An In Depth Look at the Impact of Caffeine On IQ While Intoxicated

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1. Abstract

The relationship between alcohol and caffeine on mental performance is an important area of study due to impact on public health and safety. Understanding how the pairing of caffeine and alcohol can affect cognitive function sparks critical insights, specifically in situations such as driving and circumstances where crucial decision making is required. This study aims to determine the nature of the relationship, if any, between caffeine and degree of impairment while intoxicated.

2. Introduction

The relationship between alcohol and caffeine on cognitive performance has significant implications for understanding human behavior, especially in social contexts where these substances are often combined. Understanding the interplay between alcohol and caffeine on cognitive functions can provide insights into their combined effects, which is particularly relevant for public health and safety, especially in contexts involving driving, decision-making, and risk-taking behaviors. Previous research has shown conflicting results in how caffeine affects alcohol-driven impairments, so this study aims to explore this avenue and measure caffeine and alcohol's impact on IQ tests. This study uses water consumption as a control to isolate the true impact of caffeine.

Cognitive impairment due to alcohol abuse is a massive public health concern in the United States, as alcohol increases risk-taking behavior on top of negatively affecting brain function. Central nervous system depressants like alcohol slow down brain activity by directly affecting neurotransmitters, which lead to decreased inhibition, impaired judgment, and slowed reaction times, especially on a long term basis. Alcohol is also a diuretic, and thus leads to dehydration which further exacerbates impairment and causes headaches, dizziness, and worsening mental clarity. Caffeine is a stimulant which can increase alertness and cognitive function by blocking adenosine receptors, preventing drowsiness, and at the same time increasing the release of neurotransmitters like dopamine or norepinephrine, which improves alertness and concentration. Caffeine’s impact on mitigating adverse effects of alcohol is unclear, although it is suggested that caffeine reduces the sedative effects of alcohol, even though it may not improve motor and cognitive impairments.

Participants are divided into age groups (21-30, 31-40, 41-50, 51-60) and sexes (male, female), ensuring no related individuals and one observation per household to maintain independence. We are expecting when participants consume alcohol to have a significant decrease in the results of their IQ test. While water is important for hydration, it is unlikely that it will significantly counteract the effects of alcohol on cognitive function, even though it may improve their physical well-being. We are expecting participants who consume alcohol and caffeine to show a mitigation on alcohol’s effect on IQ. Caffeine, a stimulant, may help enhance alertness and partially restore cognitive functions affected by alcohol. We aim to determine the true impact of caffeine in mitigating the effects of alcohol on IQ by comparing the performance of those in the water group to those in the coffee one. This study seeks to explain the combined effects of alcohol, caffeine, and water on cognitive performance. The findings will contribute to a better understanding of how these substances interact and influence cognitive functions, which is crucial for public health and safety.

3. Procedure

We selected 160 islanders from Providence island, ensuring there were no islanders from the same household. We began by testing every islander on their IQ, and then gave each of them 6 shots of 30ml vodka. We then waited 30 minutes and gave the subjects either 250ml of water or 250ml of coffee. 30 minutes after the water/coffee, we retested their IQs. We used 20 men and 20 women from each age group 21-30, 31-40, 41-50, and 51-60, with 10 men and 10 women getting coffee and 10 men and 10 women getting water.

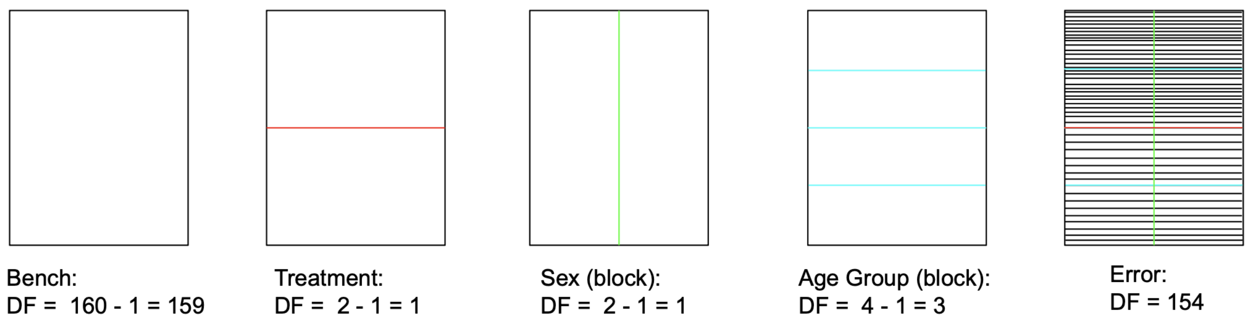
4. Design

Our study used a Randomized complete Factorial Block Design with two blocks. Specifically, our treatment factor was the type of drink given to subjects after 30 minutes of ingestion of alcohol (2 levels: 250 ml of water or 250 ml of coffee). Our first block was gender (levels: male or female), and our second block was age group (levels: (21-30), (31-40), (41-50), (51-60)). Finally, our response variable was the difference in IQ score where the subject's initial IQ score was recorded before they ingested alcohol, while their second IQ score was recorded thirty minutes after the ingestion of their treatment drink, and thus a full hour after the injection of alcohol. We provide a table below, formally listing the different variables used in our study and as the mathematical model used.

Variable	Description
Response Variable	Difference in IQ score
Treatment Factor	Drink (250 ml water or coffee)
Blocking Factor 1	Sex (Male, Female)
Blocking Factor 2	Age Group ((21-30), (31-40), (41-50), (51-60))

$$
\begin{aligned}
&y_{ijkl} = \mu + \tau_i + \beta_j + \gamma_k + \epsilon_{ijkl}, \\
&i = 1, 2\ , \\
&j = 1, 2, \\
&k = 1, 2, 3, 4, \\
&l = 1, 2, ..., 160
\end{aligned}
$$

The diagram below provides a better visualization of our design, with the various degrees of freedom provided for each source of variation. It's worth noting that we did not consider any interactions as we only have one treatment factor and do not consider the interactions between treatment and blocking factors.



Since we wanted to study the effect caffeine may have on alcohol intoxication, we decided to use a caffeinated drink—in this case, coffee—as one of the levels of our treatment factor and water as a control. Furthermore, our two blocking factors were utilized to help control for variation between the ways males and females of different ages metabolize alcohol. The differences in how these groups metabolize alcohol are expanded in greater depth in our introduction.

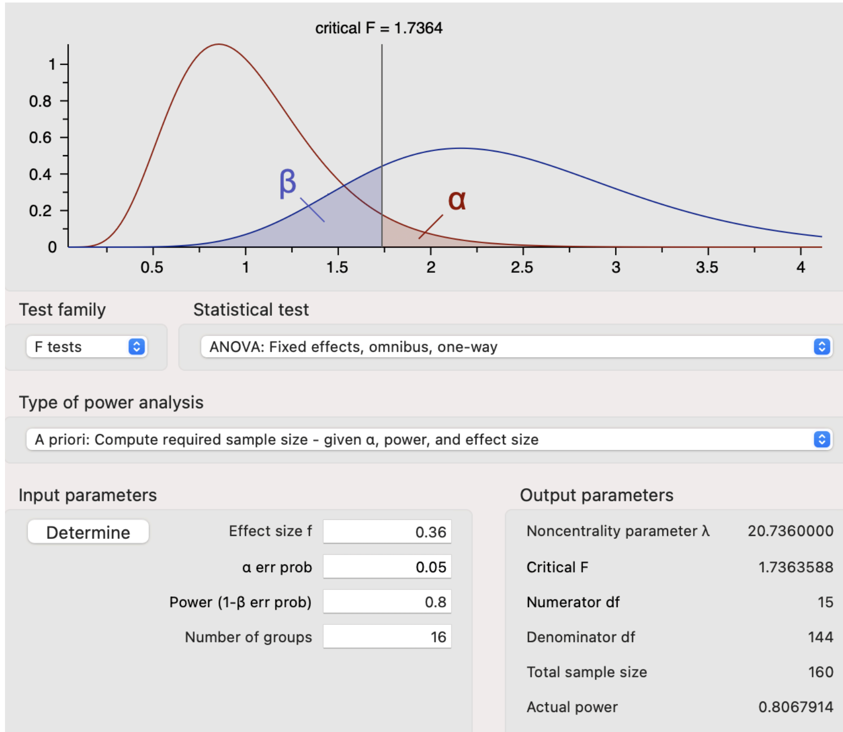
5. Data Analysis

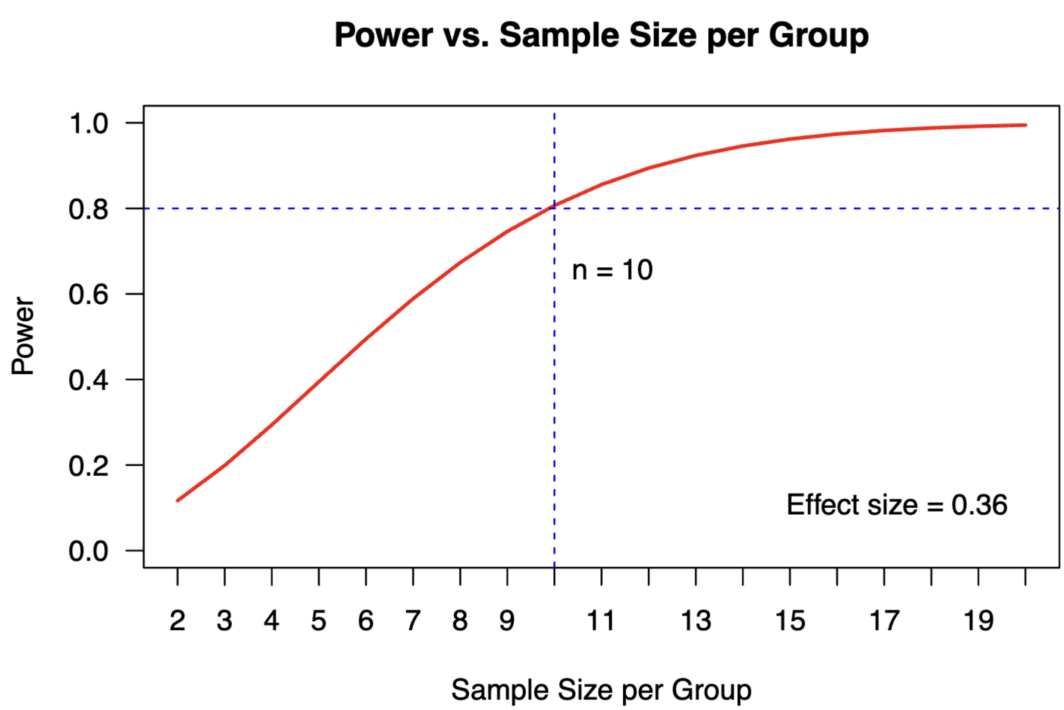
5.1 Statistical Test Type

Using R, we will now run ANOVA on our collected data. We plan to test whether the type of drink given to subjects yields a significant effect on their respective IQ drop via an F-test, using blocks of Sex and Age Group. This is done to minimize person to person variation, as both age and sex have a significant impact on how a person processes alcohol and caffeine.

5.2 Determination of Sample Size

We divided the subjects into 4 different age groups, 21-30, 31-40, 41-50, and 51-60, and divided each of the 4 groups into males and females. We then randomly assigned half of the members in each of the 8 groups to the water treatment and the other half of the group to the coffee treatment, giving us 16 total groups. Using a moderately small effect size of 0.36, a power of 0.8, and an alpha level of 0.05, we were to calculate a sample size of 160 using G* Power. That gives 10 subjects per group.


critical F = 1.7364
β
α
Test family
F tests
Statistical test
ANOVA: Fixed effects, omnibus, one-way
Type of power analysis
A priori: Compute required sample size - given α, power, and effect size
Input parameters
Determine
Effect size f 0.36
α err prob 0.05
Power (1-β err prob) 0.8
Number of groups 16
Output parameters
Noncentrality parameter λ 20.7360000
Critical F 1.7363588
Numerator df 15
Denominator df 144
Total sample size 160
Actual power 0.8067914


Power vs. Sample Size per Group
Power
n = 10
Effect size = 0.36
Sample Size per Group

6. Results

6.1 ANOVA Table

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Age.Group	3	260.8917	86.96389	4.7836403	0.0032428
Sex	1	570.0250	570.02500	31.3554811	1e-07
Drink.Given	1	7.2250	7.22500	0.397427	0.5293554
Residuals	154	2799.6333	18.17944		

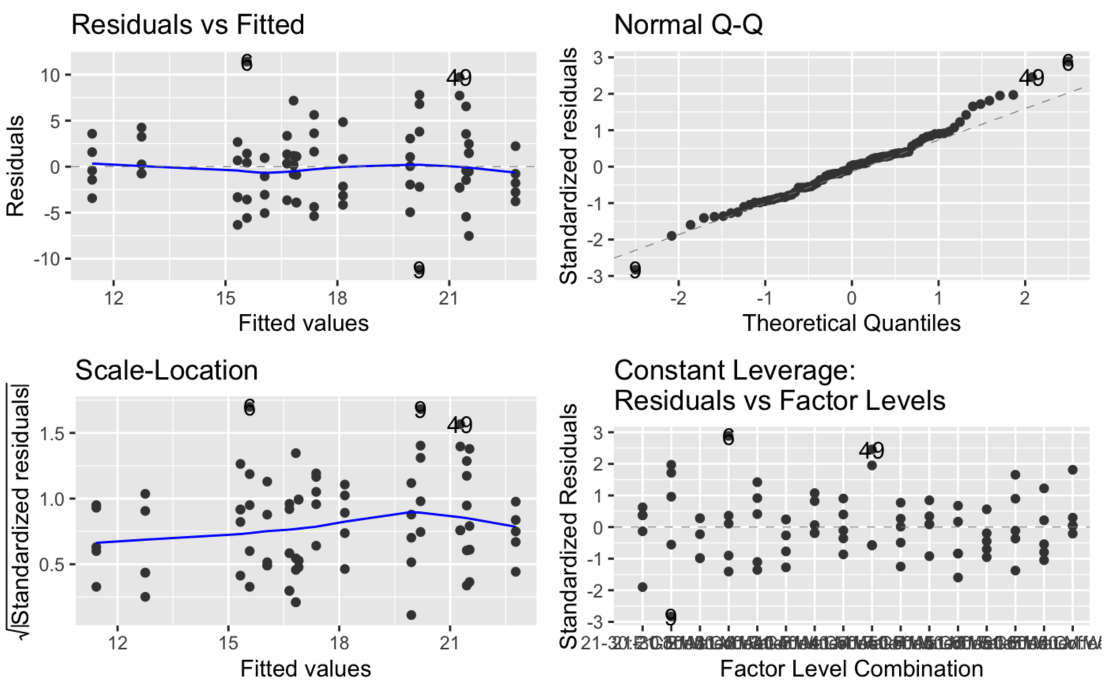
Using the aov() function in R, with no interaction (as we only have one treatment variable), we generated the table seen above. As the literature indicated, both age group and sex were highly significant in predicting the IQ drop of a subject. However, our treatment variable has a p-value of about 0.53, which does not clear the 0.05 threshold set, indicating that the type of treatment, either coffee or water, does not have a significant impact on the IQ drop of an individual. So, while the blocking was very effective, our treatment did not have a significant impact on the response variable, indicating that caffeine may not have a significant effect on intoxicated individuals. The R-squared for this model is about 0.38, meaning that about 62% of the variation of IQ scores is unexplained by the model. Of course, most of the 38% variation that the model predicts can be attributed to the age group and sex variables, which are blocking variables outside the scope of this study.

6.2 Tukey HSD Table

	diff	lwr	upr	p adj
(31,40)-(21,30)	-1.15833	-3.41885	1.10218	0.54473
(41,50)-(21,30)	1.175	-1.8578	4.2078	0.74598
(51,60)-(21,30)	2	-0.47627	4.47627	0.15843
(41,50)-(31,40)	2.33333	-0.52602	5.19268	0.1515
(51,60)-(31,40)	3.15833	0.89782	5.41885	0.00217
(51,60)-(41,50)	0.825	-2.2078	3.8578	0.89438

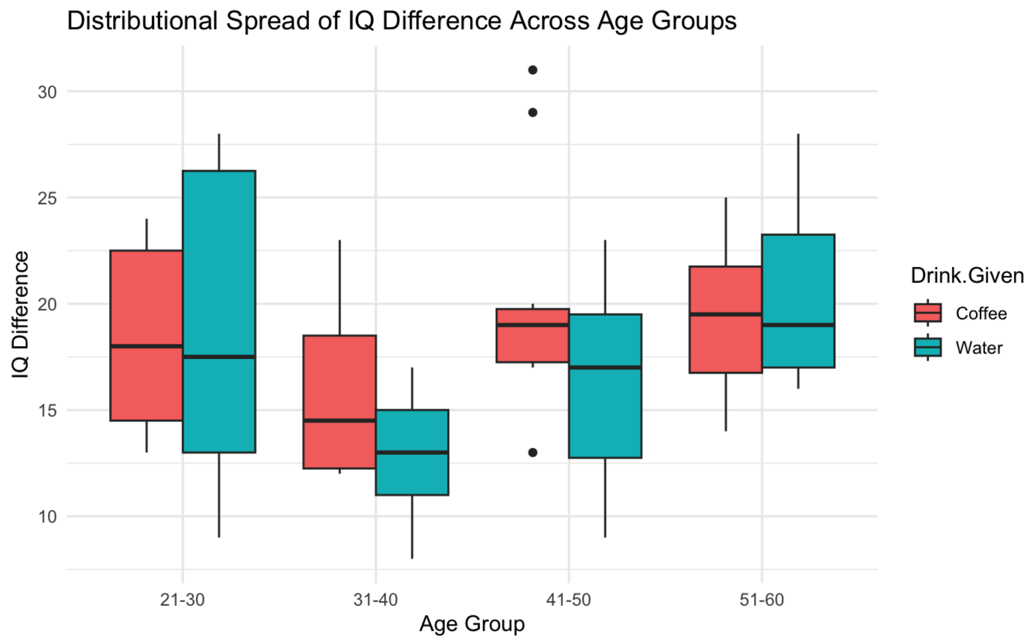
So because the treatment variable was not significant, even though age group was a blocking factor, we decided to look into what age groups were significantly different from the others. As seen by the Tukey table above, even though the F-test indicated that the age group was a significant variable, there is only one pairing of age groups that were significantly different from each other in terms of IQ drop - that being the pairing of (51,60) and (31,40). And although the other two pairings involving (51,60) both have p-values of about 0.15, which does not clear the 0.05 threshold, it appears that the age group of (51,60) is somewhat different from the other 3 age groups, dropping more IQ points on average than the others. While not researched, this makes intuitive sense - as older people tend to have weaker livers and process alcohol less effectively than younger people. While age group was a blocking factor, this Tukey test provides some interesting patterns, and could be explored in possible future experiments.

6.3 Residual Plots

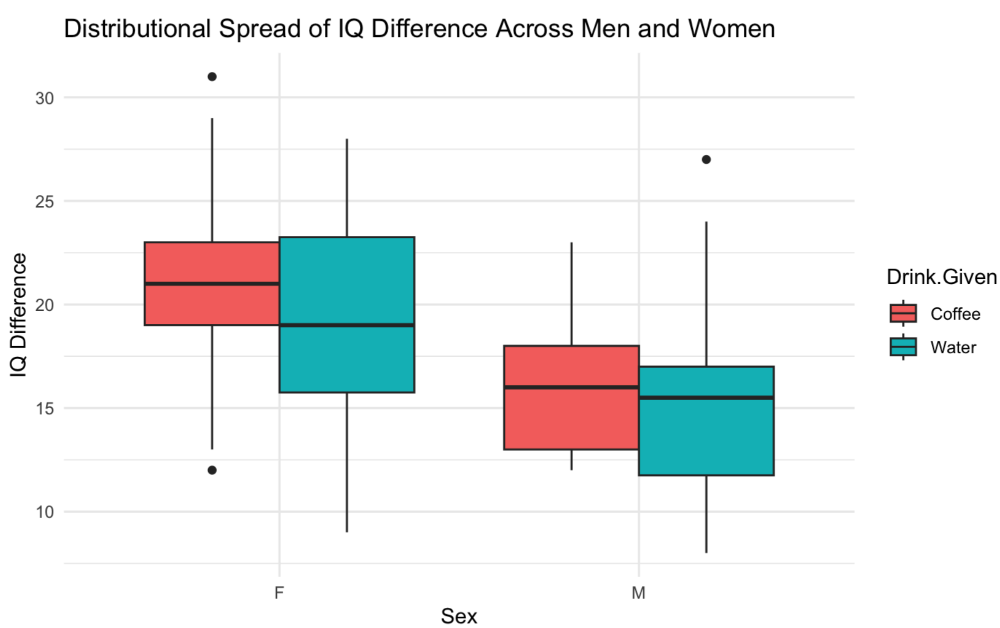


Based on the residual plots above, it appears as though the model assumptions of normally distributed errors and constant variance hold, so the conclusions of the ANOVA model and F-tests are valid.

6.4 Box Plots



Above is the boxplot that looks at how different age groups react to the drink given. As indicated by the Tukey test performed above, while only one pair of age groups are significantly different, age groups do have a strong effect on the drop of IQ. However, as demonstrated by the F-test and shown in the plot above, the treatment variable does not have a significant impact on the IQ difference, however, age groups of (31-40) and (41-50) have larger gaps between the two treatments, indicating that different age groups react to caffeine differently while intoxicated. However, this is not the main focus of this experiment, but this pattern could be tested in possible future experiments.



Above is the boxplot separating how the treatment affected both men and women. And while it appears as though caffeine may affect women more negatively than it does men, sex was a blocking factor for this experiment and was not the focus of this study, but this could be yet another area to explore with future research and experiments.

7. Conclusion

Given the importance of understanding and researching the effect of substances when combined with alcohol, particularly in contexts involving motor vehicles and decision-making, our study explored the combined effects of alcohol and caffeine on cognitive performance. We hypothesized that caffeine would mitigate the cognitive impairments caused by alcohol consumption. This relationship was examined by conducting IQ tests before and after administering both alcohol and caffeine—using water as a control—on 160 participants from Providence Island. The participants were separated into age and gender groups to control for demographic differences. ANOVA tests and post-analysis showed that while age and sex factors significantly influenced IQ, the type of drink did not have a statistically significant impact on mitigating alcohol-induced cognitive impairment.

Interestingly, the factor age group (particularly the oldest group, 51-60) showed a notable difference in IQ drop compared to younger groups, confirming the common understanding that older individuals metabolize alcohol less efficiently. Our Tukey HSD test helped visualize that the cognitive impact of alcohol was more pronounced in the 51-60 age group compared to the 31-40 age group. Despite these findings, our study was relatively limited, and further research should be conducted to help understand how cognitive functions are affected when consuming caffeine and other substances alongside alcohol. Future research could focus on different age and sex interactions with alcohol and caffeine, potentially uncovering more nuanced effects. Specifically, it would make sense to take into account weight when giving participants alcohol as such would help mitigate the differences seen in men and women as explained by the difference in average weight.

We acknowledge that there are some limitations and weaknesses to the design of our experiment, and places where it could be improved. Because everyone processes alcohol differently, and factors such as weight, ethnicity and blood pressure can impact how alcohol is processed, there is high person to person variation in this experiment. And although we used some blocking factors to attempt to reduce this variability, it is likely that there are more contributing factors to how people respond to caffeine and alcohol than just age and sex. So this experiment could have possibly been improved through a repeated measures block design - testing each individual's reaction to water while drunk and then retesting it later with coffee. So although there is room for possible improvement for future experiments in this area, we do believe the conclusion that caffeine does not have a significant improvement on cognitive ability while impaired when compared to water.

8. References

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