The Effects of Sleep Duration and the Time to Fall Asleep on the Short-term Memory Performance

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Abstract: Sleep is an issue that scientists have devoted to researching in recent decades, particularly with the decreasing sleep time due to job obligations. The association between sleep and people's work performance has become increasingly relevant. This study investigates how sleep duration and time to fall asleep affect short-term memory performance in individuals aged 16 to 22. Data was collected throughout a 10-day sleep quantitative experiment on 61 participants using the digit span test and sleep monitor app. By analyzing using R studio, the original hypothesis was compared to reach the following conclusions: there is no significant correlation between the time to fall asleep and short-term memory performance, with a moderately positive correlation between 6.5-7.5h and a moderately negative correlation between 7.5-8.5h. These findings show how young adults can enhance sleep duration to achieve the most spectacular optimization of short-term memory performance, which is critical for supporting people in forming healthy lifestyles.

1 INTRODUCTION

With the fast pace of social life becoming increasingly popular, it is essential to pursue a reasonable and healthy sleep habit, especially for teenagers. Sleep is a state that can be easily reversed when the human body is less responsive to the surrounding environment and less interacting with the environment. As an expected behaviour in higher vertebrates, sleep deprivation will affect all aspects of human life to a certain extent.

According to the statistics provided by Loessl (Loessl, Valerius, Kopasz, Hornyak, Riemann, & Voderholzer 2008), it is reasonable that the number of sleep adolescents gets declines, and also the Medical News Today suggests that about one-fifth of students pull all-nighters at least once a month, and even 35% of students stay up until 3 am at least once a week on weekdays.

So far, researchers have taken sleep quality or sleep duration as independent variables and conducted multiple surveys on obesity, disease, work efficiency and other aspects, even including different age groups. To be specific, for example, the researches conducted by both Hargens (Hargens, Kaleth, Edwards, & Butner 2013) and Newman (Newman, Nieto, Guidry, Lind, Redline, Pickering, Quan 2001) prove that obesity and cardiovascular disease influence it. Plus, as the conclusion obtained from the quantitative data of 20,778 students, sleep quality is directly proportional to study performance ， which is highly consistent with the conclusion provided by Okano and Kaczmarzyk (Okano, Kaczmarzyk, Dave, Gabrieli, & Grossman 2019). In many studies, the relationship between sleep and memory has always been a primary focus of researchers because sleep plays a vital role in the formation of memory and consolidation, like the quantitative research provided by Durrant (Durrant, Cairney, & Lewis 2013) and the findings uncovered by Stickgold (Stickgold 2005). Specifically, REM sleep and slow-wave sleep (SWS) are associated with memory consolidation (Marshall, & Born 2007, Moroni, Nobili, Curcio, De Carli, Tempesta, Marzano, De Gennaro, Mai, Francione, Lo Russo, & Ferrara 2008). However, in the existing research results, few people focus on the relationship between short-term memory and sleep duration, but more focus on the neural mechanism of sleep on the formation of long-term memory (Born 2010). Based on the study of the class performance of 40 participants with uniform distribution of male and female, compared with the sleep-deprived group, the

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paired-associate test showed that the non-sleep-deprived group had about a 20.6% increase in long-term memory.

Therefore, this paper focuses on the two Young adult groups, 16-18 (high school students) and 19-22 (college students). This work analyzed the literature on factors affecting short-term memory. In particular, many researchers in the past few decades have suggested that interference is the only cause of short-term memory forgetting (Oberauer, & Lewandowsky 2008). Nevertheless, recent data suggest that short-term memory loss is actually due to time-based forgetting, known as the Trace Decay theory (Altmann, & Schunn 2012). In particular, direct evidence was found that the cause of short-term memory forgetting was traced decay after 72 college students tested visual images (Deliens, Schmitz, Caudron, Mary, Leproult, & Peigneux 2013). On the other hand, the current literature supports the dynamic relationship between sleep and memory trace (Ricker, Spiegel, & Cowan 2014). Most importantly, according to Sadeh's study in 2003 (Sadeh, Gruber, & Raviv 2003), appropriate sleep supplementation can significantly improve people's digit span, reflecting the improvement of their short-term memory. In summary, it is reasonable to assume the correlation between sleep duration and short-term memory. This paper addresses the following hypothesis:

Hypothesis-1 The time to fall asleep is negatively correlated with short-term memory

Hypothesis-2 Sleep duration is positively correlated with short-term memory

However, it is worth noting that there is still a gap between theory and reality, and further investigation is needed to verify the hypothesis about the influence of sleep duration and short-term memory. Therefore, a 10-day group experiment was conducted to verify the hypothesis using the Digit Span test and other technologies. In addition, this work also collected age, gender, education level and other data through online questionnaires for further hypothesis and analysis. In this experiment, researchers adopted two proven techniques to measure short-term memory and sleep-related variables, respectively. Since Richardson (Richardson 2007) elaborated on the Digit Span test as a quantitative measurement tool, recognized and validated by many other researchers (Jones, & Macken 2018). In addition, for the Sleep Recorder app, its working principle has been proved feasible by literature. Since actigraphy is the core technology for sleep monitoring, and all muscles except the eye muscles are inhibited during REM sleep, even when the brain is active (University of Toronto. 2012). By recording changes in body movement and sound decibel levels caused by slight muscle changes during sleep, the software can use programmed programs to calculate the user's sleep duration and other sleep-related indicators (Mohr 2015).

2 PARTICIPANTS

Participants were recruited on Wechat Moment using posts, which described the research study, research benefits, and inclusion criteria. Inclusion criteria included people who were either high school students or college students. Before completing the study, participants were instructed to sign a consent form acknowledging their willingness to participate. A guardian's signature was required if the participant was under 18 years of age. See Appendix 1 for the sample consent form.

A handbook including a sleep monitor app tutorial and an online numeric working memory test tutorial was sent to all participants via Wechat. Participants were instructed to send the sleep report and online numeric working memory test to the researchers via Wechat in 10 consecutive days. To protect participants' privacy, each participant was assigned a unique code. Specifically, participants with high school education levels were assigned to group A coded from A01 to Axx, while participants with college education levels were assigned to group B coded from B01 to Bxx. All research notes and documents adopted the unique codes.

3 MATERIALS AND METHODS

Designing the experiment to support the stated hypothesis proved to be challenging as research ethics had to be carefully considered alongside the rigour of the experimental design.

Specifically, limited resources, coupled with the test cycle of half a month, proved to be an obstacle. Researchers consulted as part of the initial information collection played a vital role in determining the outline of the subsequent design of the experiment. Research participants completed a study to investigate the correlation between sleep duration and short-term memory performance and between time to fall asleep and short-term memory performance. They filled out an online questionnaire, used the sleep monitor app, and took online numeric working memory tests.

3.1 Online Questionnaire

Volunteers are recruited by the posts that were posted on Wechat Moment. The posts provided potential participants with a brief description of the research, the benefits of the program, requirements for volunteers, and the work this research need volunteers to perform. Prospective participants can scan the QR code to access the online pre-experiment questionnaire for signing up for participation, and the questionnaire collected basic demographics information, including gender, age, and education level. See Appendix 1 for specific questions in the questionnaire.

3.2 Sleep Monitor App

Participants were instructed to use the Snail Sleep app (Apple or Android supported) to monitor their time to fall asleep and sleep duration every night for a total of 10 consecutive days, from August 15, 2021, to August 25, 2021. All participants were instructed to send the screenshots of sleep duration and the time to fall asleep to the researchers.

3.3 Short-term Memory Test

In the experiment, this research used the online digit span test to test participants' short-term memory levels. Participants were instructed to learn a series of numbers (Human Benchmark 2007). Participants completed an online numeric working memory test twice in a row one hour after waking up for 10 consecutive days, from August 15, 2021, to August 25, 2021. The numerical average of two consecutive memory test levels represented participants' performances each experimental day. All participants were instructed to send the screenshots of memory test levels to the researchers after finishing the memory test.

Microsoft Excel was used to record the data and organize data manipulations. R studio was used to statistically analyze. Shapiro test was used to test the normality of data. Spearman test was used to test the association between sleep duration and memory test level and the association between the time to fall asleep and memory test level.

4 RESULT AND ANALYSIS

4.1 Participants

According to the online questionnaire, as shown in Figure 1.1 and Figure 1.2, 61 qualified participants participated in the experiment, of which men accounted for 41%, and women accounted for 59%. Regarding age distribution, people with high school education levels accounted for 52%, and those with college education levels accounted for 48%. The distribution is relatively even. Specifically, 21-year-old participants accounted for the largest proportion, accounting for 23.0% of the total. See Figure 1 for detailed variable distribution data.

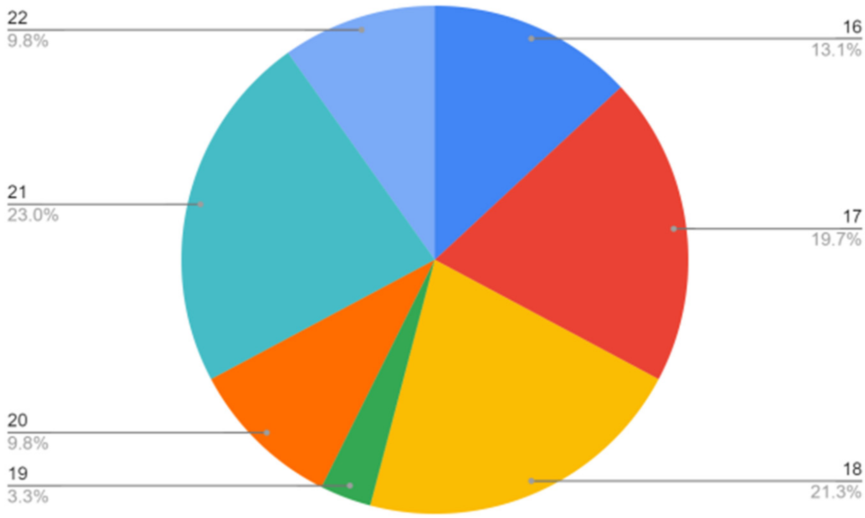

Figure.1.1(left) the distribution of gender; Figure.1.2(right) the distribution of the age

4.2 The Completion of the Experiment

The experiment lasted for 10 days. A total of 61 participants participated in the study, except for one participant in the university group who dropped out due to personal reasons. The completion rate of high school participants was 96.9%, and that of college participants was 96.4%, which could be used for data collection and analysis.

4.3 The Time to Fall Asleep and the Short-term Memory Performance

In terms of data analysis, Microsoft Excel was used to record the data and organize data manipulations. Researchs used R studio to analyze statistically. Shapiro test was used to test the normality of data, and the result showed that the time to fall asleep was not normally distributed. Thus, Spearman's test was used to test the association between the time to fall asleep and memory test level. A Spearman correlation coefficient revealed no significant correlation between weight and age, rho(61) =-0.067, p =0.11. The result was as follows:

Table 1: Correlation between the time to fall asleep and memory test performance.

	Whole group	
Condition	***p***	***rho***
	0.11	-0.067

As shown in table 1, as p value > 0.05, there is no correlation between the time to fall asleep and the short-term memory performance, regardless of the rho value (Spearman's correlation coefficient). The result is essential because it suggests that it does not matter what time people sleep, breaking the stereotype in modern society.

4.4 Sleep Duration and the Short-term Memory Performance

Researchers further analyzed the impact of sleep duration on short-term memory. Similarly, R studio was used to perform Spearman's test after the disposal of data. A Spearman correlation coefficient revealed no significant correlation between weight and age, rho(61) =-0.006, p =0.8843. The result was as follows:

Table 2: Correlation between the sleep duration and memory performance.

	Whole group	
Condition	*p*	*rho*
	0.8843	-0.006

As shown in table 2, as p value > 0.05, there is no correlation between the time to fall asleep and the short-term memory performance, regardless of the rho value.

5 FURTHER FINDING AND ANALYSIS

As analyzed above, the results do not fit with the original hypothesis, but by analyzing the graph of sleep duration and memory test performance and using the technique of fitting asymptotes, it can be found that sleep duration has a linear relationship at 6.5-8.5h. As shown in Figure 2, the red line represents the positive correlation, and the black line represents the negative correlation. As a result, this paper put forward a new hypothesis:

During 6.5-7.5h and 7.5-8.5h, there is a correlation between sleep duration and short-term memory performance.

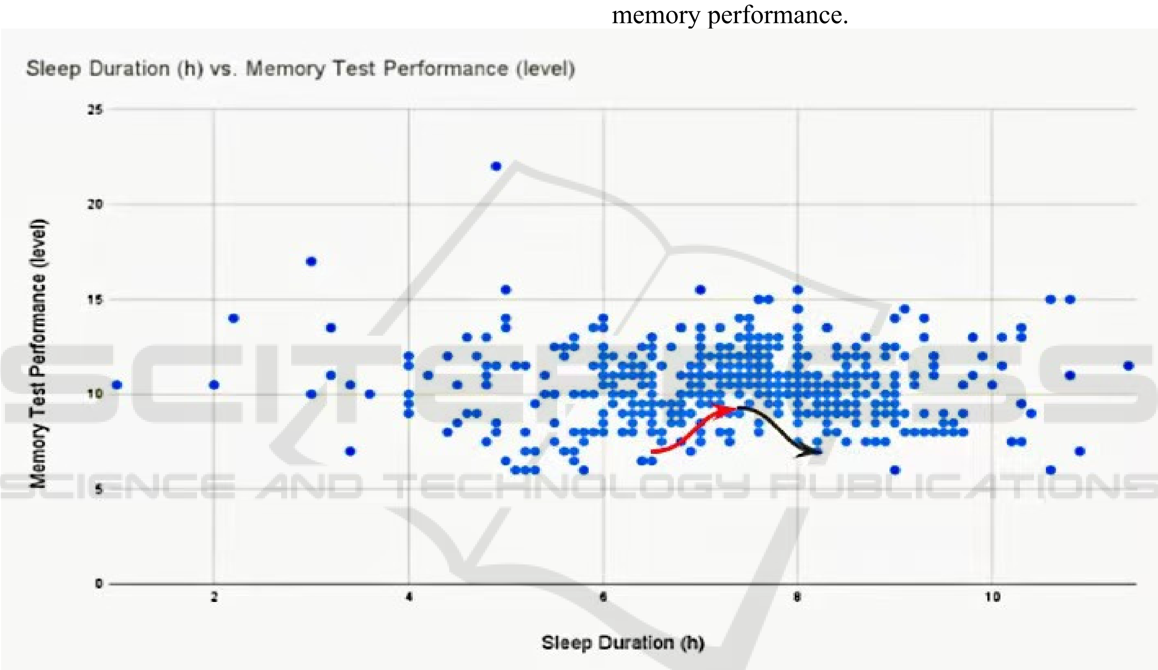

Figure.2: The effect of sleep duration on the memory test performance. Each point represents the daily sleep duration and the memory test performance of 61 participants in 10 consecutive days.

In order to verify whether this hypothesis is true, this work used Spearman's test to test its correlation by importing the interval data into R studio. The results are as follows:

Table 3: Correlation between the sleep duration and memory performance (sleep duration 6.5-8.5h).

	Whole group		6.5-7.5h group		7.5-8.5h group	
Condition	*p*	*rho*	*p*	*rho*	*p*	*rho*
	0.88	-0.01	< .001	0.41	< .001	-0.47

It is worth noting that when the sleep duration is between 6.5 and 7.5h, the p value is less than 0.05, and the rho value is 0.41 as shown in table 3. During this period, there is a moderate correlation between sleep duration and short-term memory performance.

In addition, according to the research by David Spurgeon (Spurgeon 2002), he conducted a study of the sleep habits of more than one million people over six years. The result showed that people who slept for six or seven hours had a lower death rate than those who regularly slept eight or more hours. Plus, the best survival rates were found among those who slept seven hours a night. A group sleeping eight hours was 12% more likely to die within the six years than those sleeping seven hours. Thus, the sleep duration between 6.5-7.5h shows the positive implication corresponding to the further finding.

6 CONCLUSIONS

According to the ten days of experiment and data analysis, the following conclusions can be determined. First, no significant correlation between the time to fall asleep and short-term memory performance, and there are no significant correlation between the sleep duration and short-term memory performance if all the periods are permitted. Plus, if it is limited to a specific sleep duration range, there is a positively moderate correlation between 6.5-7.5h; there is a negatively moderate correlation between 7.5-8.5h.

The research discussed the relationship between short-term memory and sleep-related variables of 16-22-year-old young adults by collecting data from participants for up to 10 days. However, due to the limitations of experimental equipment and experimental period, the researcher cannot perform any interventions such as sleep deprivation. The sleep duration data provided by each participant is not evenly distributed, and most of the data come from the interval of 6.5-8h. This leads to the possibility that rho in the result obtained using Spearman's test in R studio may increase, making the conclusion biased.

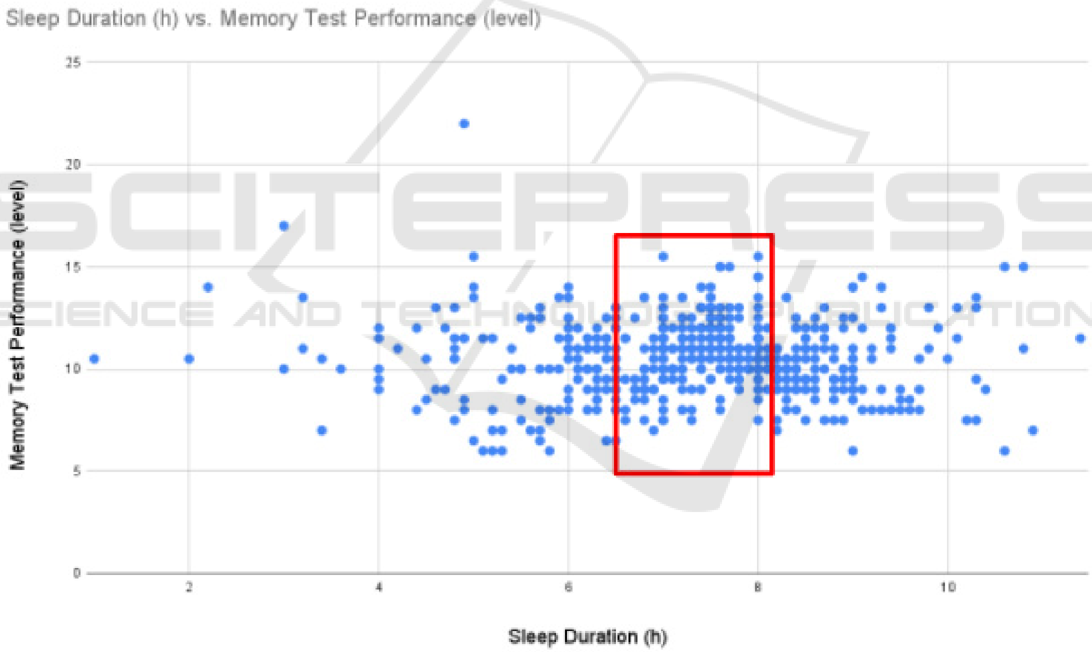

Figure.3: The scatter diagram of sleep duration and memory test performance. The red line encloses the concentrated data set.

All the participants in the study are Chinese nationals, especially those in the high school education level group who are students from the International Department, and they face the pressure of applying for foreign undergraduates. This extra pressure makes the sleep duration of the overall data smaller to some extent. In the distribution of male to female ratio, female participants are 18% more than males, which may lead to the data provided by women occupying most of the theoretical basis of the conclusion.

In terms of future research directions, researchers can focus on sleep duration in the 6.5-8.5h period and conduct further analysis by controlling other variables except for age. Because the major group analyzed in this experiment is young adults, recent studies have also shown that sleep duration has a non-negligible effect on other age groups; future related research can allow an analysis of both the elderly and middle-aged people. In addition, future research can pay extra attention to people's occupations and rest habits, making the research group more specific and detailed. Considering the technology limits of the experiments, it is recommended that future researchers can apply for permission from relevant international human rights organizations to conduct laboratory experiments, that is, recruit volunteers to closed laboratories, while using EEG and other technologies to perform more precise measurements.

As shown in Figure.4, on the other hand, the average range of the collected sleep duration data is 6.89h, which means that the participants' sleep duration will differ by about 7 h at most. The uneven distribution of such massive data implies irregular sleep habits of the studied group, so it is recommended that future research directions control the range of sleep-related variables provided by the subjects.

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