For each of the three age groups, numbers 1-96 were assigned randomly to the members of the age group. Then, we used the following equation to assign them to treatment groups:

$$Group\ \# = ceil(\ Assigned\ \# / 24\ )$$

Essentially, people numbered 1-24 were assigned to group 1, people numbered 25-48 were assigned to group 2, and so on. Groups were then asked to drink their assigned drink(s) according to the following list:

Group 1: No coffee and no alcohol
Group 2: Coffee and no alcohol
Group 3: No coffee and alcohol
Group 4: Both coffee and alcohol

30 minutes after consuming the drink(s), the participants were asked to do a timed comprehension test. The results were then recorded.

Figure 1: Design of the Experiment

3.3 Methodology

Systematic random sampling was used to obtain the data. 288 villagers were chosen using the following steps:

1. Give each city a number. Randomly generate a list of 11 numbers, each corresponding to a city.
2. For each of these randomly selected cities, visit every community.

3. In each of the communities, visit only the odd-numbered households.
4. Give each person in the same household a number. Data was only collected from odd-numbered people in each household.
5. If the person does not give consent to the study, skip to the next odd-numbered person.

If any of the groups had reached a total of 96 people, stop the process for that age group and continue for the other groups until all groups reach the 96 people.

3.4 Randomization

All of the randomizations were done in Python using the random function. To make the pseudo-random process resemble true randomness as much as possible, all the random functions were invoked without a seed set. Thus, all randomizations were done with different seeds, thereby reducing the bias in the pseudo-random process.

4 Data Analysis

4.1 Type of Statistical Analysis

Using R, we conducted an Analysis of Variance (ANOVA) on the collected data. The statistical analysis that we used to test if coffee or alcohol have any effect on comprehension ability is an F-test within treatments and blocks. Our control group is given no alcohol and no coffee. We assume that drinking a liquid in of itself does not affect comprehension ability. We will be comparing the other treatment groups to this control group to observe the comparative effects of coffee and alcohol consumption.

4.2 Sample size determination

The parameters that we used to determine the sample size are: The power of the experiment, set to 0.8, which is the probability that we will correctly reject the false null hypothesis; a significance level of 0.05, which is the probability of falsely rejecting the null hypothesis; and the effect size (f) of 0.25, which is how we can quantify the difference between our groups. Utilizing the pwr.anova.test function in R, we determined the sample size to be 288, where n is the sample need in each group k (levels of age * treatment groups).

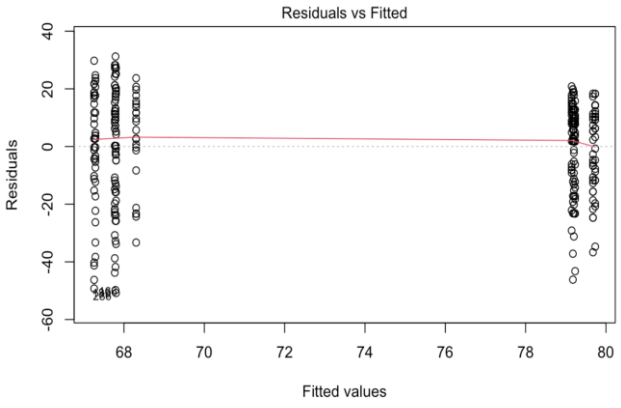
pwr.anova.test Output:

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

              k = 12
              n = 23.23364
              f = 0.25
      sig.level = 0.05
          power = 0.8
```

5 Analysis Results

5.1 Model Accuracy



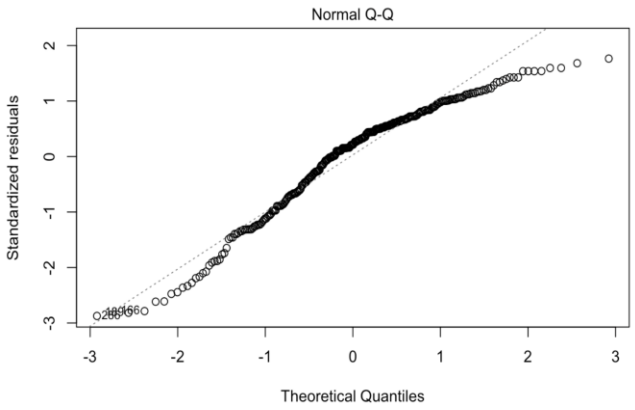


Figure 2: Residuals vs. Fitted Plot

Figure 3: Normal Q-Q Plot

According to the Residuals vs. Fitted Plot above, there is nothing unusual occurring. The observations do not have any evident patterns, such as any fan-shaping. Therefore, it is safe to conclude that the model meets the assumption of equality of error variance and linearity. Moreover, the QQ Plot shows that the observations do not deviate far from the QQ line, even though they are not perfectly following the line. This is not worrisome since it still shows that the residuals of the model follow normality. Overall, the model meets the assumptions of linearity, equality of error variance, and normality of residuals, and thus it is safe to conclude that there is model adequacy.

5.2 ANOVA Analysis

We ran a 3-way ANOVA analysis using the Alcohol, Coffee and Age factors as well as the interaction of Alcohol and Coffee and obtained the following output table:

	DF	Sum Sq	Mean Sq	F Value	P-Value > F
alcohol	1	9788	9788	30.622	6.74e-08 **
coffee	1	4	4	0.012	0.913
Age	2	17	9	0.027	0.974
alcohol:coffee	1	6	6	0.018	0.893
Residuals	282	90077	319		

Table 1: ANOVA on the data of reading comprehension performance by 288 Islanders

Our ANOVA output indicates that the only factor that results in significantly different comprehension scores is alcohol. The alcohol variable is reported with a p-value that is much lower than the standard significance value of α= 0.05. Furthermore, none of the other variables, such as coffee, nor the interaction of coffee and alcohol indicate significant differences in the average

comprehension scores. Not only did coffee not alter the comprehension scores, but our initial hypothesis of coffee diluting the effects of alcohol are also evidently not true.

5.3 Post-hoc Analysis

```
Tables of effects

 as.factor(project$coffee)
as.factor(project$coffee)
   FALSE     TRUE
-0.11458  0.11458

 as.factor(project$alcohol)
as.factor(project$alcohol)
FALSE  TRUE
 5.83 -5.83

 as.factor(project$age)
as.factor(project$age)
      1       2       3
-0.1875  0.3438 -0.1562

 as.factor(project$coffee):as.factor(project$alcohol)
                          as.factor(project$alcohol)
as.factor(project$coffee) FALSE    TRUE
                    FALSE  0.14236 -0.14236
                    TRUE  -0.14236  0.14236
```

Table 2: Posthoc analysis of the effect of each factor on reading comprehension

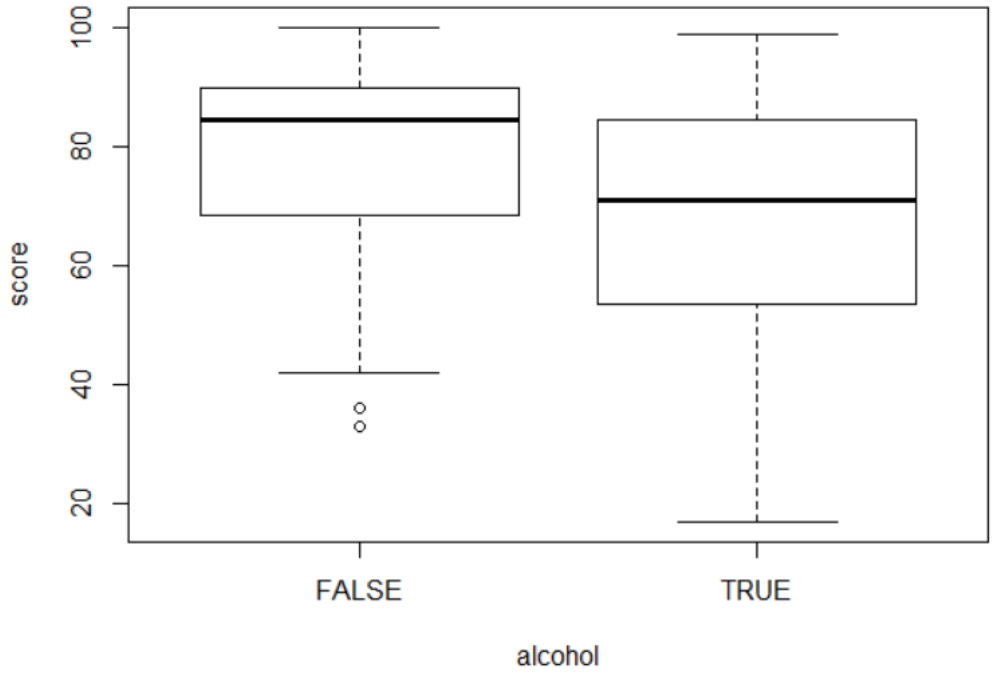


Figure 4: Box plot of Alcohol vs Score. Given the table of effects seen earlier, the box plot illustrates that drinking alcohol decreased reading comprehension scores on average by about 5.83 points from the overall mean, and was 11.66 points lower than not drinking alcohol.

5.4 Interaction Plots

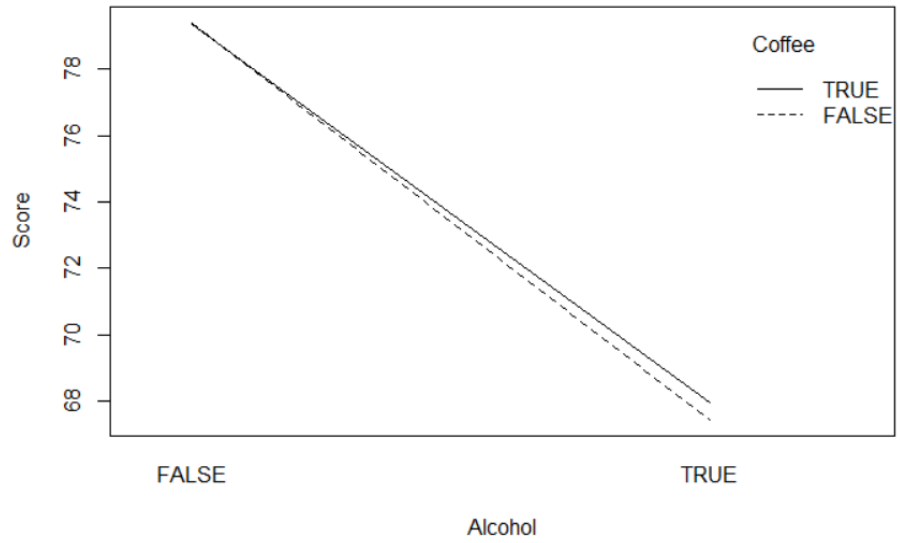


Figure 5. Interaction Plot of Alcohol:Coffee on score. The two lines being nearly identical indicate that there is no interaction between coffee and alcohol.

6 Discussion

The purpose of our experiment was to study the effects of caffeine and the effects of alcohol on comprehension ability. As detailed above, in order to do this, a complete randomized block design was created. We systematically randomized it and blocked by age factor due to its potential effects on the results. After this, we picked odd numbered people across randomized cities and assigned them to different blocks. We were able to do this because the individuals are organized by age. Then we conducted ANOVA with f-test between our control group, who were given no alcohol or coffee, and each of the 3 treatment groups: which were given only coffee, only alcohol, alcohol and coffee respectively. We also generated our required sample size of 228 by using R's pwr.anova.test function giving it the number of groups (k) and the effect size (f).

We observe from our ANOVA results that alcohol had a **very significant effect** on comprehension ability with a p-value 6 orders of magnitude smaller than 0.05. We also learned that coffee and even the interaction effect of coffee and alcohol are not significant in the islanders. As part of our test methodology, we administered the corresponding treatment and then checked reading comprehension after 30 minutes. Given that caffeine levels in the blood peak within 15-45 minutes of consumption, any change in comprehension due to caffeine levels should have shown in this time frame.

Surprised by our finding that the alcohol and caffeine treatment group did not show statistically significant results, we further used looked at the interaction plots of the two to verify our claim and found that the two lines were almost identical, indicating that they do not have an interaction effect. We also ran a post-hoc analysis to verify our ANOVA results and we arrive at the conclusion that drinking alcohol reduces comprehension ability by 5.83 on average. The Tukey-HSD confirms that the only significant factor is the alcohol consumed and that there is a 11.66 point drop in comprehension between treatment groups that consumed alcohol and those that did not.

Our work while researching the effects of caffeine confirms the strongly debilitating effects of alcohol on comprehension. It also appears that caffeine does not seem to improve reading

performance though it might help maintain reading comprehension performance. Its primary purpose seems to be to help consumers maintain their mental agility rather than to improve it. An area for future analysis could be to see if coffee helps people maintain their comprehension and memory after physical and/or mental exhaustion to see if it plays a major role in maintaining or boosting energy levels.

7 References

1) Loftfield, Erikka, et al. “Coffee Drinking Is Widespread in the United States, but Usual Intake Varies by Key Demographic and Lifestyle Factors.” *The Journal of Nutrition*, American Society for Nutrition, Sept. 2016, www.ncbi.nlm.nih.gov/pmc/articles/PMC4997286/.

2) Heffron, T. M. (2018, January 29). Sleep and caffeine. http://www.sleepeducation.org/news/2013/08/01/sleep-and-caffeine