Analysis of the Correlation of Sleep Patterns and Reaction Time

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Sleep patterns and the circadian rhythms have always been a major factor in cognitive performance. Different stages of one's circadian rhythm have always been linked to varying performance in attention, working memory, and executive function. This research project analyzed how different stages of circadian rhythm and changes to sleep patterns impact one's cognitive performance, specifically reaction time and reaction time variability. This study had participants take a reaction time test at the preferred stage of their circadian rhythm and answer questions based on their sleep habits for that particular day. The only significant result from this study was that participants who took longer naps seemed to have slower reaction times. In addition, we found that participants who took their reaction time test 5-6 hours after waking up had the best results when taking into account both reaction time and reaction time variability. This report also describes an individual case study in relation to the overall project.

Introduction

Sleep is a natural state of rest adapted by nearly all animals. It is a necessary biological function that aids in overall cognition. Sleep deprivation— not getting the required amount of sleep can have detrimental effects on cognitive function, specifically reaction time [1]. Reaction time is a measure of the time it takes for a subject to respond to a stimulus. Since the reaction to a stimulus requires attention, reaction time is an adequate measure of attention.

In addition to the amount of sleep someone receives, a person's sleep-wake cycle can also impact their reaction time. The sleep-wake cycle is a 24-hour cycle that dictates when the body should be awake and when it should be asleep. This cycle is part of the body's circadian rhythm, a natural internal process that regulates biological functions, such as sleep, on a 24-hour cycle. Circadian rhythm has an impact on attention, and there are different times of day at which alertness is high and when alertness is low [2].

This investigation examinse the relationship between reaction time and sleep and it will do so from two different perspectives. The first relationship to examine is to look at the impact of sleep deprivation and the second way is to examine the impact of the sleep-wake cycle. Participants were asked to complete a reaction time test, and following the test, they completed a survey that recorded the amount of sleep they received the previous night and their sleep-wake cycle.

Methods

Data Collection Methods

Individuals that participated in this study had an age range from 20-25 years old. Below is a distribution of the ages of the participants.

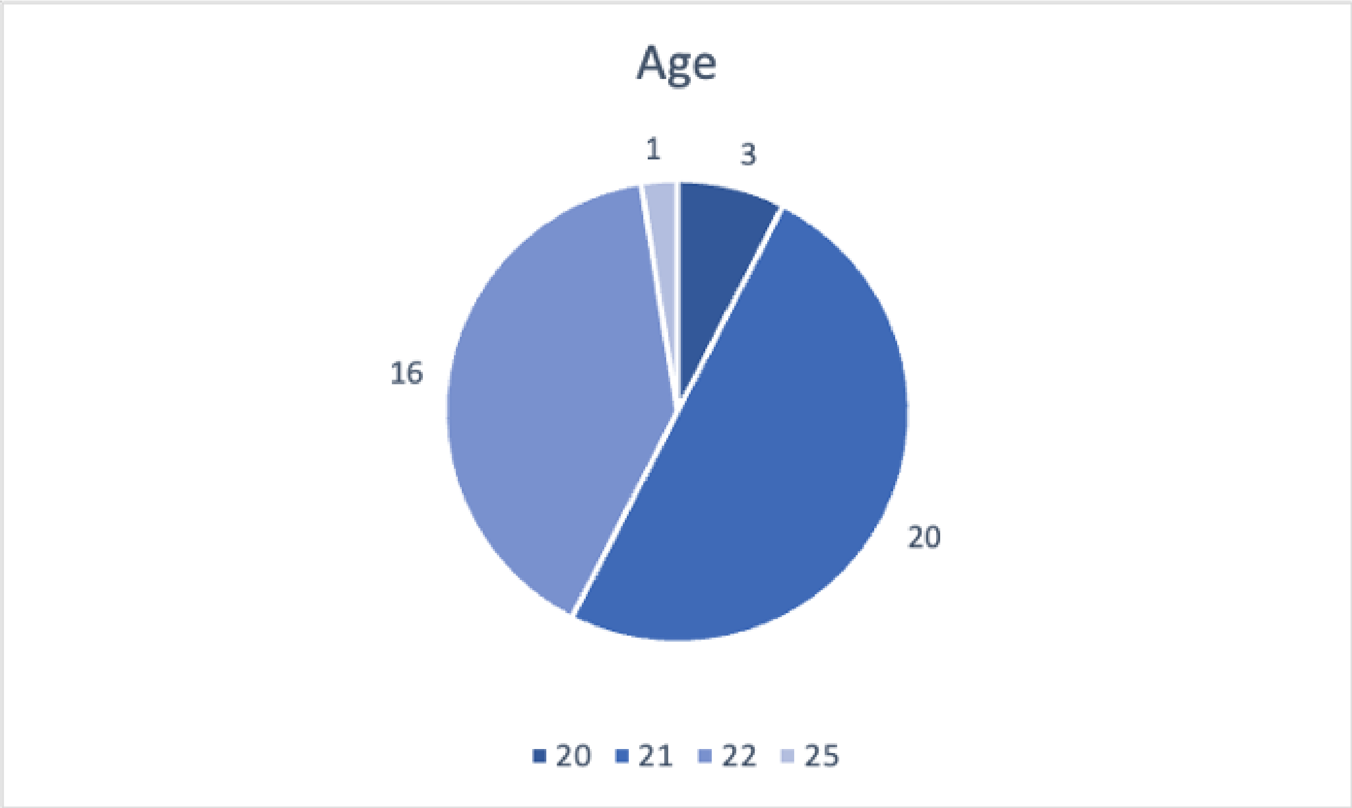

Figure 1.

The gender of the students was relatively even, with 55% of the demographic being female and 45% being male. Below is a distribution of the genders of the participants.

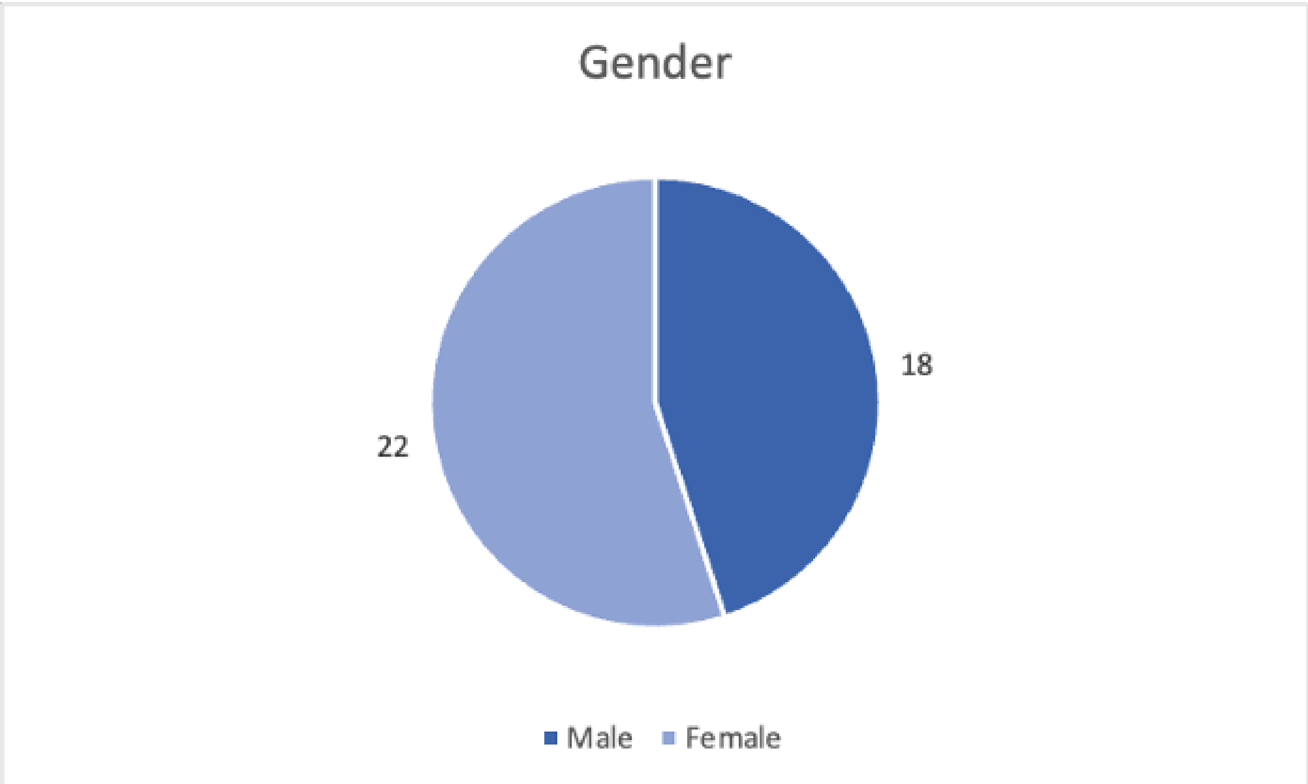

Figure 2.

To begin the experiment, subjects started by taking two Reaction Hardware tests on the Brian Gauge. The Brain Gauge “is a cognitive assessment tool that measures brain health by testing sensory perceptions in your fingertips.” Subjects were instructed to place their index and middle fingers on the two receptive points on the Brain Gauge. The subjects were then given a series of tests where they were required to click on the button corresponding to the index finger as soon as they felt a stimulus on their middle finger in order to measure reaction time. The average reaction time and variability between each reaction time were recorded for each individual test.

Upon completion of the battery test, subjects were instructed to answer questions pertaining to their sleeping patterns. The survey began with two categorical questions regarding the amount of sleep they got the previous night and how long they’ve been awake for at the time of taking the battery test. The preceding question was a dichotomous question with choices yes or no about whether the subject took a nap that day. If the subject answered “yes” to the nap question, two more categorical questions were presented in regards to how long their nap was and how many hours it has been since they woke up from their nap.

In terms of collecting data, after all participants completed the brain gauge test and survey, the data were averaged in each respective bin of hours. Reaction time and variability were averaged for each gender as well. Average hours of sleep, previous night's sleep, and how many hours after waking was the test taken were the three continuous predictors we used to see if there was any relationship between those variables and RT and RT variability. The data was also analyzed on a case-by-case basis, to look for any potential outliers and to identify any particular case to look at in more detail, which will be discussed in more detail later in this paper.

Data Analysis Methods

To analyze our results, we utilized Microsoft Excel and IBM SPSS. In our survey, we asked participants how much sleep they received the night before they took the reaction time test, how much sleep they receive typically, and how many hours after waking up they took the reaction time test. Since this was a categorical question, with choices such as “4-5 hours” or “1-2 hours”, we converted this variable from categorical to discrete variables by averaging “4-5 hours” to 4.5 hours or “1-2 hours” to 1.5 hours. For answer choices such as “21+ hours”, we converted the variable to 21 hours. The main reason we converted our data points from categorical to discrete was that we did not want string values in our data set, since it would limit our ability to run regressions on our data. After sorting and cleaning the data set, we ran linear regressions between each of the collected variables and Reaction Time and Reaction Time Variability to determine if there was a significant relationship between these variables and Reaction Time and Reaction Time Variability.

Results

Hours of Sleep in Previous Night		
Sleep	Average RT (sec)	Average RT Variability (sec)
4 - 5 hours	243.65	26.45
6 - 7 hours	232.02	19.38
7 - 8 hours	250.04	18.61
8 - 9 hours	266.51	28.03
9 - 10 hours	215.30	17.65

Table 1. *Average Reaction Time and Reaction Time Variability based on Hours of Sleep in the Previous Night*

Average Hours of Sleep

Average RT (sec)	Average RT Variability (sec)	
4 - 5 hours	233.07	15.40
6 - 7 hours	245.29	21.83
7 - 8 hours	257.60	23.61
8 - 9 hours	210.03	20.90

Table 2. *Average Reaction Time and Reaction Time Variability based on Average Hours of Sleep*

Hours After Waking Up		
Average RT (sec)	Average RT V (sec)	
1 - 2 hours	283.88	32.62
3 - 4 hours	252.60	22.20
5 - 6 hours	206.92	8.18
7 - 8 hours	238.88	12.84
9 - 10 hours	239.30	28.73
11 - 12 hours	234.20	19.88
13 - 14 hours	220.07	18.13
15 - 16 hours	301.07	29.30
17 - 18 hours	194.60	21.40
19 - 20 hours	320.60	36.10
21+ hours	204.80	34.00

Table 3. *Average Reaction Time and Reaction Time Variability based on Hours after Waking up*

Gender		
Average RT (sec)	Average RT V (sec)	
Male	236.53	25.10
Female	250.20	19.52

Table 4. *Average Reaction Time and Reaction Time Variability based on Gender*

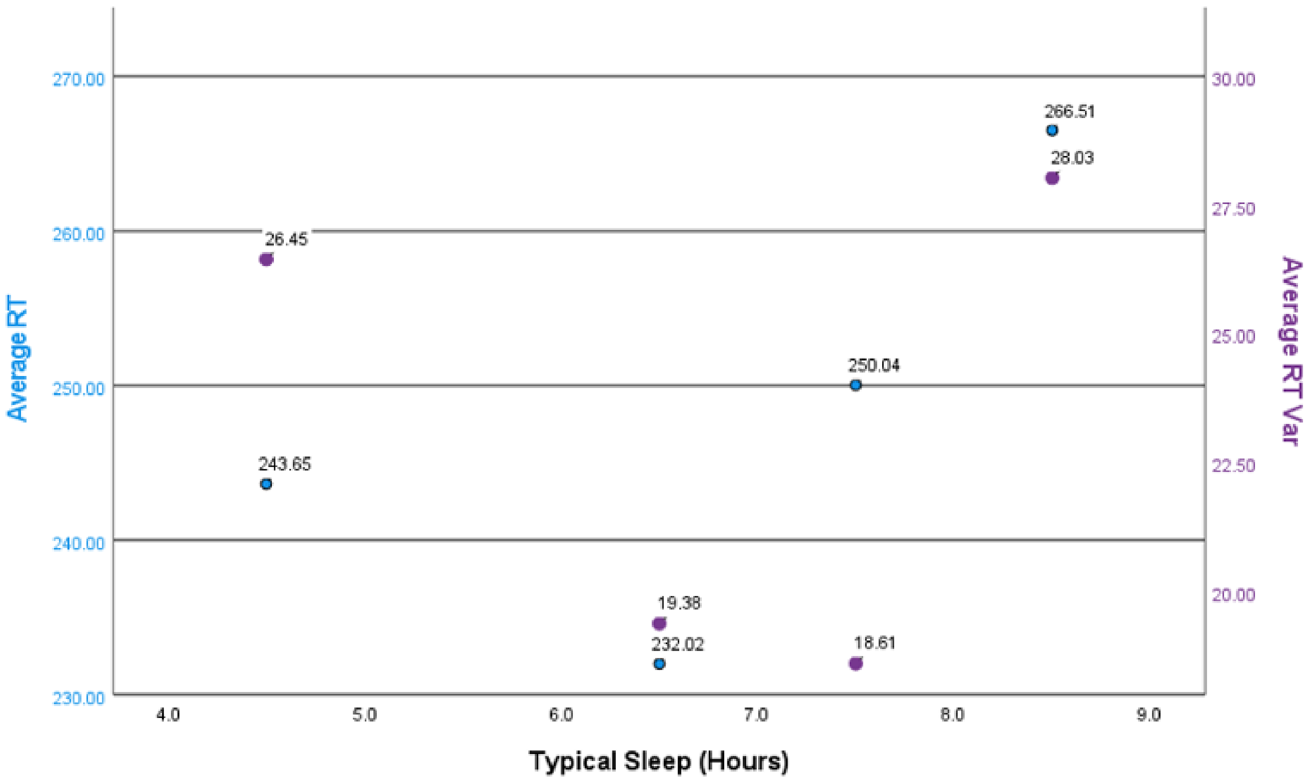

Figure 3. *Scatterplot showing the relationship between Average Hours of Sleep and Average Reaction Time and Variability*

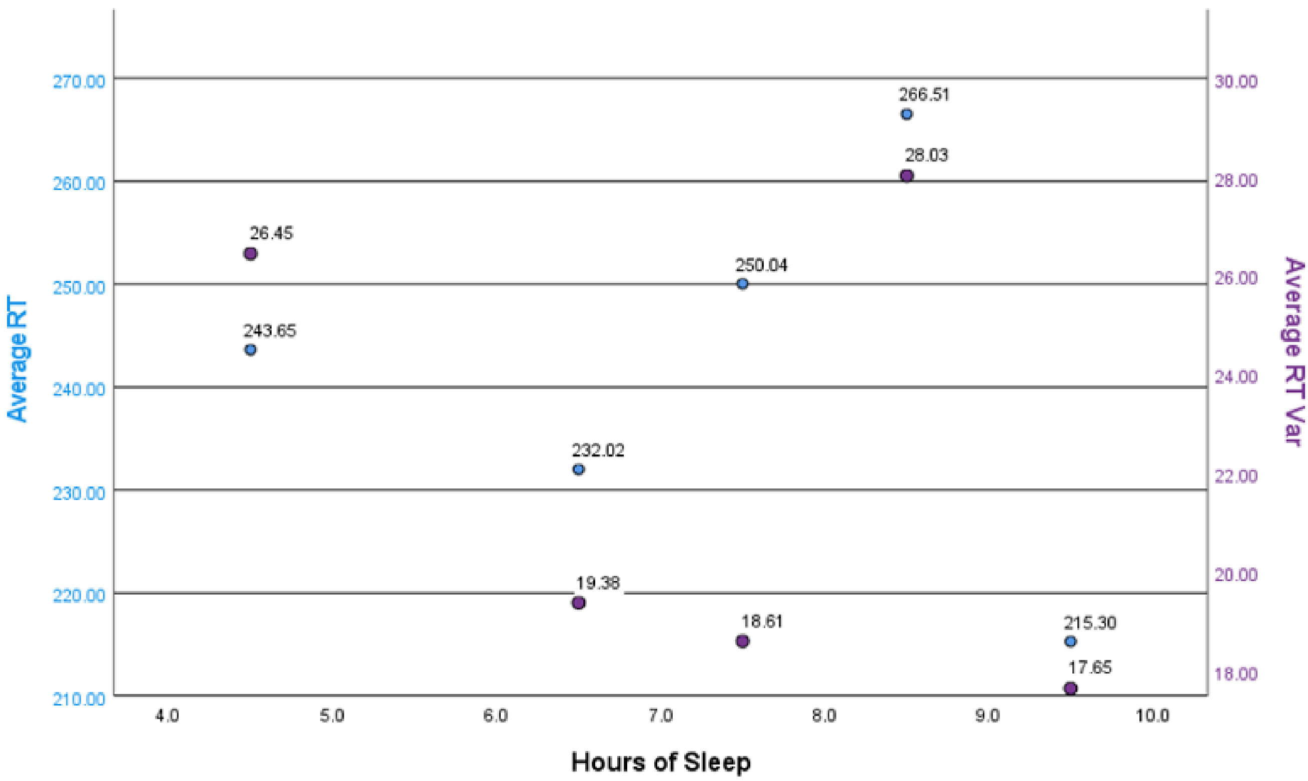

Figure 4. *Scatterplot showing the relationship between Hours of Sleep in the Previous Night and Average Reaction Time and Variability*

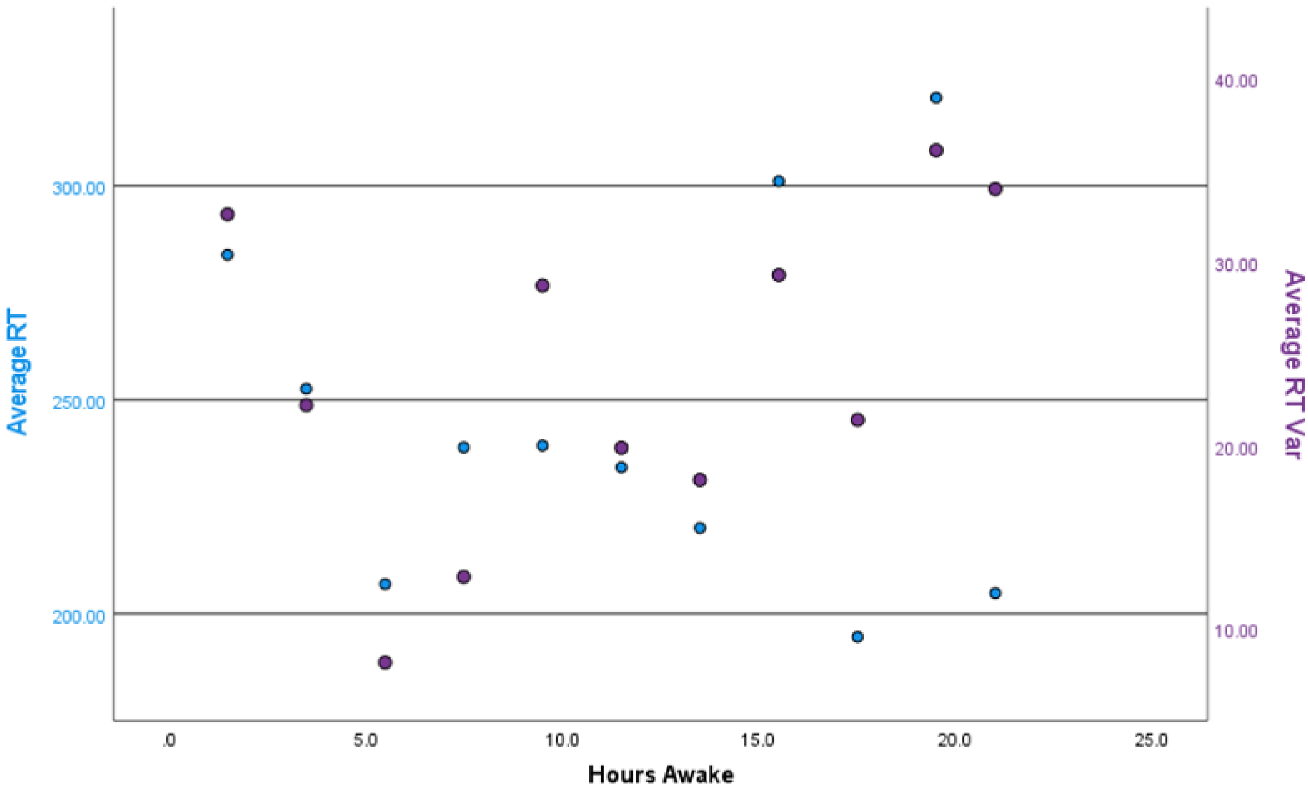

Figure 5. *Scatterplot showing the relationship between how many hours after waking up the test was taken and Average Reaction Time and Variability*

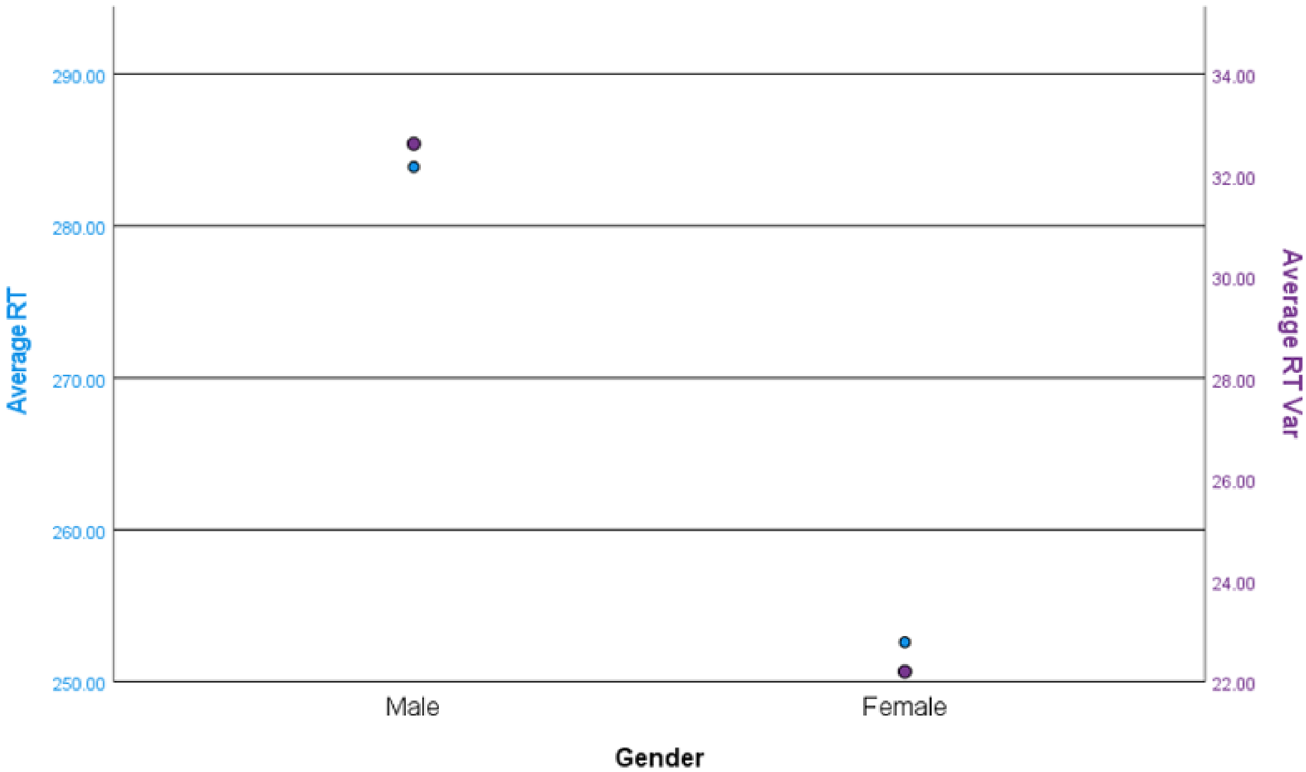

Figure 6. *Scatterplot showing the relationship between Gender and Average Reaction Time and Variability*

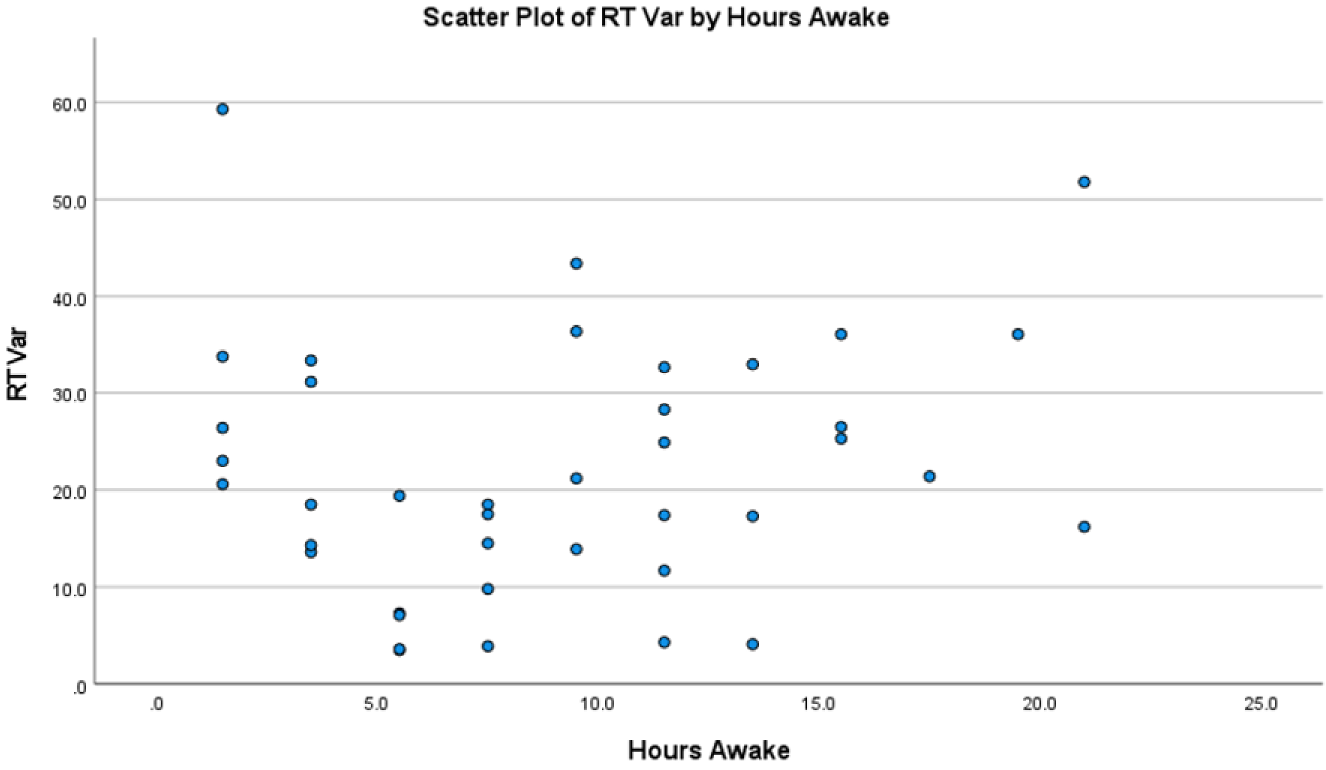

Figure 7. *Scatterplot showing the relationship between Reaction Time variability and hours awake.*

Figure 8. *Histogram showing the distribution of hours of sleep.*

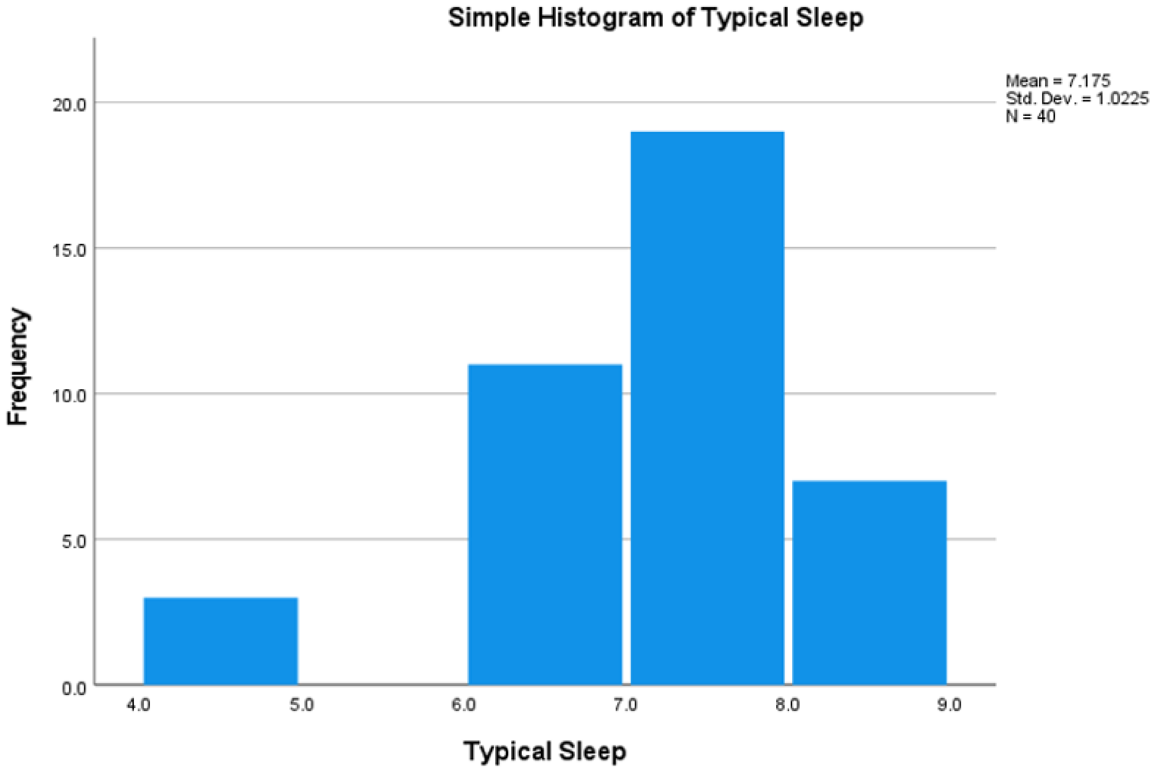

Figure 9. *Histogram showing the distribution of hours of typical sleep*

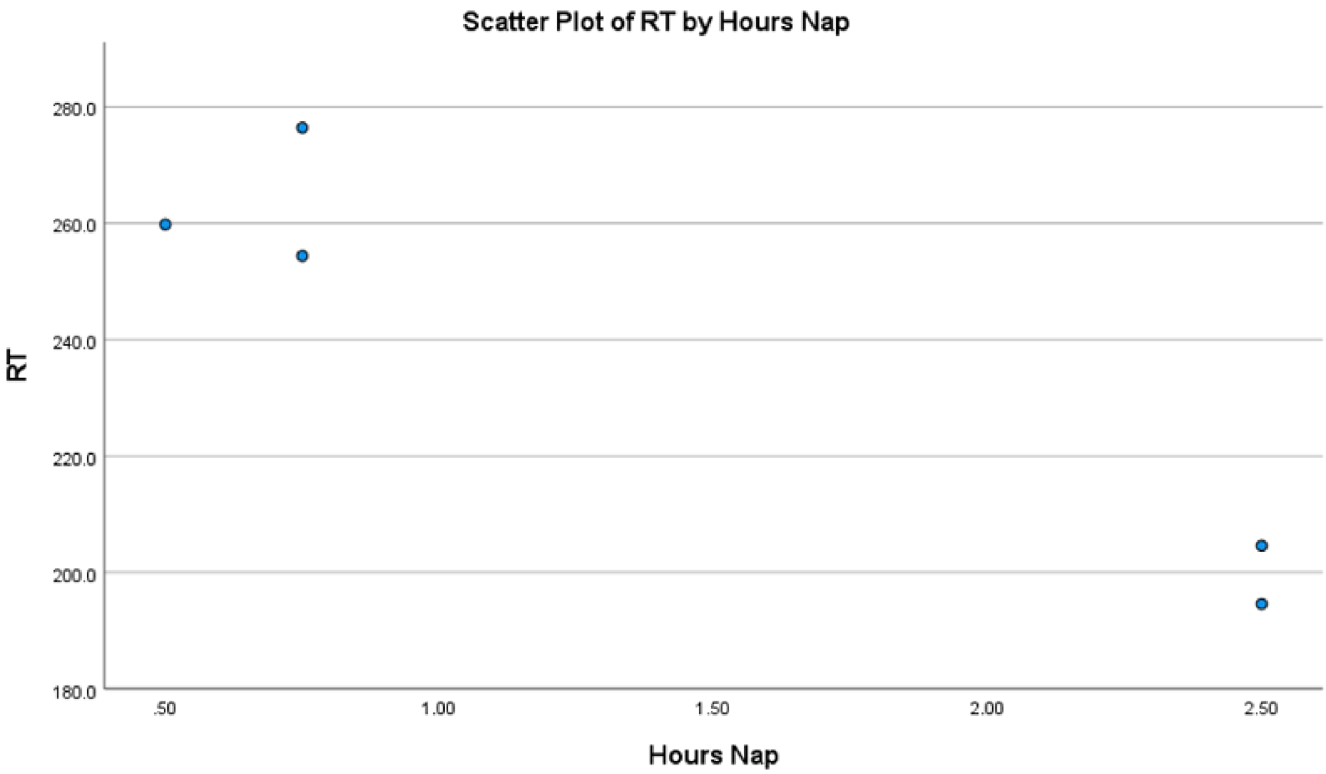

Figure 10. *Scatterplot of Reaction Time vs. Hours of Nap*

Variable	Significance
Hours of Sleep	0.664

Typical Sleep	0.649
Hours Awake	0.596
Nap	0.782
Hours Nap	0.010
Gender	0.413

Table 5. *Table summary of the significance between various variables collected and Reaction Time*

Table 5. .

Variable	Significance
Hours of Sleep	0.699
Typical Sleep	0.527
Hours Awake	0.376
Nap	0.843
Hours Nap	0.394
Gender	0.185

Table 6. *Table summary of the significance between various variables collected and Reaction Time Variability*

Table 6. .

Unstandardized Beta Coefficient	Significance
Intercept	285.96
Hours Nap	-34.287

Table 7. *Table summary of the relationship between Hours Nap and Reaction Time*

Discussion

Throughout this experiment, *Reaction Time* and *Reaction Time Variability* were used as metrics to study and quantify cognitive function. We utilized the following factors to determine the role of circadian rhythm in this regard: hours after waking (*Hours Awake*), hours of sleep during the previous night (*Hours of Sleep*), typical hours of sleep on an average night (*Typical Sleep*), whether or not the participant took a nap that day (*Nap*), how long they napped for (*Hours Nap*), and the participant's gender (*Gender*).

After conducting linear regression tests to determine statistical significance between the variables mentioned above and *Reaction Time* and *Reaction Time Variability*, we found that, according to Table 5, the only linear relationship that was statistically significant was the negative correlation between *Hours Nap* and *Reaction Time*. The statistical relationships between the rest of the variables can be found in Tables 5 and 6.

We believe one of the reasons we could not find a statically significant relationship between reaction time and different variables used to quantify circadian rhythm was our small sample size. According to the histogram in Figure 6, *Hours of Sleep* had a relatively normal distribution, with a few outlier variables. In addition, Figure 7 shows that *Typical Sleep* also had a relatively normal distribution, aside from a few outliers. This shows that our sample did not represent those who have “abnormal” sleep patterns. Therefore we cannot assume there is no relationship between circadian rhythm and cognitive function simply based on the results of our study.

Despite not finding a statistically significant relationship between our variables, we were still able to find tests within our collected dataset. One trend we would like to highlight is that according to Figure 5, as *Hours Awake* increases, *Reaction Time Variability* also increases, meaning that participants’ variability in reaction time test scores increases the longer they are awake after sleeping. Reaction time variability is a metric that reflects participants’ lapses in judgment. A high reaction time variability means that the individual taking the reaction time test had many lapses in judgment, which may signify lower cognitive function. If reaction time variability increases as a person is awake for more hours, the longer a person is awake, the lower their cognitive function is.

In addition to trends, we also found interesting points in our scatterplots that show reaction times and reaction time variabilities that are significantly different from other points. According to Figure 1, participants who had 6.5 hours of *Typical Sleep*, or average sleep per night, scored the lowest on their reaction time and reaction time variability tests, on average.

Another interesting variable we analyzed was *Hours of Sleep*, which measured the participant's hours of sleep in the night prior to taking the reaction time test. Hours of sleep experienced by the subject the night before taking the test is an integral element here since it provides insight into circadian rhythms as a whole and highlights sleep deprivation and how it influences reaction time. We found that reaction time average reaction time was lowest at 6.5 hours of sleep, according to Figure 2. This was after the reaction time for 9.5 hours was removed since this was an outlier.

We also looked at how *Hours Awake* influences reaction time and reaction time variability. The *Hours Awake* aspect of our study is a crucial way to understand better how circadian rhythms and sleep patterns impact alertness. We found that participants who were awake for 19.5 hours scored the highest in their reaction time tests. Another interesting trend we found was that male participants, on average, had a much higher reaction time and reaction time variability than female participants.

Case Study: How does taking a nap influence Reaction Time and Reaction Time Variability?

One of the parameters we also looked at was whether or not the subject took a nap before taking the reaction test and how long their nap lasted. Of the 40 subjects we were able to survey, only five said that they took a nap. When we ran a linear regression between *Hours Nap* and *Reaction Time*, we found there to be a significant relationship, according to Table 6. According to Table 7, as *Hours Nap* increases by one unit, *Reaction Time* decreases by 34.287 units.

This finding can be visualized in Figure 8, where we see that the five subjects fell into three categories, 0.5 hours, 0.75 hours, and 2.5 hours. Solely looking at the data presented, we see that there is a negative linear relationship between the total time of nap and reaction time. As the time of the subject’s nap increased, their reaction time decreased.

This is contrary to popular belief that a 15-30 minute “power” nap is ideal in order to increase your alertness and focus. Naps longer than 30 minutes result in an effect called “sleep inertia,” which leads to a reduction in the ability to perform upon awakening due to sleep [3]. Symptoms of this effect include confusion, grogginess, and deficits in cognitive performance [4]. Based on the results from this study, we see that the subjects experienced the opposite of this; they instead showed signs of more alertness and wakefulness, which led to their slower reaction time.

Unfortunately, due to our small sample size of five participants, our findings are not reliable. However, we believe that this is a good start point for future studies to study how the length of a nap affects cognitive function. Also, an additional parameter on what time the nap was taken and how that affects cognitive performance would be a good study to evaluate.

References

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