The Influence of Sleep on Memory Consolidation

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The purpose of this study was to examine the influence of sleep and wakefulness on memory consolidation. The 28 participants were broken down into four different conditions. They were given a list of 12 hard or easy words and had to learn the words at either 10am or 10pm and recall the words 12 hours later. It was hypothesized that the participants who learned the words at 10pm would have a higher recall rate since their memories were given a period of sleep in order to consolidate the words. The results of the study indicated that there was no significant effects or interactions between the word type, time of learning and time of recall. Therefore, it provides evidence in support of the idea that memory does not consolidate better while sleeping.

The ability to encode, retain and recall information has been a function of the brain that has allowed humans to be able to create a meaningful society. This function has been termed memory. Memory, as defined by the Dictionary of Behavioural Science (1989) is, “the characteristic of living organisms involving the reliving of past experiences and consisting of four phases: learning, retention, recall and recognition.”

Memory consolidation is a phenomenon that has been plaguing researchers for years. Although there has been much development in memory research, there are still many intricate details about this advanced process that remain unknown. A variety of theories have been proposed about memory consolidation. Jie Zhang proposed that data encoded into short term memory during the day has the ability to transfer into long term memory during sleep due to lack of incoming information from the environment around us. He
states that information entering the brain is transferred to our temporary memory and information can only be retrieved from our long term memory, not stored, while we are awake. During sleep, the lack of incoming information allows the brain to transfer information from our temporary memory to our working memory. From our working memory, Zhang (2004) suggest, relevant information can then be transferred into our long term memory. Although Zhang does not explicitly use empirical evidence to substantiate his claims, this theory is readily testable and has been based on much research and observations.

Zhang's theory (2004) can be supported by research done in 1924 by Dallenbach and Jenkins. They tested the process of forgetting during periods of wakefulness and periods of sleeping. Based on Ebbinghaus' evidence supporting the idea that forgetting is a function of time (as cited by Dallenbach, 1924), Dallenbach and Jenkins tested two undergraduate students in order to compare the rates of forgetting during wakefulness and sleep. For a month and a half, the two participants lived in a special dormitory where the experiment was conducted on a daily basis. Every morning, the participants were given a list of nonsense syllables and were told to recite the syllables until they were memorized. Once the syllables were memorized, they were no longer exposed to the words. Following intervals of one, two, four and eight hours after the initial memorization period, the participants were asked to recall as many words as possible. The same process was executed at night. The participants were given a new list of syllables right before they retired for the night. After one, two, four and eight hours of sleeping, the participants were woken and asked to recall as many words as possible. The results of this study
found that the participants recalled the syllables at a much greater rate during the sleep intervals. Almost twice as many syllables were recalled after periods of sleeping than periods of wakefulness. Furthermore, there was only a minimal amount of memory loss between the two and eight hour intervals during sleep. The results of this study provide evidence in support of the idea that memory consolidation is greater after periods of sleep due to the lack of interference.

Twenty two years later, Dallenbach and Minami (1946), based on the findings by Dallenbach and Jenkins (1924), investigated a similar idea with cockroaches. It was hypothesized that the cockroaches would remember learnt information better following periods of inactivity than periods of activity. In order to test this, Dallenbach and Minami used twelve female and twelve male cockroaches and subjected them to a situation where they had to learn to avoid the dark part of a box to prevent receiving a shock. The box used in this experiment was developed by Dallenbach and Minami and had two areas, the practice box and the learning box. These two areas were very similar, but differed in one respect. The distinguishing factor between the learning box and the practice box was a dark area that was connected to a shock device, located at the end of the learning box. If the cockroaches went into that area, they received a shock. The cockroaches were initially put into the practice area in order to become habituated to their surroundings and were then moved into the learning box so they could learn to avoid the dark area. The study was broken down into two parts and consisted of three different conditions. In the first condition, the cockroaches were exposed to the practice box and the learning box and were then place on to a treadmill and were required to remain active. In the second
condition, the cockroaches were once again exposed to the boxes and then placed into a circular container in order to obtain some natural rest. To ensure the subjects would just rest in this condition and not sleep, a circular container was purposefully chosen because cockroaches tend to only sleep in corners. In the third condition, following the exposure to the boxes, the cockroaches were placed in a controlled environment which induced a comatose state, without physically harming the cockroaches. In the first part of the study, following exposure to the boxes, the cockroaches were separated into the first two conditions, the treadmill and rest condition, and were tested at intervals of ten, twenty and thirty minutes. Following each interval, the subjects were placed into the learning box in order to test their memory and see how long it takes them to remember to avoid the dark area. The first part of the study concluded that the cockroaches performed better after the rest condition then following the condition where they were forced to remain active, regardless of the time interval. In the second part of the study, the second and third conditions were compared at intervals of one, two, and three hours of induce inactivity or natural rest. Following the results of the one, two or three hour intervals, the subjects were tested at an eight and twenty four hour intervals. Regardless of the interval time, it was found that the cockroaches in the comatose state performed significantly better then the subjects who were naturally resting. Similar to the finding by Dallenbach and Jenkins (1924), the results of this study provided evidence to support the idea that activity interfered with the ability to consolidate memory.

Based on the theory outlined by Zhang, the findings of Dallenback and Jenkins study (1924) and the results of Dallenbach and Minami (1946) experiment, the following
study has been set out to examine the effects of sleep and wakefulness on the ability to recall words learned by human participants. It has been hypothesized that participants who had to recall words after sleeping will perform better than participants who had to recall the words after a day of wakefulness. In addition, it has been hypothesized that the difficulty of the words will have an influence on the participants’ ability to recall them. It has been proposed that the participants will be able to recall words used more frequently in the English language much better then the words used very rarely, regardless of the sleep or wakeful conditions. The following report has been developed to examine whether or not these hypotheses are indeed correct.

Method

Participants

The participants in this study were recruited through verbal discourse and were friends or relatives of the researcher. This study consisted of 28 participants, ranging in age from 18 to 45. Out of the 28 participants, 14 were male and 14 were female. The majority of the participants in the study were current residents of London, and attended the University of Western Ontario. The participants who did not live in London resided in the Greater Toronto area. All of the participants grew up in the Greater Toronto Area and were Caucasian. The participants all shared a similar, middleclass socioeconomic background.

Materials

The core materials used in this study consisted of two different lists of twelve words. One list consisted of harder words and one list consisted of easier words. All the
words were retrieved from Thorndike and Lorge’s book entitled, *The Teacher’s Word Book of 30,000 Words* (1944). This book contained 30,000 words with ratings listed next to each word. The harder words used were arbitrarily chosen from the words that had a ‘1’ next to it. Based on the findings by Thorndike and Lorge, words with a ‘1’ rating next to it were words that were found to occur once in a million words. As a result, these words were not as commonly found in the English language and were therefore considered to be harder words. All the easy words chosen for this study were words that had ‘AA’ rating next to it and this represented words that were found over 100 times per million words. Refer to Appendix A for a list of the words. Based on Thorndike and Lorge’s ratings, the words chosen for this study can be considered relatively easy or hard due to their frequency in the English language. The other materials used in this study were paper for the participants to write down the words that they were able to recall.

**Procedure**

The participants in the study were arbitrarily and equally divided into one of four conditions. In the first condition, the participants were given the list of hard words at 10am and were asked to recall as many words as possible at 10pm. In the second condition, the participants were given the easy word list at 10am and were asked to recall the words at 10pm. In the third and forth conditions, the participants were given either the easy or hard word lists at 10pm and were asked to recall the words at 10am, the following morning. As soon as all of the participants were originally presented the word list, they were given fifteen minutes to memorize the list to the best of their ability. Following those fifteen minutes, the participants were no longer exposed to the word lists. When it
was time to recall the words twelve hours later, the participants were given five minutes
to write down as many words as they could recall. After the recall period was over, the
participants were given the word list in order to fulfill the curiosity of which words they
forgot.

Results

A two way between ANOVA was performed in order to examine the effects of
sleep or wakefulness on the ability to recall word lists of varying difficulty. The test of
main effect on the time of day that the words were recalled found that the mean of the
recall after having no sleep condition (M=9.28) did not differ significantly from the mean
of the recall after sleep condition (M=8.42), \[F(1, 24)=.441, \text{n.s.}\] In addition, the test of
main effect on word difficulty found that there was not a significant difference between
the mean of the easy word list (M=9.21) and the hard word list (M=8.50), \[F(1,24)=.520,\n\text{n.s.}\]. The test of the interaction effect was also found to be insignificant \[F(1,24)=.520,\n\text{n.s.}\].

Discussion

This study was conducted in order to examine the influence of sleep on memory
consolidation. It was hypothesized that the amount of words recalled would be higher for
the groups that learnt the words at night and recalled the words in the morning, in
comparison to the groups that learnt the words in the morning and had to recall them in
the evening. It was also hypothesized that the easier word list would have a greater,
overall recollection level then the hard word list. However, the two way between
Figure 1. The number of words recalled after two different recall conditions.
ANOVA analysis did not support the hypotheses of this study. All of the group means were found to be insignificant. Therefore, the results of this study provide evidence in support of the idea that memory does not consolidate more effectively during sleep than during times of wakefulness. However, although the results were found not to be significant, the mean for the 10am recall group with easy words was 1.5 words higher than the mean of the hard words. This could potentially support the idea that greater memory consolidation may have occurred overnight for the easier words in comparison the harder words. It is possible that if more data was collected, the difference between these means could be found to be significant.

The idea for this study was based around theories and other studies conducted in this field. However, the results of this study do not parallel the results of the studies that this research was based around. Zhang (2004) theory proposed that memory consolidation occurs more powerfully during sleep due to a lack of the interference that tends to occur during the day. Although Zhang did not have any empirical evidence supporting this theory, the results of both Dallenbach and Jenkins (1924) and Dallenbach and Minami (1946) studies provide evidence in support of Zhang’s theory. The latter studies, based on the experimental evidence gathered, suggest that memory consolidation occurs better during periods of unconsciousness than periods of alertness. The results of this study do not support the findings of these studies since no significant results were found based on the time of learning, time of recall and word difficulty. Although the results of this study were not found to be significant, the trend of the results appears to be
headed in the significant direction. In both the easy and hard word conditions, the recall of the words has been found to be higher during the 10am recall condition, regardless that the differences between the means are insignificant. From this, it could be assumed that if there were more participants in the study, there would be more data to analyze, therefore potentially resulting in significant data. As apparent, the small sample in this study hindered the results and has acted as a limitation to this study. When the idea of this study was originally proposed, the researcher had presumed that forty people would be willing to participate in this study. However, when it was time to collect data, the researcher realized that it would be difficult to find forty participants. Considering the fact that this study is carried out in two parts, with a twelve hour interval between them, it was difficult to find many people willing to participate. Numerous people asked to participate questioned if there would be any compensation for their time, and when they were told that there would not be, they refused to participate. As a result, the small sample size, due to a lack of compliance, drastically contributed to the insignificant results.

In addition to the small sample size, another possible limitation is the words chosen for both the hard and easy word conditions. The words were ambiguously chosen from Thorndike and Lorge's *The Teacher's Word Book of 30,000 Words* (1944). Since the words were chosen arbitrarily, it is possible that the hard words were not equivalent in their difficulty as the easy words were in their simplicity. For the most part, the hard words were long words, with an average of 8.1 letters and the easy words had an average of 5 letters. Due to the discrepancy in word length between the two conditions, it is
possible that the hard words were much more difficult to recall based on their length. Thus, the difficulty in recalling the words may have been based on the length of the word, rather than the semantics of the words. This is not what the researcher had intended and it may have influenced the outcome of the study.

There are a few control issues that may have influenced the results of this study. One of these issues was the inability of the researcher to control the effort the participants exerted into memorizing the words. When providing the participants with the list of words to memorize, the research indicated that the words should be memorized to the best of the participants’ ability within the given fifteen minutes. Although this was stated, it is very possible that they may not have cared to put forth their utmost ability and may not have memorized the words as best as they can. As a result, when it came time to recall, their recollection of the words may not have been as superior as possible.

It is possible that some of the participants may have used mnemonic strategies to encode the words. By using such an approach, the participants may have been continuously reciting their mnemonic strategy through the interval between time of encoding and retrieval. By doing so, they did not give their memory the time necessary to allow for the typical forgetting curve, as suggested by Ebbinghaus (Dallenbach 1924), and were constantly refreshing their memories of the words. If participants actually did this, the results would have been negatively influenced because the point of the study was to examine memory consolidation during sleep and wakefulness, not examine the effects of mnemonic strategies on memorization.
The intelligence levels of the participants may have also influenced the study. The researcher was unable to determine the intelligence of each participant. This acts as a control issue because participants who are of greater or poor intelligence may have different memory capacities. Although it would be beneficial to have participants from ranging intelligence levels, it is possible that intellectual distribution of this sample may be weighted towards one side of the curve. If this occurred, the average number of words recalled per condition may have been influenced by intelligence levels that are not representative of the general population. Therefore, the overall results could not be generalized and may have been hindered. Also, it is possible that the intelligence levels of the participants in one of the conditions might have been higher or lower than that of the other conditions. This may have acted negatively upon the outcome of that specific condition.

The final control issue was the environment where the learning and recollection of the words took place. Although the learning and recall took place in comfortable, relaxed environments, there may have been various stimuli distracting the participants from performing to their fullest ability. Such distractions might have been that they were people conversing in the room, the television could have been on or a range of other interruptions that could occur in uncontrolled settings. Although the participant may not have been focusing on these disturbances, they still could have distracted the participant from fully memorizing the words or may have caused them to lose their train of thought while recalling the words. Therefore, the background stimuli may have had an affect on the outcome of the study.
There are a few things that could have been done in order to improve the outcome of the study. Primarily, there should have been a larger subject pool, consisting of at least forty participants. This would have ensured that enough data is collected in order to obtain accurate results. Based on the results of this study, a large subject pool may have allowed significant results. Furthermore, the word lists should be changed and the average amount of letters in both the easy and hard word lists should be consistent, in order to allow for the difficulty and ease of memorization to be comparable. In regards to the use of mnemonics, the researcher should have emphasized that mnemonic use is prohibited and that the participants should simply memorize the words and not think about them again until the time of recall. This would allow the study to examine what it had set out to study. Another improvement that could be made is the environment in which the study took place. In the future, the participants should both learn and recall the words in an isolated environment, where no distractions can occur. This would enable the participants to have no external stimuli that may prevent them from participating to their fullest ability.

In order to control for the varying intelligent levels and improve the study, it may be beneficial if this study were a two way mixed design, rather then a two way between design. Each participant should be given two different word lists of equivalent difficulty or ease. They should be told to memorize and recall one list during the 10am condition and one list during the 10pm condition. If each participant were given the same two word lists (either the easier lists or the harder lists) and told to do this, it would help control for the varying intelligence levels because the different intelligence levels would be
represented in each recall condition. The way the current study is designed, it is possible that the intellectual average of the participants in one condition may be higher or lower than the average of the intelligence is another condition. Having a two way mixed design would help control for this discrepancy. If the same hypothesis were to be tested in the future, it would be beneficial to implement all of the latter improvements in order for the experiment to be carried out under more control, potentially resulting in more accurate results.

Although the results of this study were not found to be significant, the results appear to be headed in a significant direction. As stated above, it could be assumed that more data would have lead to significant results. With that said, there are a few practical implications to the significant results of this study. The most noted implication would be intended primarily for students studying for examinations. There are many students who feel that it is necessary to stay up all night in attempts to learn as much material as possible before an exam the upcoming day. Based on the significant results found in the background studies and the trend that this study is headed in, it can be said that staying up and studying all night would not be beneficial. It would be more advantageous to study as much as possible during the day and get a good sleep in order for the memory of the information learnt to consolidate to the fullest possibility. Students should be notified of this so that they can utilize this valuable information in order to benefit their academic achievement.

If the findings to this study were significant, it would be beneficial to inform those in the field of business about the results of the study. This is because it would notify
them of the relevance in getting a good night’s rest in order to recall information to the fullest of their abilities. For example, a business woman who has been told intricate details of a new account and has a meeting with these clients the next day would benefit from a good nights sleep so that she is able to recall the complex information she learnt the prior day. If she does not get a proper sleep, it is possible that she would not be able to remember this precise information and jeopardize her interactions with these clients. Therefore, it would be favorable for people in this situation to get a good sleep in order for their memories to be working to their fullest potential.
References


Appendix A

Easy words:
Butter, chair, city, clothing, flower, dollar, forest, home, journal, meat, paper, water

Hard words:
Abasement, allegory, bagpipe, centennial, detonation, emancipation, limelight, medallion, mucus, perjury, proxy, tripod