Impact of Various Alcoholic Beverages on Memory Performance: A Latin Square Design Analysis

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1 Abstract

This study employs a Latin Square design to account for age and the amount of time after drinking to examine the effects of various alcoholic beverage types on memory performance. The Memory Card Test was used to evaluate memory function in 125 male participants aged 21 and above. Participants' memory performance was assessed before and after consuming 500ml of light beer, regular beer, Guinness, red wine, or white wine. ANOVA analysis indicated no significant differences in memory performance across the different types of alcoholic beverages. This suggests that drinking habits do not appear to have a significant effect on memory function. These findings imply that alcohol quantity—rather than type—is a more important factor in its cognitive effects. To fully understand alcohol's impact on cognition, future studies should consider a more comprehensive demographic and additional cognitive tests.

2 Introduction

Alcohol consumption is a common behavior that significantly impacts memory performance and other cognitive functions. According to the World Health Organization (WHO), the average person aged 15 and older consumed 5.5 liters of pure alcohol worldwide in 2019, with per capita consumption surpassing 12 liters in countries such as Moldova, Latvia, and Czechia. People consume various alcoholic beverages, each with distinct compositions and potential effects on the brain. Understanding how different alcoholic beverages impact memory is crucial for public health.

Previous studies have shown that alcohol influences cognitive functions, including memory. Some research suggests moderate alcohol consumption may offer cognitive benefits, while heavy drinking is associated with cognitive decline. Cognitive decline is an early preclinical symptom of neurodegenerative diseases like Alzheimer's. Acute alcohol consumption can disrupt short-term memory formation, leading to difficulties in encoding new information. Research also indicates that individuals with higher IQs generally perform better on memory tasks, and cognitive functions decline with age. Given the mixed findings, the specific impact of different types of alcoholic beverages and the effective time after consumption remains unclear.

This study aims to determine whether different types of alcoholic beverages have distinct effects on memory performance. By using a Latin Square design, we control for the variability introduced by age and time after drinking, isolating the impact of each beverage on memory.

3 Methods

3.1 Participants

Participants were recruited from a virtual platform called Island, focusing on male participants aged 21 and above to meet the legal drinking age. A total of 125 observations were collected, aligning with the requirements of a Latin Square design with five repetitions. Participants provided informed consent before participating in the study.

3.2 Design

A 5x5 Latin Square matrix was created, with each treatment occurring once per row and once per column. The different alcohol drinks (light beer, regular beer, Guinness, red wine, and white wine) were assigned a number from 1-5. The matrix was randomized using the sample() function in R to create five randomized Latin Squares. Each participant was assigned to a column representing the test time after drinking the alcohol.

The primary objective was to evaluate the impact of the five alcoholic beverages on memory performance, controlling for age and time after drinking. The age intervals were 21-34, 35-46, 47-58, 59-70, and 71+, and the time intervals were 5, 10, 15, 20, and 25 minutes.

3.3 Instruments

The Memory Card Test was used to measure memory performance. Participants were shown 10 cards drawn from a standard 52-card deck for two minutes and then had one minute to recall and write down all the cards they could remember. Each participant consumed 500ml of each type of drink during the study sessions.

3.4 Procedure

1. Recruit participants and obtain informed consent.
2. Record participants' ages and conduct the initial Memory Card Test.
3. Divide participants into five age intervals and randomly assign one of five effect times (5, 10, 15, 20, 25 minutes) using the sample() function in R.
4. Place participants into a Latin Square matrix, ensuring randomization and balance.
5. After a one-week interval, participants consumed 500ml of one type of drink per session and waited for the assigned time before retaking the Memory Card Test.
6. Calculate the difference between the pre-drink and post-drink memory test scores for data analysis.

4 Data Analysis

4.1 Data Visualization

Data were loaded into R, and boxplots were created using the geom_boxplot() function to visualize the distribution of memory scores across different treatments. Tables of effects were generated using the model.table() function.

4.2 Linear Modeling

Linear models were fitted to both individual Latin Squares and the entire dataset using the lm() function. Diagnostic plots were generated with the autoplot() function from the ggfortify package to check for linearity, constant variance, and normality of residuals. If assumptions were violated, methods such as log transformation or Box-Cox transformation were applied.

4.3 Handling Influential Points

Standardized predicted residuals and the Bonferroni correction were used to identify and address influential points. Model selection techniques, including comparing adjusted R-squared values, were employed to identify the best-fitting model.

4.4 Analysis of Variance

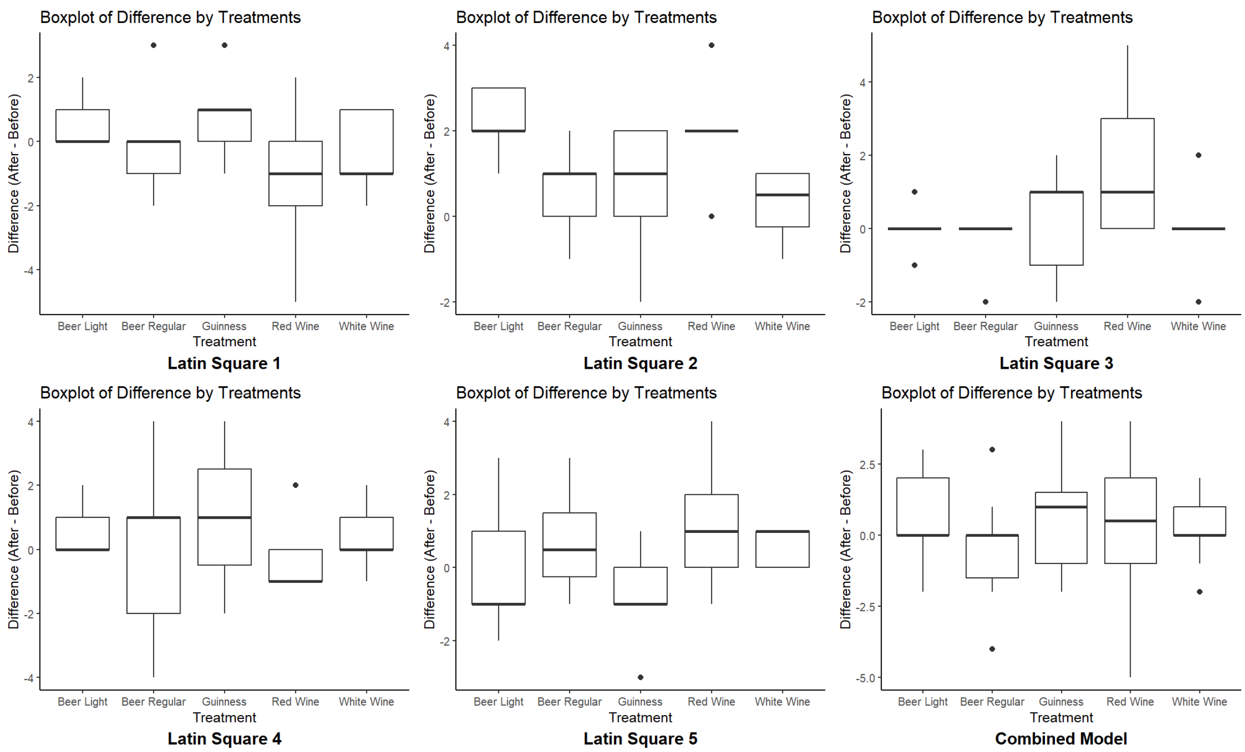
ANOVA was performed using the anova() function to determine significant differences between treatments. Degrees of Freedom, Sum of Squares, Mean Sum of Squares, F-statistics, and P-values were calculated.

4.5 Post-hoc Analysis

The TukeyHSD() function was used to provide adjusted p-values and confidence intervals for pairwise comparisons of the five treatments.

5 Results

5.1 Boxplots for Latin Squares



Boxplots for all 5 Latin Squares and the full data (in R). These boxplots were used to visualize the distribution of memory scores across different types of alcoholic beverages. The median memory score for each beverage type was indicated by the line within each box, while the interquartile range (IQR) was represented by the height of the box. Whiskers extended to 1.5 times the IQR from the quartiles, and any data points beyond this range were considered outliers. This visualization provided a clear summary of the central tendency, variability, and potential outliers in memory performance associated with each type of drink.

5.2 Table of Effects of Different Treatments

Treatment	Effects	Rep
Beer Light	0.6679	25
Beer Regular	0.2082	24
Guinness	0.2737	23
Red Wine	0.7079	25
White Wine	0.1796	24

Table 1: Table of effects of different treatments with grand mean 0.4132231 (NA removed).

5.3 Diagnostic Plots of Models

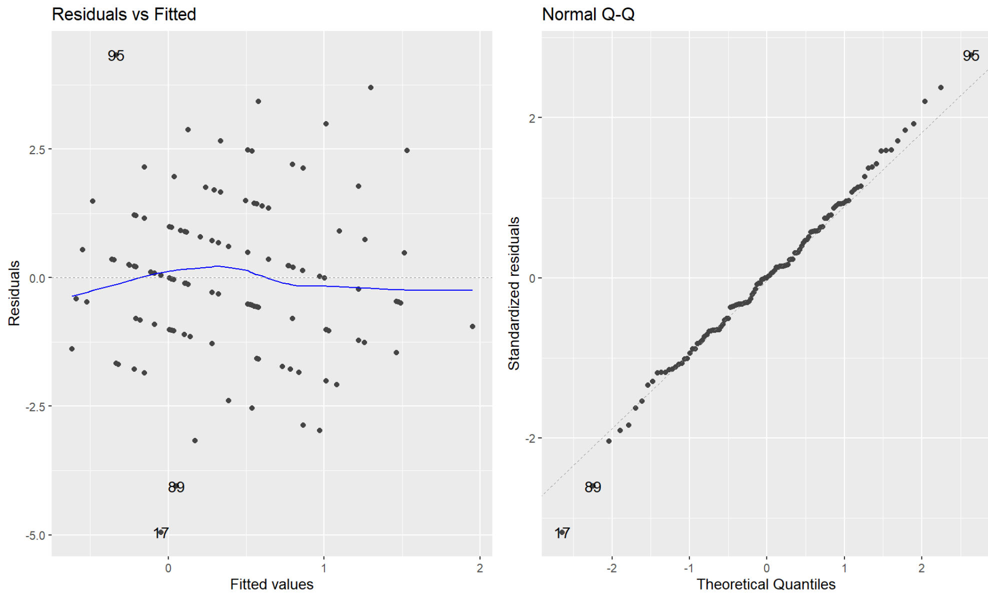


Figure 1: Summary plots of residuals for the entire model with NA values removed. The residuals vs fitted value plot shows no clear pattern, suggesting that the linearity assumption holds.

Plots above are the diagnostic plots for the entire model, model with all observations, with NA value removed. In the residual vs fitted value plot, the residuals should be randomly distributed around the fitted line. Any systematic pattern indicates potential issues like non-linearity. In this plot, there is no clear pattern, suggesting that the linearity assumption may hold. In the Q-Q, the points should lie on the diagonal line if the residuals are normally distributed. The plot shows that most points lie on the line, but there are deviations at both ends (e.g., points 95 and 89), indicating some potential departures from normality. Therefore, it is important to test for potential outliers.

5.4 Scatter Plot of P-Value of Outlier Test vs Observation ID

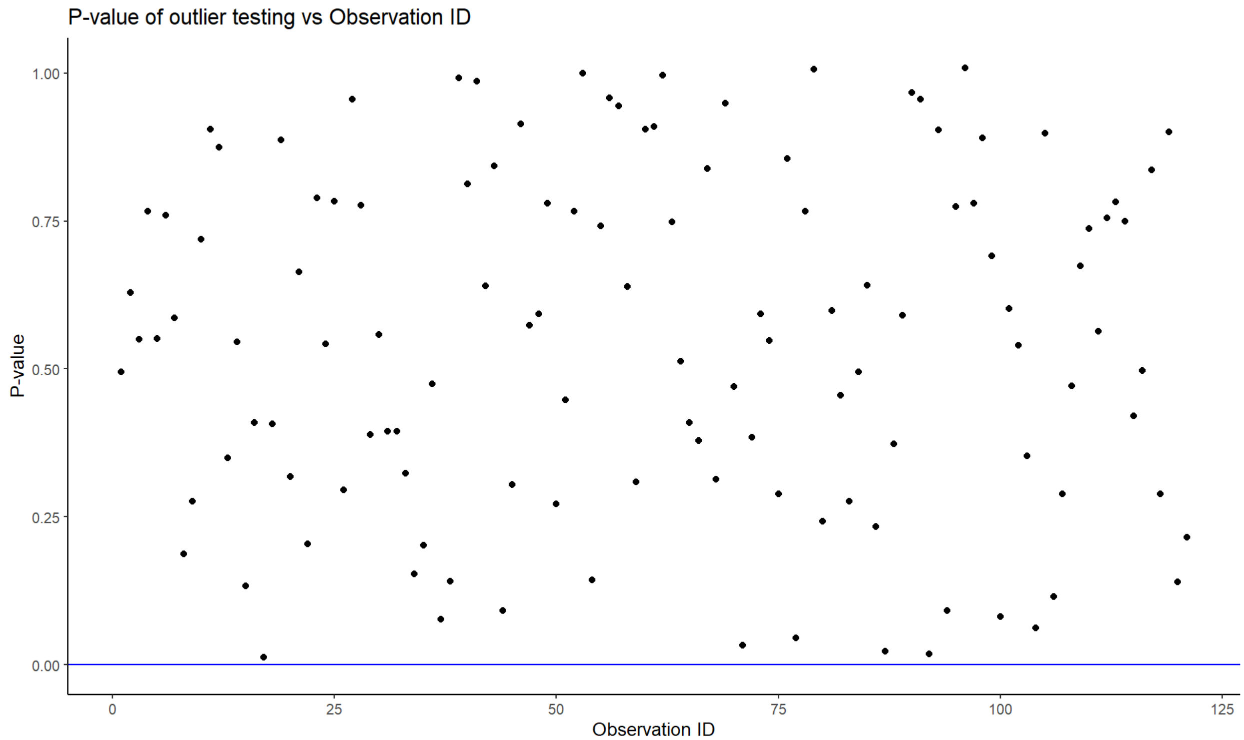


Figure 2: Scatter plot of p-value of t-test for standardized predicted residuals. No potential outliers were identified when fitting the full model.

This is the scatter plot of p-value of using t-test to tell whether standardized predicted residual for one observation is big enough to be an outlier with alpha adjusted with Bonferroni adjustment (0.004, the blue line.). This plot shows there is no potential outliers when fitting the full model. Additionally, the plot demonstrates considerable variability among individual testers.

5.5 ANOVA Tables

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Age	4	26.16	6.5400	3.1044	0.05708
Time	4	8.56	2.1400	1.0158	0.43761
Treatment	4	12.96	3.2400	1.5380	0.25322
Residual	12	25.28	2.1067		

Table 2: ANOVA table for Latin Square 1.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Age	4	5.333	1.3333	0.7383	0.5851
Time	4	5.2625	1.3156	0.7285	0.5809
Treatment	4	14.8708	3.7177	2.0585	0.1552
Residual	11	19.8667	1.8061		

Table 3: ANOVA table for Latin Square 2.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Age	4	9.84	2.46	1.3226	0.3169
Time	4	10.64	2.66	1.4301	0.2832
Treatment	4	14.64	3.66	1.9677	0.1638
Residual	12	22.32	1.86		

Table 4: ANOVA table for Latin Square 3.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Age	4	5.520	1.3799	0.3434	0.8427
Time	4	22.754	5.6885	0.14158	0.2978
Treatment	4	6.418	1.6046	0.3994	0.8049
Residual	10	40.178	4.0178		

Table 5: ANOVA table for Latin Square 4.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Age	4	11.783	2.9458	1.4431	0.2842
Time	4	13.150	3.2875	1.6108	0.2401
Treatment	4	13.950	3.4875	1.7088	0.2178
Residual	11	22.450	2.0409		

Table 6: ANOVA table for Latin Square 5.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Age	4	23.896	5.9741	2.2061	0.07309
Time	4	8.406	2.1015	0.7760	0.54314
Treatment	4	6.568	1.6420	0.6064	0.65890
Residual	108	292.468	2.7080		

Table 7: ANOVA table for the full model.

The minimum p-value for all these models is 0.1552 from Latin square 2, which is still greater than 0.05 suggesting that there is no statistically significant difference between the effectiveness of affecting memory performance of the different treatments being compared. This means that any observed differences in memory performance across the five types of alcoholic beverages are likely due to random variation rather than a true effect of the treatments.‘

5.6 Post-hoc analysis

Given that no significant relationship was found between the different treatments and the differences in memory scores, further post-hoc analysis is unnecessary.

6 Discussion

The primary objective of this study was to investigate whether different types of alcoholic beverages—light beer, regular beer, Guinness, red wine, and white wine—have distinct effects on memory performance. Using a Latin Square design, we controlled for age and time after drinking. The ANOVA results indicated no significant differences in memory performance across the different types of alcoholic beverages. This suggests that the type of alcoholic beverage consumed does not differentially impact memory performance in male participants aged 21 and above.

Our findings imply that the type of alcoholic beverage does not significantly affect memory performance, aligning with the notion that alcohol-related cognitive impairment is more dependent on the quantity of alcohol ingested than the type of beverage. This has practical implications for public health messaging, simplifying the narrative around moderate alcohol consumption and its effects on cognitive function.

Several limitations must be acknowledged. The study sample was restricted to male participants aged 21 and above, limiting generalizability to other demographics. Other individual differences, such as baseline cognitive ability and drinking history, were not specifically controlled for. Furthermore, the study’s-controlled setting might not adequately represent the complexity of drinking behavior in the real world, where variables like social context, concurrent drug use, and other types of alcoholic beverages might be important considerations. Finally, the Memory Card Test was the only memory test used in the study, which might have limited the findings’ applicability to other kinds of memory or cognitive processes. Future research could benefit from a more comprehensive assessment of these variables and a range of cognitive tests to fully understand alcohol’s impact on cognition.

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