The correlation between an individual's reaction time and diurnal pattern based on circadian rhythm

Ze Qian Wu
1002192254
November 14, 2018

Table of Content

Summary

The study focuses on examining the diurnal pattern of an individual's reaction time by separating 24 hours of a day into four time periods. From using the data obtained from a group of undergrad students, there are two variables that are correlated to a person's reaction time: fatigue level and ill. As a conclusion, fatigue and ill are significant findings in this study, whereas no other significant variables are found with the support of linear mixed models and ANOVA analysis.

Introduction

Reaction time is a measure of the amount of time that it needs to respond to a particular stimulus, which is an inspiring topic that many experimenters intend to study. As human-beings have individual reaction time and it varies throughout the day, this study focuses on the factors that correlates to a person's reaction time, either positively or negatively. The purpose of this study is to examine if there are any interactions between time of the day and reaction time, along with 7 other variables: busy/light day, hours of sleep, MEQ, fatigue, hunger, stimulants and ill.

To explore the research question based on the data that was acquired, a physiological approach was taken in this data analysis to analyze the diurnal pattern based on circadian rhythm. Instead of focusing on the exact clock time, we were looking at the same biological clock among all individuals. Four different times of a day were used to represent the exact clock time and we are using the time variable to examine how it correlates with a person's reaction time. Considering there were random errors in between all the individuals, the models that were used in the data analysis only concerned about the within-group differences. Reaction time differences between individuals were ignored and we were mainly interested in what factors correlates with a person's reaction time and how reaction time varies throughout the day.

Methods

Raw data was collected from a sample of students from an undergrad class in University of Toronto and preliminary data was recorded by each students who participated in this study. A total of 8 observations were received from each individual, with a sample size of 39 students. In order to acquire a more valid dataset, all the respondents in the study were asked to use the same device to measure their reaction time on the same website[1]. Students were only allowed to do the test once and extra practice runs were prohibited. One "busy" day and one "light" day were recorded at four times throughout each day, which were identified as: 1 - within one hour of waking up, 2 - 4-6 hours after the first measurement, 3 - 4-6 hours after your last measurement and 4 - within one hour of going to bed. Measurements were taken with dominant hand with no excuse of having problems with visual ability. A few other sources were used to measure a student's MEQ, fatigue and hunger level. The Morningness Eveningness Questionnaire[2] allowed participants to indicate if they are more of a morning person or night person, which was also a potential factor that might correlate with a person's reaction time. Fatigue and Hunger were both measured with a scale, Samn-Perelli 7-pt scale[3] and Hunger scale[4], which lays out a person's fatigue level and hunger level with numbers, with 1 indicating fully alert and beyond hungry, and bigger numbers represent less alert and not as hungry. Stimulants and ill were indicated every time a student records an observation as these two factors might have intersections with reaction

---

[1] https://questionnaire.censusatschool.ca/practice/reaction
Practice- Reaction from Census at School

[2] https://sleephabits.net/morningness-eveningness-questionnaire

[3] https://www.icao.int/safety/fatiguemanagement/FRMSBangkok/4.%20Measuring%20Fatigue.pdf)

[4] https://medical.mit.edu/sites/default/files/hunger-scale.pdf)

time. After everyone finished the raw data collection, all the data files were then compiled and cleaned based on the research question: What is the diurnal pattern of reaction time?

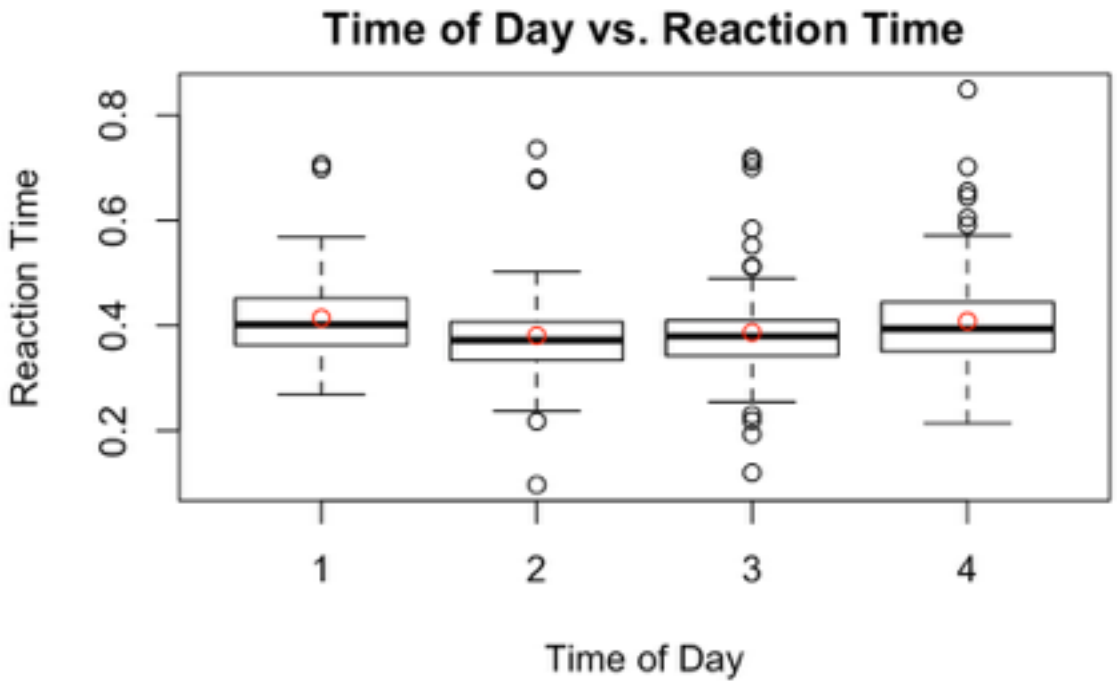

Figure 1. Time of Day vs. Reaction time

By taking the physiological approach to answer the research question, a linear mixed model is appropriate for capturing within-group differences. Figure 1 above illustrates the relationship between time of day and reaction time. By looking at the box plot, there is no specific pattern based on all the reaction time as the mean, indicated by a red dot, of each period of time does not show any trend. In this case, it would be more appropriate to investigate if there are any factors that has a relationship with reaction time.

To identify which variable has a significant correlation with reaction time and time of day, two mixed models, full model and reduced model, are used to compare with each other. The

full model consists of all fixed variables that potentially interact with reaction time, whereas the reduced model only includes the random variable, which is student ID. By using the linear mixed models, two fixed variables appeared to be significant: fatigue and ill.

Considering that fatigue and ill were both significant, it was important to investigate how they interact with reaction time and time of day. Therefore, ANOVA test is used to test the difference between the means of the two variables.

Result

From constructing linear mixed models and using ANOVA , two variables, fatigue and ill had significance level of 0.001 and 0.01, which both rejected the null hypothesis of them having no interactions with reaction time and time of day. This result shows that these two variables are correlated with reaction time, with fatigue being more statistically significant. From the two tables below, Table 1 listed out all the variables in the two models that we used to compare, and Table 2 summarized which variable was significant to our research question.

Linear Mixed Models	Fixed Variables	Number of Fixed Variabes	Random Variables	Number of Fixed Variabes
Full Model	busy/light day, hours of sleep, MEQ, fatigue, hunger, stimulants and ill	7	Student ID	1
Reduced Model	N/A	0	Student ID	1

Table 1. Two Linear Mixed Models used to identify significant correlation

Fixed Effects	P-value	Significance Level
Busy/Light day	0.50404	
Hour of Sleep	0.25934	
MEQ	0.19878	
Fatigue	2.22E-13	*** (0.001)
Hunger	0.42958	
Stimulants	0.58455	
Ill	0.00728	**(0.01)

Table 2. Summary of Full Model

Based on the linear mixed models that were used to examine the interaction effect between variables and reaction time, there was no evidence showing that busy/light day, hours of sleep, hunger and stimulant have any interaction with reaction time. Taking fatigue and ill into account, it does make sense that an individual's performances is associated with how tired they are, in addition to if they are sick or not. According to the final result, if someone has marked that they are extremely tired and exhausted, the reaction time has a tendency of being slower than when the person is fully alert. On the other hand, being sick interrupts a person's functionality, which also correspond to the result. The conclusion of fatigue and ill being significant is supported by linear mixed models and ANOVA, which implies that they move together with an individual's reaction time throughout the day.

Conclusion and Discussion

Based on the nature of the study, we are interested in seeing if there is any correlation between individual's reaction time with other potential factors. Due to the fact that every student has their own schedule as a result of having different MEQ, it is more valid to focus on the change in reaction time within each student. From building linear mixed model, the random effects and fixed effects are both taken into account, which is appropriate to examine the correlation in this study. After processing the statistical approaches, two fixed variables, fatigue and ill seemed to have significant interactions with an individual's reaction time regarding time changes throughout the day.

This study might be limited through the process of data collection by using an electronic device to measure a person's reaction time. The use of an electronic device might not reflect the measurements precisely and accurately due to delays of touch screen, mouse or keypad. Considering that the website that is used to determine a person's reaction time requires people to be in an environment that has access to the internet, all devices have possibilities of experiencing lags regarding connection or other technical issues. Despite the fact that only in-person differences are considered instead of in-group differences, the same electronic device does not guarantee consistency for every single measurement of each individual. Secondly, all samples are from the same group — 4th year student from University of Toronto. Due to that all students are around the same age and are in the same program, samples with similar background do not represent the general public as the diversity between each student is very limited. Besides all the biases that occurred during the process of data collection, one of the most considerable limitation for this study is the sample size. Having a sample size of n=39 is not big enough to conduct any

complex statistical analysis that might help with obtaining a valid and reliable result. Insufficient sample size can directly cause biased result and findings. As a way to eliminate the effect of insufficient information, a much bigger sample size is preferred for human's reaction time study.