The Effects of Sleep Deprivation on Cognitive Function

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Abstract

The experiment was designed to test the effect of sleep deprivation on basic levels of cognitive function. We predicted that there would be decreased performance during tests of cognitive function with reduced levels of sleep. Fifty-seven students between the ages of 20 and 22 were asked to fill out a short survey asking about their sleep the night before and were tested while attached to a Pulse oximeter. All subjects participated in a reaction test, a Stroop test and a simple multiplication table. Participants were asked to come back to repeat the experiment during a following week, all subjects were then split into intra- and inter-personal for those who were able to return and those who were not, respectively. Our results for interpersonal were mixed, in that there was no significant correlation for reaction time. There was significant correlation for higher performance in the math test with more sleep, however, the Stroop test showed a significant correlation with decreased levels of sleep. For intra-personal there was no significant correlation between the amount of sleep received and any of the cognitive tests. The results of our study showed no significant correlation in the amount of sleep received with basic cognitive function.

Introduction

Sleep is an integral process of human life. Though sleep may seem like a passive process, many studies have shown how active the brain is during sleep. It helps to consolidate existing memories and to make new connections which inherently enhance performance on a variety of tasks.

Sleep is not stagnant but it consists of many dynamic stages of sleep. There are four stages of sleep and EMG studies show how unique the brain activity is with each one. The first stage of sleep is very light and people are easily wakened. During stage two sleep, people start to lose awareness of the outside world and their brain activity shows two unique characterics: sleep spindles and K complexes. Stage three and four are also known as slow wave sleep and brain patterns show delta waves which are low frequency, high amplitude waves. The last stage of sleep is rapid eye movement (REM) sleep which shows brain activity similar to when we are awake. A recent study conducted in 2015 by Diekelmann and Feld show that slow wave sleep and REM sleep are both important in memory acquisition and consolidation.

Many people suffer from some type of sleep loss or deprivation due to our fast paced society. There are two types of sleep loss: acute and chronic. Acute sleep loss is when a person is awake for a continuous extended period of time, whereas chronic sleep loss is when a person continues to get an insufficient amount of sleep over several days. We measured these effects by asking the participant that had suffered sleep loss if it was a regular or irregular event (Miller & Wright & Hough & Cappuccio 2014).

College students participated in a study conducted at Bradley University in 2010 by Pilcher and Walters where the students were either allowed to have 8 hours of sleep or they were kept awake for 24 hours straight. They were then tested on a variety of performance tasks that measured their cognitive function and ability to focus. Students that were deprived of their sleep performed significantly worse on the tasks and self reported that they thought they performed poor on the tasks as well. Students with a full night of sleep reported to have more focus and performed much better on the tasks than the non-sleepers. This study took a dramatic approach to the idea of sleep deprivation creating cognitive dysfunction (Pilcher and Walters 2010).

There have been studies conducted looking at the effects of sleep loss on memory, cognitive function, and emotion. Cases on sleep deprivation have debated whether the consequences of sleep deprivation are higher on tasks for simple versus complex order thinking. These studies have speculated that the repercussions of sleep deprivation are higher on memory and vigilance than complex higher order thinking (Philibert 2005); however, there are not enough specific tests conducted to support this theory. Although there has been no higher order thinking conclusions, there are studies supporting sleep deprivation having a significant impact on simple and sustained attention and speed (Doran *et al*. 2001).

There are two main approaches to the effects of sleep deprivation: decreased alertness and attention and changes in brain activity of different brain structures. These effects cause decreases in reaction time by impairing ability to focus. This impairment is said to be amplified during timed tasks which is the approach that our project adapts (Alhola & Polo-Kantola 2007). Attention, specifically, is controlled by the frontal lobe which is vulnerable to the effects of sleep deprivation (Alhola & Polo-Kantola 2007).

In our approach, we studied college students that are deprived of sleep on a more regular basis, also known as chronic sleep deprivation. We hypothesized that the participants who acquire less sleep will be less alert, which will be demonstrated by longer reaction time scores. Participants will have decreased abilities to sustain their attention and therefore will perform worse on the cognitive tasks like the stroop and math test than participants that are well rested. We performed an interpersonal and intrapersonal study to investigate the effects of sleep deprivation on reaction times, ability to focus and cognitive performance on a math test under timed pressure. We speculate that participants will perform better on these tasks when they get more sleep than when they perform these same tasks with less sleep. We hypothesize the physiological effects would be increased heart rate for sleep deprived participants compared to themselves and other participants with normal levels of sleep.

Materials and Methods

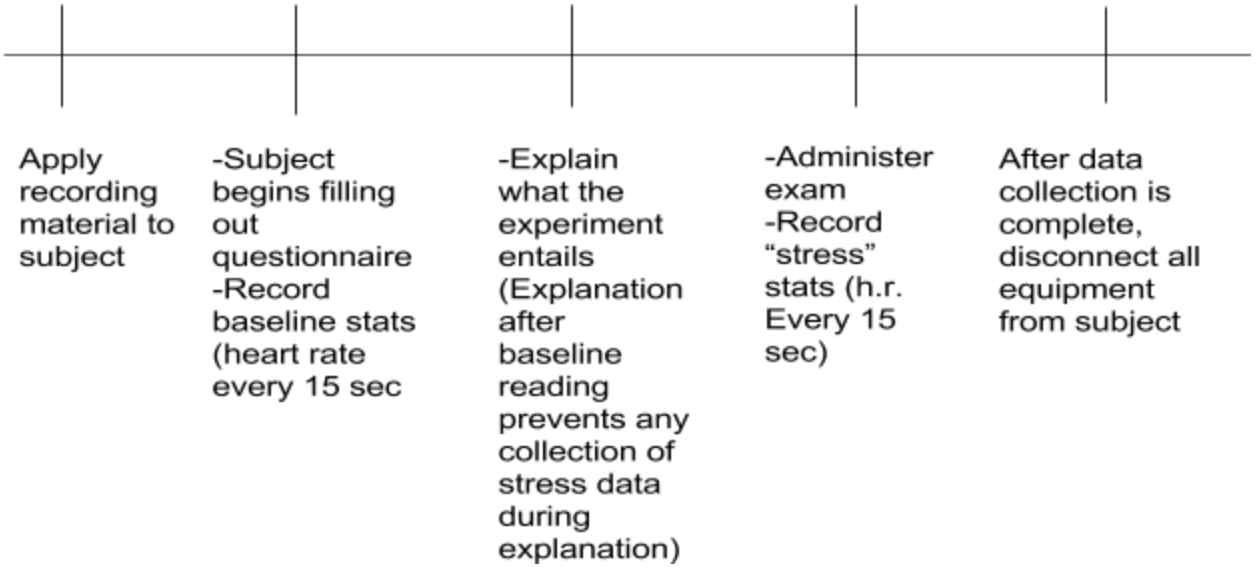
A Nonin pulse oximeter and carbon dioxide detector and Biopac reaction test were obtained for this experiment. Also, a stroop test of 60 items and a multiplication table ranging from single by single digits to triple by double digits. There were 57 participants that participated in our study that were students at the University of Wisconsin-Madison. The average age was 21.3 and ranged from 20 to 22 years old. Participation in this study was completely voluntary.

All participants were given a consent form describing the dangers and incentives of the study they were participating in. The consent form was signed, participants were given a sleep questionnaire with questions relating to sleep, hydration, and overall living habits. The questions about sleep were the only ones pertaining to our study, while alcohol intake and diets were asked to prevent subjects from knowing the exact purpose of our study. Then participants filled out the

questionnaire, their heart rate was recorded using a pulse oximeter, which represented their baseline heart rate. When the survey was completed, participants were tested on their reaction time using a Biopac reaction timer. After ten attempts, their mean reaction time was taken and recorded.

The second test, a Stroop test, was administered with a time limit of thirty seconds while their heart rate was recorded every 15 seconds. Subjects were to say the color of the word, not the word itself. Participants only were able to have one attempt at each word and were scored for how many they completed and how many they got correct. Finally, a two minute multiplication exam was administered, with warnings when one minute, thirty seconds, and ten seconds remained. None of the questions were weighted, so participants were able to freely choose which questions they wished to answer. Heart rate was recorded every 15 seconds and averaged.

Scoring for Stroop and math tests was calculated as two percent-style scores: number correct out of the total number of questions and number correct out of questions attempted. This minimized individual differences when assessing scores. Once participants completed the three tests, they were told to come back if their sleep has changed (for better or worse) and if hydration changed (to reduce bias). If the participants came back (n=25), they repeated the same exact tests as above and their new results were compared to their initial results. The trial that was preceded by the least amount of sleep was put in the intrapersonal experimental group. If the participant did not return, they were put in a separate interpersonal group. The control group (n=13) in the interpersonal cohort was anyone with eight or more hours of sleep. The experimental group (n=19) consisted of subjects with less than 8 hours of sleep. All statistical calculations were made using RStudio and the one-tailed t-test.



Results

Interpersonal experiment

Reaction time

According to figure 1, the mean reaction times were 0.2515 (SD=0.0548) seconds and 0.2498 (SD=0.0417) seconds for experimental and control groups respectively. However, the p-value was 0.0683 so there was no statistical significance between the two values.

Stroop Test

According to figure 2, the mean overall scores for the Stroop Test was 49.47% (SD=0.1140) and 52.59% (SD=0.0825) for experimental and control groups respectively. The p-value was around 0 indicating statistical significance between the groups.

According to figure 3, the accuracy scores (number correct over number attempted) for the Stroop test was 98.18% (SD=0.0287) and 96.57% (SD=0.469) for experimental and control groups respectively. The p-value value was around 0 indicating that the group that received less than 8 hours sleep were more accurate than the control group.

Math Test

According to figure 4, the test scores were 33.04% (SD=0.0475) and 39.89% (SD=0.0919) for the experimental and control groups respectively. The p-value was close to 0 so there is statistical significance that the control group performed better on the math test overall than the experimental.

According to figure 5, the accuracy scores for the math test was 86.17% (SD=0.0952) and 88.40% (SD=0.0639) for experimental and control groups respectively. The p-value was also close to 0 so the difference between the two groups was significant.

Heart Rate

There was no statistical significances between the heart rates of all the control and experimental groups on any of the experimental tasks.

Intrapersonal Experiments

Reaction Time

According to figure 6, the mean reaction times were 0.2528 (SD=0.0497) and 0.2549 (SD=0.0567) seconds for the decreased and the increased sleep groups respectively. The p-value was 0.012, showing significance when the participants experienced less sleep they had faster reaction times than when they had more.

Stroop Test

According to figure 7, the mean overall scores were 59.80% (SD=0.134) and 57.33% (SD=0.117) for the decreased and the increased sleep groups respectively. The p-value was close to 0 indicating that there was statistical significance between the two scores.

According to figure 8, the accuracy scores were 97.82% (SD=0.0396) and 97.08% (SD=0.0534) for the decreased and the increased sleep groups respectively. The p-value was close to 0 demonstrating that when the participants received less sleep, they were more accurate on the Stroop Test.

Math Test

According to figure 9, the over test scores for the math exam were 42.07% (SD=0.0876) and 39.70% (SD=0.104) for the decreased and the increased sleep groups respectively. The p-value was close to 0 which displays significance between the two groups overall math scores.

According to figure 10, the accuracy on the math scores was 92.58% (SD=0.0724) and 91.60% (SD=0.0701) for the decreased and the increased sleep groups respectively. The p-value was close to 0, which argues significance that when the participants received more sleep, they were less accurate on the math test.

Heart Rate

There was no statistical significance between the heart rates of the participants who had more or less sleep on any of the experimental tasks.

Discussion

"There are two kinds of truth, small truth and great truth. You can recognize a small truth because its opposite is a falsehood. The opposite of a great truth is another truth." -Niels Bohr

Sleep is an important biological function needed to perform cognitive activities. Unfortunately, some people do not sleep an appropriate amount on a regular basis. The goal of our study was to investigate the differences in performance between students who have slept more or less than eight hours of sleep. The objective of this study was investigate if performance increases when participants got an extra hour or more of sleep. We applied this to college students because we believe that students at this university were the most likely to exhibit irregular sleep patterns.

Our experimental results in the reaction time test for the interpersonal showed no difference for the people who got the recommended amount of sleep (8 hours) and the people who got less than that. Some explanations for this could be one night of sleep deprivation may not have a direct effect on cognitive function because one hour less of sleep may be normal for a large number of the participants. Also, the studies were conducted in the morning when people could

still be tired. The results for the Stroop test were people with less sleep performed with more accuracy answering; however, people with more sleep performed more efficiently by answering more words. One explanation would be people with less sleep take their time and answer questions accurately, while rested participants would answer questions more quickly which could lead to mistakes. The math exam for interpersonal support participants who got more sleep performed more accurately and higher overall scores than sleep deprived participants. One explanation could be people could focus longer with more sleep because the math exam was the longest timed test.

Our results for the intrapersonal study showed that participants who got less sleep performed better on the reaction time test, Stroop test, and multiplication table.This goes against the interpersonal study and the original hypothesis. Many arguments could be made against the intrapersonal because of countless confounding variables that were hard to be controlled. Some examples are people already know what is on the test, participants with measured less sleep could be in their normal sleep habit, and people were tested at different times of the day, so some were very alert and others were drowsy.These results should be taken into consideration and be further tested.

Although the survey was used to determine sleep statistics, it also revealed some confounding factors. For example, some students ate breakfast before being tested, others skipped breakfast. The quality of food also differed; some participants ate a well balanced meal while others had non-nutritious food. Finally, alcohol consumption also differed among participants.

If this experiment were to be repeated, a strict sleep schedule would be enforced for the participants to determine whether sleep deprivation negatively affected their performance. The way the intrapersonal group was set up was also not optimal. In this study, participants who returned for a retest were removed from the interpersonal population and put into the intrapersonal population. Once entered into the intrapersonal population, the test in which the participant slept less was put into the experimental group and the test in which the participant slept more was put into the control group. This process occurred whether the participant met the eight hour sleep limit either time or not. This means if a participant in the intrapersonal population slept less than eight hours for both tests, the trial with more sleep would have been used as the control even though it should have been counted as sleep deprived. The intrapersonal study could have been improved if the participants in the intrapersonal study were normalized for outstanding factors like diet and physical exercise and the their sleep pattern was a greater than three hour difference. This could lead to more significant and probable outcomes.

There was a major assumption made in the interest of time. We assumed that the amount of sleep the participants recorded in the survey was average, but there were times when participants' amount of sleep deviated from their regular. This deviation could have had an effect on a participant's reaction time, focus, and cognitive function. Furthermore, it would be interesting to study the differences between chronic and temporary sleep deprivation by following participants' sleeping schedules for a longer time period.

After performing this study, many limitations were noticed. The lack of knowledge and control of the subject's sleeping schedule may have conflicted with the results. If participants were forced to sleep a set amount of time, there may have been a greater deviation and more consistent results between the two groups. Also, participants were not tested at a similar time after they awoke for both measurements. If measured later, they may have been more alert and have greater cognitive functioning than when tested shortly after they awoke. Overcoming these limitations would lead to a more accurate and applicable study.

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Awknowledgements

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Appendix

Survey

1. What time did you fall asleep last night? What time did you wake up?
2. Did you get more, less, or your average amount of sleep?
3. Did you eat breakfast this morning?
4. When was the last time you drank alcohol? (> 3 shots, 2 beers, 2 mixed drinks, or 2 glasses wine)
5. Did you eat a well-balanced meal this morning?
6. On a scale of 1-10, how would you rate your quality of sleep?

1 2 3 4 5 6 7 8 9 10

7. Have you consumed any caffeine or energy supplements within the past 6 hours?
8. How many glasses of water have you had within the past 24 hours?

Stroop Test

BROWN	RED	BLUE	BLUE	RED
RED	PURPLE	GREEN	ORANGE	GREEN
ORANGE	BROWN	PURPLE	GREEN	PURPLE
GREEN	BLUE	ORANGE	BROWN	ORANGE
BLUE	ORANGE	RED	RED	BROWN
PURPLE	BROWN	BLUE	BLUE	GREEN
RED	PURPLE	BROWN	PURPLE	RED
GREEN	BLUE	BLUE	BROWN	PURPLE
BROWN	RED	RED	ORANGE	BLUE
ORANGE	BROWN	ORANGE	BLUE	GREEN
PURPLE	GREEN	PURPLE	BROWN	ORANGE
GREEN	ORANGE	GREEN	PURPLE	RED

Math Test

9	4	5	7	3	6	1	8	2	3	8
x1	x5	x3	x7	x2	x9	x7	x4	x8	x6	x5

56	59	42	67	59	82	29	81	19	79	26
x7	x3	x4	x8	x5	x9	x2	x7	x6	x7	x1

123	543	624	749	972	307	389	476	834	691
x 7	x 6	x 8	x 5	x 9	x 2	x 3	x 4	x 6	x 8

77	91	87	51	76	46	52	67	69	23	74
x19	x22	x44	x38	x67	x92	x45	x23	x12	x98	x33

365	952	287	716	834	557	756	917	206	824	510
x11	x25	x53	x48	x89	x34	x73	x62	x56	x17	x29

Figures and Tables

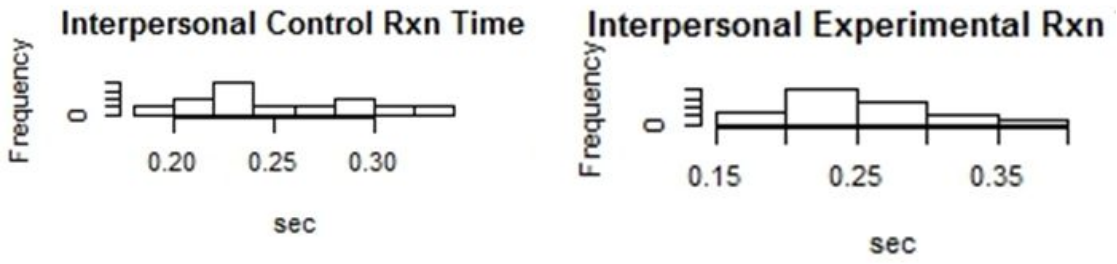

Figure One Interpersonal Reaction time (sec) Control and Experimental Histogram

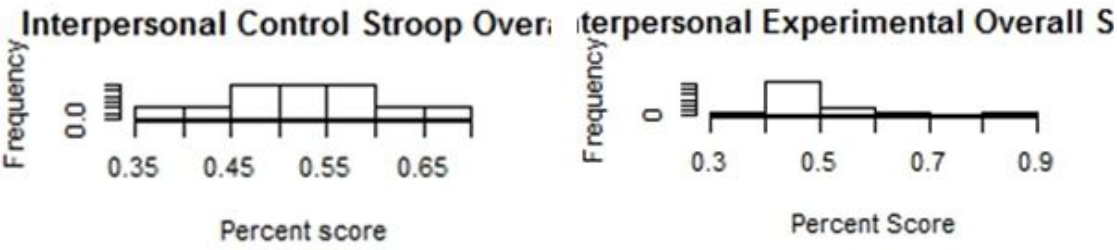

Figure Two Interpersonal Stroop Overall (correct/questions) Control and Experimental Histogram

Figure Three Interpersonal Stroop Attempted (correct/attempted) Control and Experimental Histogram

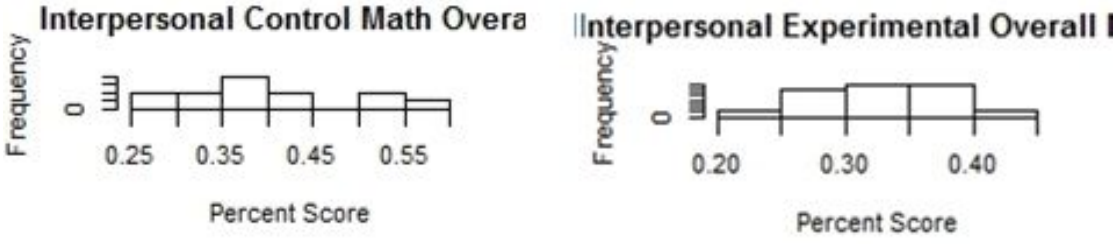

Figure Four Interpersonal Math Overall (correct/questions) Control and Experimental Histogram

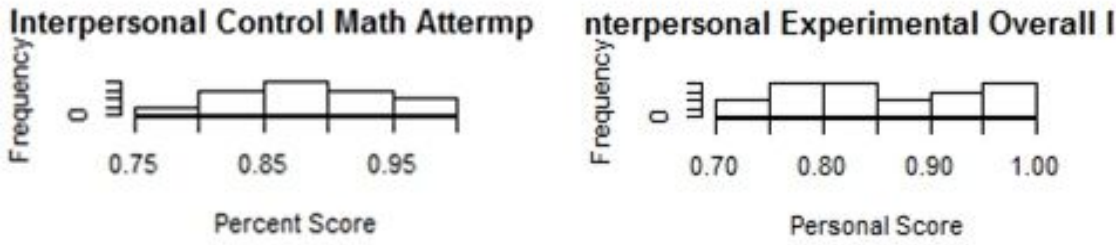

Figure Five Interpersonal Math Attempt (correct/attempt) Control and Experimental Histogram

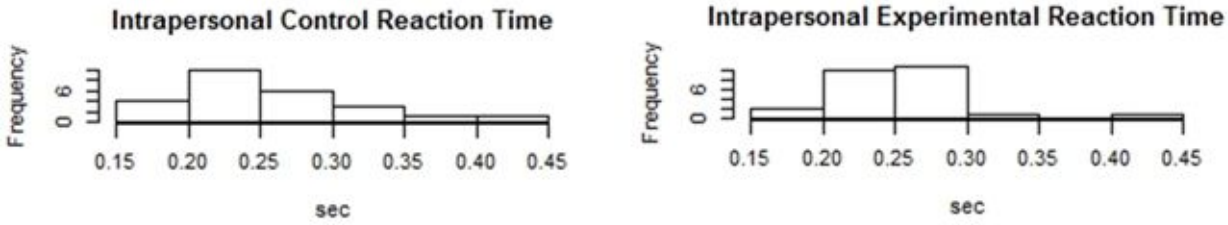

Figure Six Intrapersonal Reaction time (sec) Control and Experimental Histogram

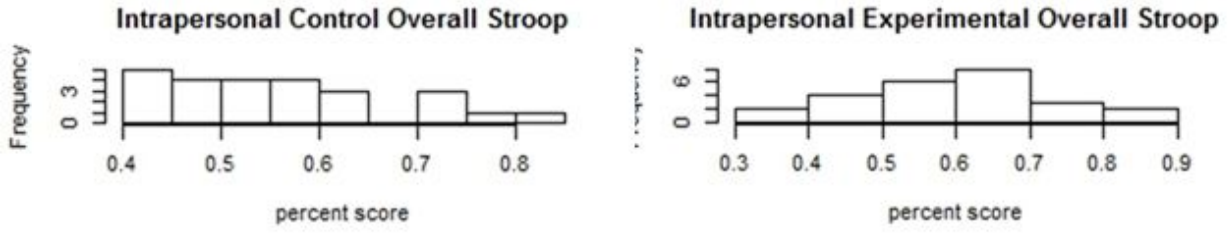

Figure Seven Intrapersonal Stroop Overall (correct/questions) Control and Experimental Histogram

Figure Eight Intrapersonal Attempted Stroop (correct/attempted) Control and Experimental Histogram

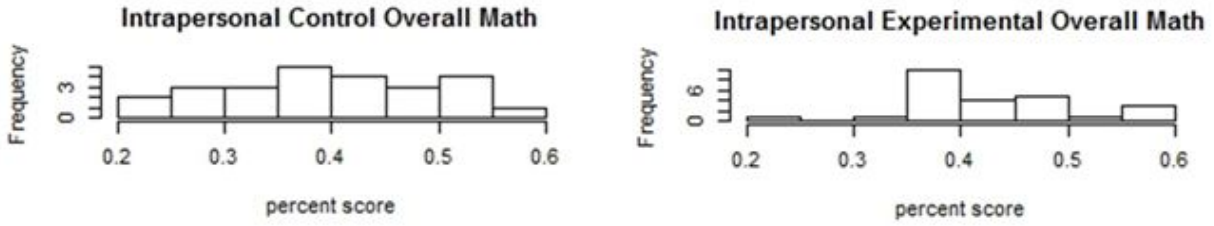

Figure Nine Intrapersonal Math Overall (correct/questions) Control and Experimental Histogram

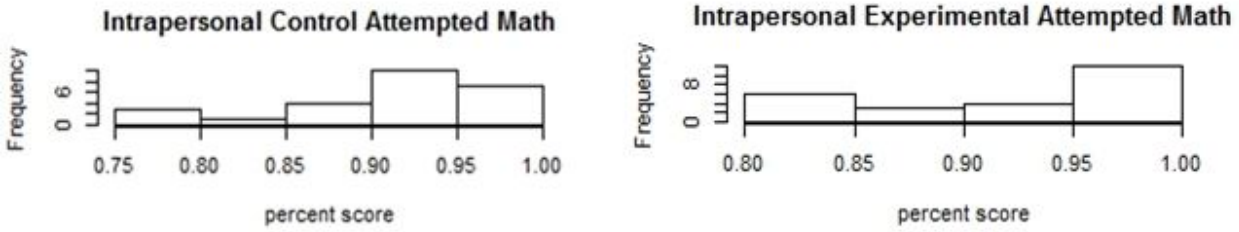

Figure Ten Intrapersonal Math Attempted (correct/attempted) Control and Experimental Histogram