DATA SCIENCE REPORT ON THE EFFECT OF SLEEP DEPRIVATION ON REACTION TIME USING MIXED EFFECT MODEL IN R

REPORT

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1 Study Description

The dataset for analysis was gotten from the study on sleep deprivation, where participants were deprived of sleep for a certain number of days, and the cognitive performance of the participants was measured in the form of reaction time. Average reaction time is a measure of how long it takes an individual to respond to a stimulus. A shorter reaction time indicates that the individual is reacting quicker to the stimulus, while a longer reaction time indicates a slower response to the stimulus. The unit of measurement for reaction time is the millisecond.

2 Data Description and Exploration

The dataset has three variables:

- **Reaction**: Average reaction time in ms
- **Days**: Number of days of sleep deprivation
- **Subject**: Subject number on which the observation was made

2.1 Unique observations

- **Days**: 10
- **Subject**: 18
- **No. of observations**: 180

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Subject	Mean Reaction Time
308	342
309	215
310	231
330	303
331	309
332	307
333	316
334	295
335	250
337	376
349	276
350	314
351	250
352	337
369	306
370	292
371	295
372	318

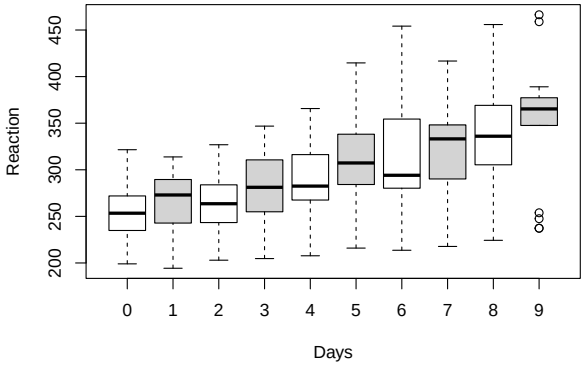
(a) Table of Mean Reaction Per Subject

	Reaction	Days
Min	194.3	0.0
1st Quartile	255.4	2.0
Median	288.7	4.5
Mean	298.5	4.5
3rd Quartile	336.8	7.0
Max	466.4	9.0

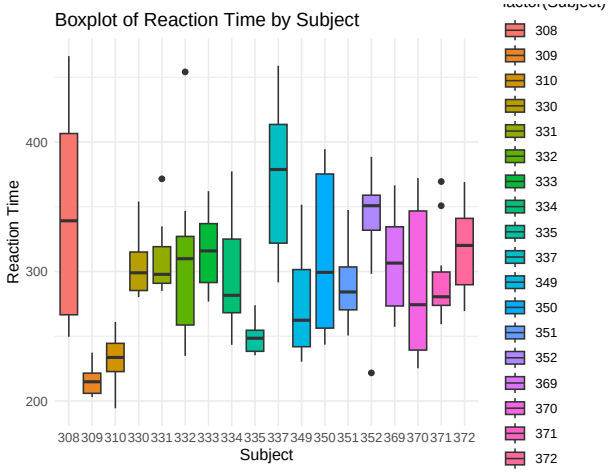
(b) Table of Summary Statistics

Figure 1: Sleep Study Statistics

From the table above, we can see that the minimum reaction time is 194.3ms, while the maximum is 466.4ms. Subject 309 had the least mean reaction time, and Subject 337 had the highest mean reaction time. From the plots below, we



(a) Box Plot Showing Descriptive Statistics of Day.



(b) Box Plot Showing Descriptive Statistics of Subject.

Figure 2: Box Plot Showing Descriptive Statistics.

can see that as the number of days increased, we had an increase in reaction time, while for the subjects, there wasn't any trend.

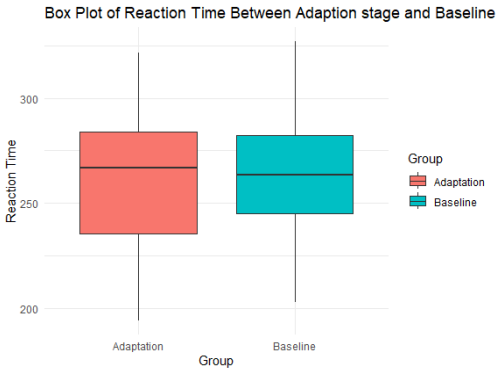
3 Approach

During the study, participants were deprived of sleep for 3 hours starting on day 3. Days 0 and 1 were used for adaptation and training of the participants, while day 2 was used to measure the baseline of reaction time before sleep deprivation started on day 3. So based on this, I subsetted the data into three subsets, subset 1 had observations for days 0 and 1, referred to as the Adaptation stage; subset 2 had observations from day 3 to day 9, referred to as the Sleep deprived stage; and subset 3 had observations for day 2, referred to as the Baseline stage. A comparison of the means was done to determine if the reaction times in all subsets were significantly different using the t test.

The P value for the reaction time comparison between adaptation stage and baseline was 0.5902, so we fail to reject the null hypothesis that the means are not significantly different. This meant the mean reaction time of the subjects in day 0 and day 1 were almost the same as their reaction time on day 2 when the baseline was taken.

Mean Adaptation	Mean Baseline	P Value
260.57	265.36	0.5902

(c) Table



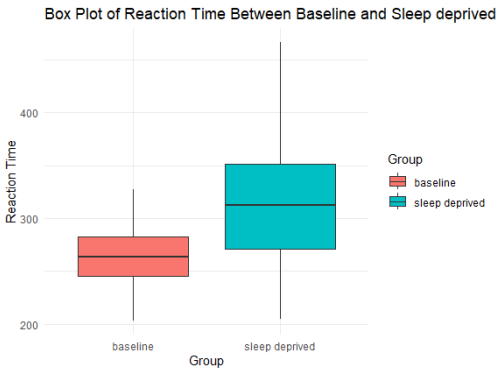
(d) Figure

Figure 3: Table and Figure for T test Adaptation and Baseline Comparison

The P value for the comparison between baseline and sleep deprived was 1.62e-06, so we reject the null hypothesis that the means are not significantly different. This meant the mean reaction time of the subjects in day 2 were different from the reaction time on days 3 to 9 showing the effect of the 3 hours sleep deprivation effect on the subjects.

Mean Baseline	Mean Sleep depr.	P Value
265.36	314.08	1.62e-06

(a) Table



(b) Figure

Figure 4: Table and Figure for T test Baseline and Sleep deprived Comparison

From the plots in figures 2 and 3, we can see that the mean reaction time at the adaptation stage is statistically the same as that of the baseline, while that of sleep deprivation, which began on day 3, is statistically different from the baseline taken on day 2. This shows that sleep deprivation had a significant effect on reaction time in the subjects.

3.1 Test for Normality

Checking for normality of the response variable using the Shapiro-Wilk test, the p value is 0.000780, so we reject the null hypothesis that the distribution is normally distributed. Based on this, data transformation was done; the distribution was right-skewed, so a logarithmic function was used for the transformation.

4 Model Implementation

The dataset has two predictors (Days and Subject). The subject variable is a repeated measure; that is, each subject reaction time is not independent of the other, meaning it has numerous measures of the reaction time for a participant,

which then makes the variable non-independent. In this case, I modeled the subject as a random effect and the days as a fixed effect. A mixed-effects model is suitable to model such predictors where both fixed and random effects are present.

$\text{Model}_1 = lmer(Reaction\ Days + (1|Subject), data = sleepstudy)$

$\text{Model}_2 = lmer(LogReaction\ Days + (1|Subject), data = sleepstudy)$

$\text{Model}_3 = lmer(LogReaction\ Days + (1|Subject), data = sleepdeprived)$

4.1 Model Interpretation

- In Model 1:
  - The intercept indicates the average reaction time without sleep deprivation, with a value of 251.4 ms.
  - With each additional day of sleep deprivation, the reaction time increases by 10.3 ms.
  - The standard deviation of reaction time for a subject is 37.12 ms, reflecting variability between subjects' reaction times.
- In Model 2 (log-transformed reaction time):
  - The exponential of the intercept shows the reaction time without sleep deprivation, with a value of 252.16 ms.
  - The t value of 13.36 indicates the significance of day on reaction time, and it is highly significant.
  - There is significant variability between subjects.

5 Residual Analysis

This was carried out to determine if the residuals of the models follow the key assumption of Normality and Homoscedacity (constant variance)

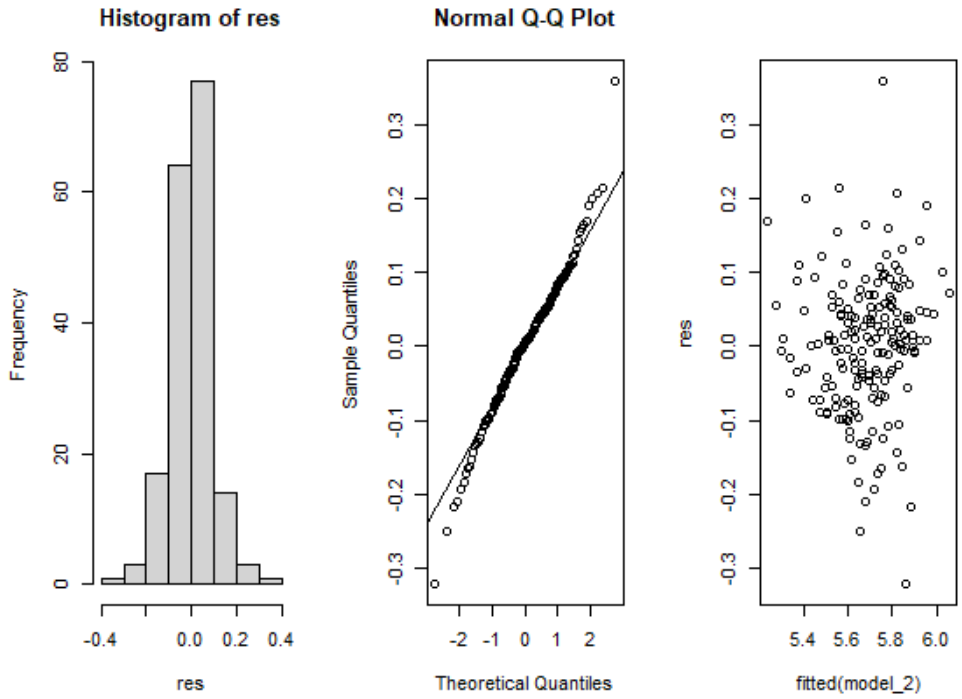


Figure 5: Plot for Model 2 with log transformed reaction time.

From the plots above, we can see that the residuals for model 2 are normally distributed, and the fitted values show the residuals as a blob without any obvious trend indicating a constant variance. These assumptions were obeyed due to the log transformation done on the reaction time variable before modelling.

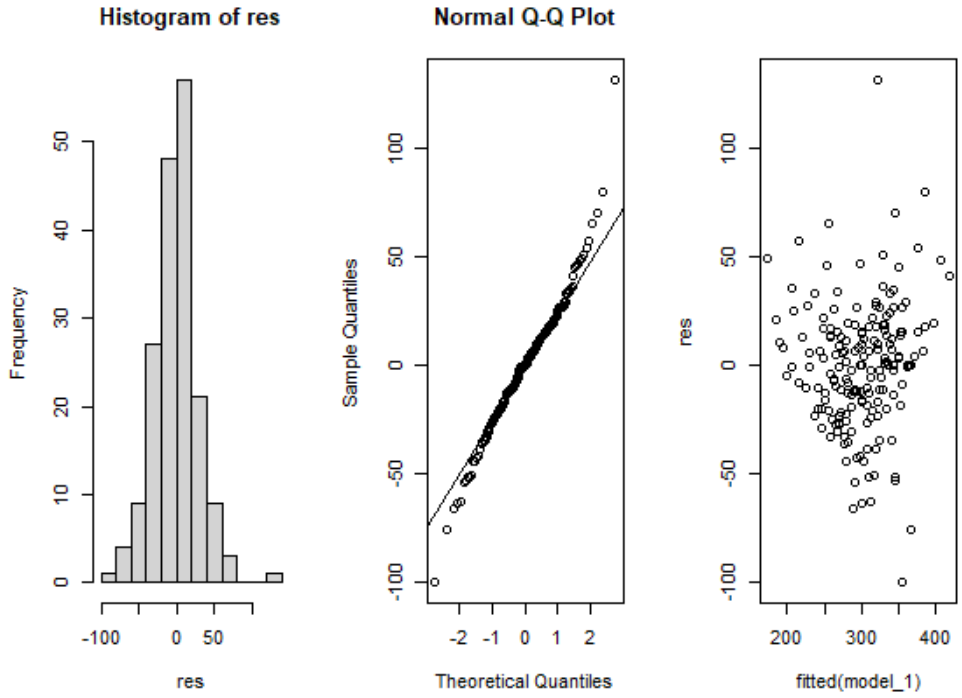


Figure 6: Plot for Model 1 without log transformed Reaction time.

While for model 1, the residuals are not normally distributed, failing to obey the key assumption of being normally distributed.

R-Code

Link to the R code: `https://github.com/Youngprof3/mixed_effect_model`