

## Adverse Effects of Benzodiazepines and Mood-Related Memories on Memory Recall Performance

### Introduction

Benzodiazepines have been shown to disrupt the positive effects of long-term potentiation between cells on memory recall and learned associations (Breggin, 1998). Therefore, by differentiating the long-term adverse impact of Alprazolam (long-term) and Triazolam (short-term), a better diagnosis may be administered to patients to mitigate any damage to memory recall ability.

### Method

The origin of the dataset was the open-source Kaggle (Memory Test on Drugged Islanders Data | Kaggle). It displays 198 rows and nine columns which contain the following information: first\_name; last\_name; age; Happy\_Sad\_group (H, S); Dosage(1,2,3); Drug(Alprazolam (A), Triazolam (T), Sugar (S)); Mem\_Score\_Before; Mem\_Score\_After; Diff(Mem\_Score\_After - Mem\_Score\_Before).

To analyse if there is any impact from the Drugs and or Dosage on memory recall, 2 Way ANOVA will be performed.

In the first moment, to test if there were differences between at least one of the levels of each factor (Drug; Dosage) and if there is an interaction between the Drug and the Dosage.

In a second moment, if any of the factors are significant, post hoc tests (Tuckey) will be applied to understand between which levels there are differences.

### Data Analysis

To better understand the data behaviour, statistics were obtained (present in the script) and boxplots and interaction plots for the variables Drug and Dosage.

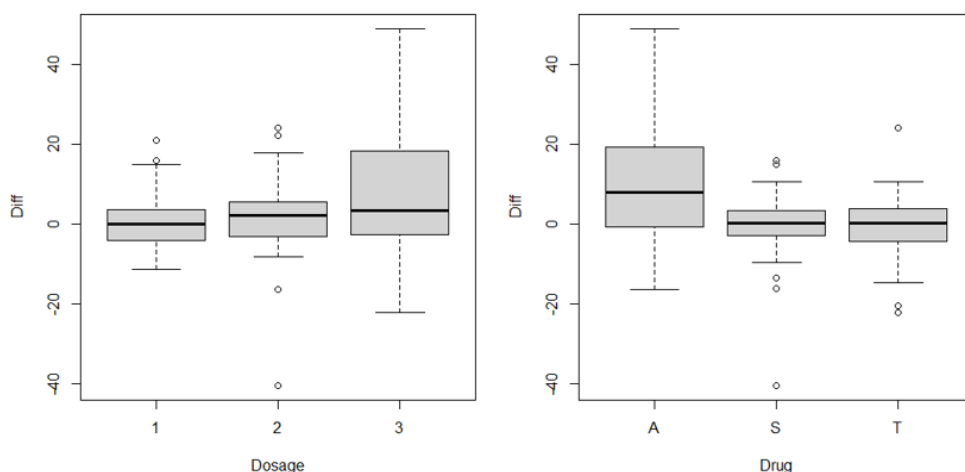


Figure 1 Boxplots for Dosage and Drug, all by Diff.

Dosage 3 seems to have a more significant impact on memory recall and more considerable dispersion, with primarily positive values, when compared with the other two dosages. Drug A, Alprazolam, seems to have a more significant impact on memory recall and more considerable dispersion, with primarily positive values, when compared with the other two drugs.

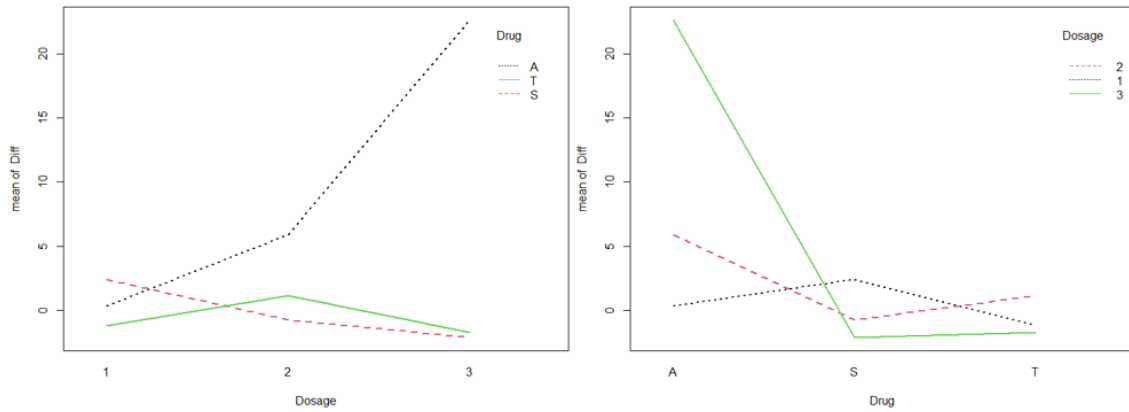


Figure 2 Interaction plots for Dosage and Drug

On Figure 2 is possible to observe the effect of Drug while moving through the levels of Dosage (Left) and the effect of the Dosage while moving through the levels of Drug (Right). There seems to be an interaction between Drug and Dosage on the memory recall given that the lines cross while heading in different directions.

## 2 Way ANOVA

From the previous analysis, there seem to exist differences between at least one level of Drug and Dosage and the interaction between these factors, but are these effects significant?

To answer this question, 2 Way ANOVA was performed with the following model:  $Y_{ijl} = \mu + \alpha_i + \beta_j + \gamma_{ij} + \varepsilon_{ijl}$   $i = A, B, C; j = 1, 2, 3; l = 1, \dots, n$ . Where  $\alpha_i$  is the Drug  $\beta_j$  the Dosage,  $\gamma_{ij}$  the interaction between Drug and Dosage and  $\varepsilon_{ijl}$  the error.

Using an alpha significance of 0.05, the ANOVA analysis has shown that Dosage and Drug were statistically significant as their p-values were 0.000118 and 3.56e-13, respectively. It was also found that the interaction between the two was statistically significant, with a p-value of 1.01e-13.

## Post Hoc Analysis

Within the additive model, it is possible to do further testing about the main effects to verify between each levels there are significant differences.

A Tukey HSD test was used to correctly adjust for the accumulation of type 1 error alphas and found statistically significant differences between Alprazolam and Sugar (placebo) with a p-value of 0.0000001 and between Alprazolam and Triazolam with a p-value of 0. In terms of Dosages, there were also observed significant differences between Dosages 3 and 1 with a p-value of 0.0011268.

## Residuals Analysis

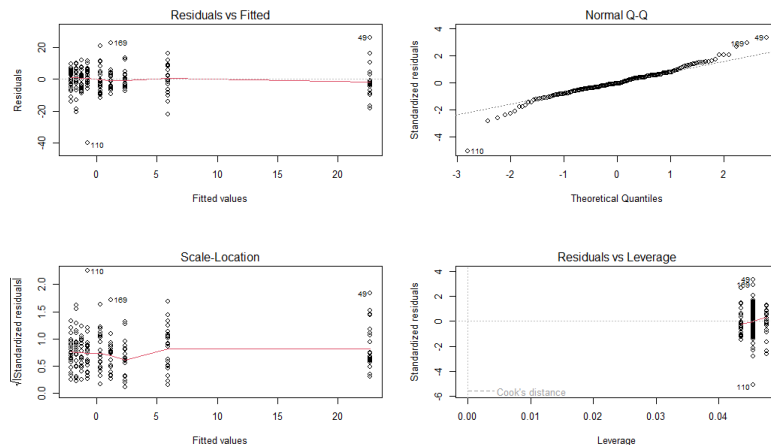


Figure 3 Residuals vs Fitted, Normal Q-Q plot, Scale-Location and Residuals vs Leverage

Portrayed in Figure 4 are the plotting of residuals, the normal Q-Q plot, the Standardized Residuals, and the Leverage plot. The residual plot lacks any pattern, and the variance follows a pattern of constancy. The Q-Q plot shows a slight problem in normality at the tail ends. However, it is assumed to be sufficient given the Shapiro-Wilk test with a p-value of 3.181e-06.

#### Discussion

Through the above analysis, statistically significant evidence was observed for an alpha of 0.01 that Drug and Dosage interact, with Dosage 3 using Alprazolam having the highest, in this case, positive impact on memory recall. It was also possible to observe that Alprazolam shows to be statistically different with an alpha of .01 than Triazolam and Sugar. Interestingly, Triazolam did not show statistical differences when compared with sugar. Finally, in terms of Dosages, there was statistically significant evidence that Dosage 3 differs from Dosage 1 for an alpha of .01.

These conclusions indicate that Alprazolam, when used in dose three, improved memory recall on average. However, Triazolam seems to have no positive impact on memory recall showing no differences from the placebo compared to Alprazolam with all doses. If dose one is used, both drugs seem to have the same effect on memory recall.