IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 15, Issue 1 Ver. III (Jan. 2016), PP 25-29
www.iosrjournals.org

Effect of Sleep on Declarative Memory Following Associative Interference in Adolescents

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Abstract:
Background*: In recent years, the effect of sleep on memory consolidation has received considerable attention. Because the majority of adolescents do not obtain the recommended amount of sleep, it is critical to study the cognitive effects of normal sleep. These effects of sleep on memory are less studied in adolescents. Given the importance of adolescent memory on academic performance and consequent social functioning, a deeper understanding of the effect of sleep on memory is needed.*
Aim: *To study the effect of sleep on declarative memory and especially when declarative memory is challenged with associative (similar type of) interference, in first and second year college students.*
Materials and Methods*: Two hundred medical students were divided into five groups of 40 each. Paired word list was taught to them and their memory tested for the same directly or after teaching a similar word list (i.e) after interference. Either a period of sleep or wake existed between the teaching and testing sessions.*
Result*: There is highly significant increase in the performance of the sleep groups compared to the wake groups.*
Conclusion*: The results of the present study clearly reveals the fact that forgetting is less in the sleep groups, both in sleep without interference and sleep with interference groups.*
Key Words*: sleep, sleep stages, memory, declarative memory, consolidation.*

I. Introduction

Sleep as everyone knows is an elemental phenomenon of life and an indispensable phase of human existence. Until 1950s most people thought of sleep as a passive, dormant part of our daily lives. In recent years, the effect of sleep on memory consolidation has received considerable attention.[1,2,3] Both REM and slow wave sleep have been associated with improved memory.[4] Sleep has been linked to brain plasticity.[5] In developing animals, sleep can induce synaptic remodelling and in humans it has been associated with memory consolidation and learning. Memory is defined as the ability to encode, consolidate and retrieve information that has been learnt.[6] Memory is classified on the basis of whether the retrieval of information is conscious or subconscious, the former called declarative and the latter called non-declarative memory.[7,8] In modern society there has been a considerable erosion of sleep time. This sleep bulimia may have adverse consequences on the physical and cognitive wellbeing of people - especially younger generation. Hence this study is taken up to unmask the benefit of sleep on declarative memory and especially when declarative memory system is challenged with competing information - interference, in adolescents.

II. Aim and objectives

The study involves 1.testing the recall performance of the target words learnt during the teaching session in the wake group and sleep group. The effect of sleep on declarative memory is studied by comparing the performance of the two groups. 2..testing the recall performance of the target words after interference in the wake with interference (Wake- I) group and sleep with interference (Sleep- I) groups. The effect of sleep in protecting declarative memory from subsequent associative interference is studied by comparing the performance of the two interference groups.

III. Materials and Methods

3.1 participants: All the participants were first and second year medical students completed 17 years of age. Right handed students were only selected. The participants completed a screening questionnaire and interview prior to selection. Individuals taking prescription, psychoactive ,or illicit drugs, those with known sleep disorders or abnormal sleep patterns, neurological and psychiatric disorders, learning disability and with family history of such disorders were excluded.

Prior consent was obtained from all participants and ethical clearance obtained from the Institute. Two hundred participants were enrolled and successfully completed the study. One hundred and sixty participants out of the two hundred were randomly assigned to one of the four groups: sleep group, wake group, sleep - I (interference) group and wake–I (interference) group. Forty participants were assigned to the fifth group- The 24 hr PM- I (interference) group.

3.2 materials: A list of 60 two syllable words with same range of image ability, frequency and concreteness were selected from the noun subset of the Toronto Word Pool (1982). These words were randomly divided into three groups of 20, forming three lists A, B and C. Each word in 'A' list was paired with one word from 'B' and 'C' lists (Eg. Tiger—Blanket—Lemon). Thus, two paired word lists; A-B and A-C (Eg. Tiger—Blanket and Tiger—Lemon) were created. Word pairs with obvious semantic relationships were re randomised. The word pairs were printed , with all letters in black in OHP sheets. All letters were in capital with same size.

3.3 procedure: Participants of Sleep and Sleep- I groups underwent Training—Learning session at 8pm and Testing session at 8am next day. Participants of Wake and Wake- I groups underwent Training—Learning session at 8am and Testing session at 8pm same day.

3.3.1 Training—Learning session: This session was conducted with the help of OHP in a quiet room in the college with four trainers. The training methodology consists of two phases, the initial study only phase and the second anticipation plus study phase. In the study only phase, paired words were presented in black and were centered on a white screen. Word pairs were presented sequentially in a fixed order for seven seconds each. Immediately afterwards in the second phase , participants were presented with the first word of each pair and were asked to say the second word of the pair. They were immediately informed whether they are correct or incorrect and the correct pairing was shown to them. After any individual pair was correctly recalled three times, it was removed from the list. Study continued until all the words were removed. The learning criterion was thus set to 100% for all the participants. After this, participants left the room for 12 hours. Participants of the Sleep and Sleep I groups were asked to avoid any medications and stick on to their usual sleep schedule. Participants of the Wake and Wake I groups were not restricted from any activity other than napping between training and testing phases of the experiment.

3.3.2 Testing session: Upon returning to the testing room, participants of the Sleep and Wake groups were immediately tested for the B word of AB pair. They were given 6minutes to complete this cued recall task.

3.3.3 Interference groups: Participants of the Sleep- I and Wake- I groups learned a new list of words just prior to testing. After learning this new list, these participants performed a 12minute finger tapping task in order to prevent rehearsal during a brief delay between training and testing. After this motor task, participants were tested for B and C list words against A list words but the outcome of interest was recall accuracy of B list.

3.3.4 The 24 hour PM-I group: To further address the concern for time of day effects, an additional independent group -the 24 hour pm to pm with interference (24 hr PM-I) was included. Participants in this group underwent the same training and testing sessions as those in the 12 hour interference groups (Sleep- I and Wake- I groups). However unlike the Sleep- I and Wake- I groups, this group was trained and tested at the same time on two successive days.

IV. Results and Statistical analysis

Table 1 Mean B List performance of all categories

Study Group	N	Mean	S.D	Confidence Interval 95%	
Sleep	40	19.75	0.63	19.54	19.95
Sleep I	40	19.6	0.74	19.36	19.83
Wake	40	17.15	2.5	16.34	17.95
Wake I	40	14.7	4.6	13.22	16.17
24 HR. PMI	40	18.25	2.49	17.45	19.04

Statistical method: Independent sample t test was performed to compare the continual variable between study groups. There is highly significant increase in the performance of sleep group compared with the wake group. A similar highly significant increase in the performance is seen in sleep –I group compared with the wake –I group.

Table 2: Comparison of Grade of Performance between groups

A	B	Mean Difference (A-B)	P value
Sleep (S)	W	2.6	<0.0001
	SI	0.15	1.000
	WI	5.05	<0.0001
Wake (W)	S	-2.60	<0.0001
	SI	-2.45	<0.0001
	WI	2.45	<0.0001
Sleep Interference(SI)	S	-0.15	1.000
	W	2.45	<0.0001
	WI	4.90	<0.0001
Wake Interference(WI)	S	-5.05	<0.0001
	W	-2.45	<0.0001
	SI	-4.90	<0.0001
24 HR. PMI	S	-1.50	0.117
	W	1.10	0.634
	SI	-1.35	0.230
	WI	3.55	<0.0001

Statistical Method – Independent Student t test

V. Discussion

Evidence that sleep increases memory was presented by a classic study in 1924 by Jenkins and Dallenbach which showed that individuals who sleep after learning remember more, than individuals who stay awake an equal time.[9] Since then , there are many reports in the literature, of investigation of relationship between different stages of sleep and different types of memory (i.e) the dual process hypothesis, which suggests SWS (Slow wave sleep) is necessary for declarative memory and REM sleep (Rapid Eye Movement sleep) is essential for non declarative memory.[10—13] Memory consists of three independent processes: encoding, consolidation and retrieval. In the process of encoding, new information inputs into neural circuits. This information is unstable and must be strengthened and transferred to long-term storage in the process of consolidation, which this study has focussed on. Finally, this information is retrieved from the areas of storage.[5] the consolidation process progressively converts labile memory traces into more stable representations, purportedly becoming more resistant to ongoing retroactive interference by similar material.[14]

The present study has demonstrated that there is a significant increase in performance in sleep group compared with the wake group.

Computer models of memory built by computational neuroscientists, to study how brain stores memory, showed a catastrophic level of memory interference when new memories were implanted.[15] But numerous psychological studies have observed that interference effect in human brain is much less than in the computer models.[16] This result is in agreement with the seminal study of Jenkins and Dallenbach(1924) in that novel information is progressively forgotten with time elapsed during time spent awake according to the Ebbinghaus' forgetting curve,[17] but that the occurrence of sleep stabilizes memories at pre-sleep level. The mechanism by which sleep makes memory traces consolidated is a matter of debate. It can be argued that sleep may selectively set memory traces in a state sensitive to updating through consolidation process.[18] Following this rapid cellular consolidation process, preferentially occurring during sleep, more substantial changes would occur. There are different ideas about how the brain avoids catastrophic interference. The gist of the idea is sleep strengthens and refines existing memories so that they are less likely to be disrupted by new learning. The mechanism by which sleep protects memory especially from being distorted by new learning—the stability-plasticity dilemma has been the forefront of memory research .

The results of the present study clearly indicates that forgetting is less in the sleep groups -- both in sleep and sleep –I groups compared to the wake and wake –I groups. The performance of the sleep –I group is statistically highly significantly better than the wake and wake –I groups.

The results of the present study has to be interpreted, taking into consideration many factors related to the arousal state of the brain and neurobiology of memory. Recently an "opportunistic theory" of memory consolidation has been posited which argues that any condition resulting in reduced exposure to interference will benefit declarative memory consolidation.[19] Lack of interference during sleep could be considered as a cause of beneficial effect.

The other possibility is the sleep learning effect. This is caused by hippocampus replaying new memories to cortex during sleep. Many earlier studies support this view.[20] This hippocampal replay mechanism, overtime, will result in strengthening of the cortical trace of the A-B pair, and it can also lead to strengthening of the hippocampal trace itself. These effects could result in an increase in recall.

Twelve hour design memory studies do not clarify whether sleep benefits memory or wakefulness impairs memory. However performance following the first 12 hour interval containing sleep or wakefulness could be compared to performance that occur during the second 12 hour interval that also contains a period of sleep or wakefulness (24 hours group). This comparison allows for a more conclusive interpretation of the functional role of sleep and wakefulness on memory processing. We used this protocol to answer questions like “Does sleep in the first 12 hour interval following training stabilize declarative memories, such that subsequent wakefulness has a diminished effect on the memory?” or “to acquire the memory benefits of sleep, do we have to sleep shortly after learning or does sleep benefit memory even when the sleep period does not begin until many hours (nearly 14 hours) after learning?” To understand whether sleep has a lasting influence on declarative memory, it is essential to answer these questions. Benson and Feinberg (1975, 1977) showed that participants who slept soon after learning unrelated paired associates retained more information 24 hours later than participants who endured a period of wakefulness before sleeping.[21,22] Our study also supports this view.

To sum up, our results evidence a specific role of post training sleep for the consolidation of recently learned memories. We have shown an interference effect suggesting that AB pair subjected to AC interference are set in a labile form only in subjects allowed to sleep during the post training night. We hypothesize that, the learned information was less consolidated due to absence of post training sleep.

VI. Conclusion

This study demonstrates that, sleep protects declarative memories from associative interference in the subsequent day and it thereby provides evidence that sleep does not passively protect declarative memories, rather sleep plays an active role in declarative memory consolidation. Adolescents should receive more than 9 hours of sleep every night. Health education to teenagers about the significance of sleep and results of sleep deficit can be given through schools and media. Although further research is needed to define the empirical limits and physiological correlates of this sleep and memory interactions, the study supports the view that sleep helps consolidate declarative memories and render them resistant to associative interference.

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