Positive Effects of Sleep on Memory Consolidation and Learning New English Words in Persian Language Speakers

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Background and Objective  The role of night sleep in learning and consolidating memory has been mentioned and researched in many studies. Different tools have been used to determine the effect of sleep. However, this kind of research in the Iranian population is limited. Thus, the objective of this study was to determine the role of sleep in immediate and late learning of new words of second language in a number of English language learners.

Methods  Forty Persian males aged 18–35 years old participated in our study in two groups. The first group completed learning steps at 8–10 AM and repeated the test after 12 hours. The second group performed the initial stages of learning at 8–10 PM and repeated the test next morning. Everyone completed the Pittsburgh Sleep Quality Index Persian version for evaluating their sleep habits during last month and the effect of their sleep habits on achieved task scores.

Results  Comparison of the number of recalled words (NRW) between the two groups showed a significant difference (p-value < 0.001) with better performance in night group. The NRW during the second stage was positively influenced by better subjective sleep quality, lower sleep latency, higher sleep efficiency, and more sleep duration significantly (p-value < 0.05). There was no significant relationship of NRW with sleep disorders, sleep medications, or day-time dysfunction.

Conclusions  Adequate night sleep could improve late learning of second language in our research subjects. Sleep quality, latency in falling asleep, and subjective sleep quality might play a role in this learning process.

INTRODUCTION  Learning a second language is required to communicate with the international community. This is a testament to the growing importance of learning a second language [1]. Memorizing words and ability to remember them play an important role in learning a new language. According to scientific documents and research, long-term and short-term memory both play an important role in learning new words in a language other than the mother tongue [2]. Over the years, several factors such as sleep, nutrition, and exercise that are effective in enhancing or weakening the memory have been identified [3]. Among various factors mentioned, sleep has a more prominent role than other factors. In many research studies, roles of sleep components have been specifically addressed. Among these components, the duration of sleeping, the time it takes for a person to fall asleep, and the time of the day and night when a person sleeps have been very carefully considered.

According to the National Sleep Foundation, 7–8 hours of sleep is essential for adults because it plays a key role in the normal functioning of the central nervous system and cog-
nitive functions. Studies have shown that getting enough sleep after learning can increase the retention of explicit information and allow new information to be processed and stabilized without the intervention of the sensory system [2]. In recent years, many studies have looked at the role of sleep as a factor in memory. Sleep patterns, how long you sleep, when you fall asleep, and when you wake up are all factors that can affect memory [4,5]. Kurdziel and Spencer [6] dealt with the category of sleep and its role in learning. They studied stages of learning and remembering words of a second language in two groups. One group performed these stages during waking hours and another group performed these stages after night sleep. Their results showed a better ability to remember words and their meanings in the group re-tested after a good night’s sleep. Their study emphasized the role of sleep as a memory enhancer [6].

A large-scale systematic review of more than 450 sleep-related research projects has emphasized sleep’s role in strengthening memory in human and animal models [7]. Another study has clearly described the significant role of a short sleep period of 60 to 90 minutes in enhancing memory-dependent perceptual skills [8].

Due to the importance of learning new words in a second language (generally English) in Iran, the challenge of remembering new words, and the lack of a comprehensive study in Iran, we decided to investigate the role of sleep in stabilizing memory and learning new words of a second language (English) in Persian speakers using the methodology described by Kurdziel and Spencer [6]. In this study 45 words were drawn from the English Lexicon Project database. Participants were divided into two groups. Subjects completed two sessions of study. Four experimental phases were spread across two sessions (passive encoding, active encoding, and immediate recall occurring during session 1 and delayed recall during session 2). The wake group started Session 1 in the morning (between 8–10 AM). Session 2 was performed 12 hours later in the evening. The sleep group started Session 1 in the evening (between 8–10 PM). Session 2 occurred 12 hours later in the following morning. All participants’ sleep parameters were evaluated by Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale, and Stanford Sleepiness Scale (SSS). This research showed that sleep not only promoted newly learned word-definition pair’s retention, but also facilitated the retention of items that were inaccurate but close to correct.

By designing this study, we tried to provide useful suggestions for Persian-speaking people to learn English with a high efficiency.

**METHODS**

**Participants**

This study was performed using the methodology described in the study of Kurdziel and Spencer [6]. Forty Persian-speaking male adults aged between 18 and 35 years who were learning English as their second language with an intermediate English language level with at least six hours of sleep at night participated in this study. They were learning English in an English language school. After meeting them in person and explaining the study process, they decided to participate in the study. Subjects were divided into two groups by the head of the educational institution. Subjects had no history of neurological diseases or sleep disorders. They had an average of six hours of sleep a night. They did not take any medications that might interfere with their sleep process. For this study, individuals were randomly divided into two groups. The first group learned new words between 8 and 10 in the morning. Cognitive assignments and second stage tests were performed between 8 and 10 in the evening. The second group learned new words between 8 and 10 PM. Cognitive tasks of the first stage were performed at night. Cognitive measurements of the second stage were performed between 8 and 10 in the next morning after sleeping at night.

The researchers had no role in this random selection. Subjects who participated in the study provided informed consent and completed sleep related questionnaires. No participants dropped out of this study.

**Stimuli**

Stimuli consisted of 20 words, including nouns or verbs selected from the lexicon project database. Each word was located between two standard deviations below the Hyperspace Analogue to Language (HAL) index, a scale that includes 131 million words from 3000 sources and refers to the degree of similarity of two words [9]. A low HAL index indicates the absence of similar words in the English language. That is, the word is specific without resembling other words. Words used and their meanings [6] are attached to this article.

**Tasks and Procedures**

Research steps were carried out in the following order: 1) Passive encoding phase: selected words and their meanings were displayed side by side on the monitor screen in two separate boxes for 20 seconds. 2) Active encoding phase: the subject was asked to write down the meaning of the phrase shown on the monitor. If the written meaning was incorrect, the correct form of the word and its meaning would be displayed again for 1 second so that the person could receive the correct feedback. All words and their meanings were displayed to the test taker in this way until the person finally reached a minimum of 62% of correct answers. At this time, the participant was tested for his immediate recall ability. 3) Immediate recall period: the subject was asked to write the meaning of a phrase shown to him on monitor. However, feedback was not given to the person for recalling the meaning of the word. The first stage of the experiment ended here. Based on correct answers of the subject, the
Levenshtein distance (LD score) of his immediate recall was calculated. 4) Delayed recall period: it is performed at least 12 hours after the first stage of the experiment, just like the immediate recall stage.

Evaluation of Sleep Parameters
1) All participants completed the Pittsburgh Sleep Quality Index Questionnaire (PSQI) Persian version [10] to examine their last month's sleep habits. 2) All participants completed the SSS questionnaire Persian version [11] to assess their drowsiness during the experiment. People who were drowsy during the test were excluded from this study.

This study was approved by IR.QUMS.REC.1395.247 in the Medical Ethics Committee of Qazvin University of Medical Sciences.

Statistical Analysis
Amount of LD for determining of the correctness of each response was calculated. LD was used to measure two words' differences such as insertion, deletion, and substitution [12]. For example, the distance between words “bitten” and “sitting” would include two substitutions (“s” for “b,” and “i” for “e”) and one insertion (“g”). As such, the LD number would be 3. We calculated LD errors for all participants. The difference in the mean of obtained data was compared with the statistical software SPSS version 21 (IBM Corp., Armonk, NY, USA).

Total scores of Pittsburgh Sleep Quality Index and SSS in each person were calculated and evaluated.

RESULTS
In statistical studies, the average age of study subjects was 24.08 ± 4.3 years. Regarding the academic degree of individuals, 20% with a diploma, 50% with a bachelor's degree, 20% with a master's degree, and 5% with a PhD were found. Examining subjective quality of sleep revealed that most participants had a good sleep quality.

<table>
<thead>
<tr>
<th>Study time</th>
<th>Subjects number</th>
<th>Mean ± SD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early recall LD error*</td>
<td>0.073</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning (first group)</td>
<td>20</td>
<td>78.99 ± 13.68</td>
<td></td>
</tr>
<tr>
<td>Night (second group)</td>
<td>20</td>
<td>72.78 ± 15.44</td>
<td></td>
</tr>
<tr>
<td>Delayed recall LD error</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning (first group)</td>
<td>20</td>
<td>86.82 ± 8.69</td>
<td></td>
</tr>
<tr>
<td>Night (second group)</td>
<td>20</td>
<td>69.15 ± 6.26</td>
<td></td>
</tr>
</tbody>
</table>

*LD error means the error that a person makes in recall (immediate or delayed) of the correct spell of the word studied in the past 12 hours.

LD, Levenshtein distance; SD, standard deviation.

Table 2. Correlation between Stanford questionnaire drowsiness index and early or late recall

<table>
<thead>
<tr>
<th>LD error*</th>
<th>r</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early recall</td>
<td>0.238</td>
<td>0.138</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>0.190</td>
<td>0.240</td>
</tr>
</tbody>
</table>

*LD error means the error that a person makes in recall (immediate or delayed) of the correct spell of the word studied in the past 12 hours.

LD, Levenshtein distance.

The two groups of subjects showed no significant difference in immediate recall LD of words (p = 0.07). However, they showed a significant difference in delayed recall LD (Table 1).

For evaluating the relationship between SSS questionnaire acquired scales and LD error numbers, correlation analysis was performed. Results showed that the amount of drowsiness based on the Stanford questionnaire was not enough to affect early and late recall (Table 2).

Evaluation of the relationship between the mean score of subjective quality of sleep scale with the mean error rate of early LD in all participants showed a significant decrease in the number of words memorized in people who had a poor quality of sleep (p = 0.03).

After examining the correlation between quality indicators of sleep in the Pittsburgh questionnaire on immediate and delay recalls of words in two groups of tests separately, it was found that subjective quality of sleep, sleep duration more than 5 hours and 45 minutes, and no delay in falling asleep had some positive but insignificant effects on the amount of immediate recall in the two groups. On the other hand, the duration of adequate sleep had a significant effect on the amount of vocabulary delay recall in the second group (p = 0.007, r = -0.581) (Table 3).

Results of analyzing the effect of subjective sleep quality on the error rate of delayed LD showed that although the average number of delayed LD errors was lower in people with adequate sleep quality, this difference was not statistically significant.

Analyzing the effect of sleep duration on delayed LD error showed a significant LD error difference between people with appropriate sleep length and those with an inappropriate sleep length (t = 9.1, df = 1, p = 0.005). Repeated measure analysis of variance (Greenhause-gaser: df = 14, f = 3.92, p-value = 0.002) showed that people who slept more than 5 hours and 45 minutes could remember more words than those who slept less in the second stage of the test (Fig. 1).

DISCUSSION
The general result of the present study showed an effect of night sleep on the level of recall of new English words in Persian speaking people. Results of the Stanford questionnaire indicated that study participants did not have drowsiness while...
Table 3. Correlation between the Pittsburgh questionnaire on immediate and delay recalls of words in the two study groups

<table>
<thead>
<tr>
<th>Subjective sleep quality</th>
<th>Sleep duration</th>
<th>Sleep latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>Night (first group)</td>
<td>Night (second group)</td>
</tr>
<tr>
<td>Early recall LD</td>
<td>1.000</td>
<td>0.090</td>
</tr>
<tr>
<td>Delayed recall LD</td>
<td>0.301</td>
<td>-0.200</td>
</tr>
<tr>
<td>p</td>
<td>0.723</td>
<td>0.440</td>
</tr>
<tr>
<td>r</td>
<td>-0.040</td>
<td>-0.182</td>
</tr>
<tr>
<td>Morning</td>
<td>Night (first group)</td>
<td>Night (second group)</td>
</tr>
<tr>
<td>Early recall LD</td>
<td>0.300</td>
<td>0.700</td>
</tr>
<tr>
<td>Delayed recall LD</td>
<td>0.300</td>
<td>-0.232</td>
</tr>
<tr>
<td>p</td>
<td>0.500</td>
<td>0.300</td>
</tr>
<tr>
<td>r</td>
<td>0.151</td>
<td>-0.411</td>
</tr>
</tbody>
</table>

LD, Levenshtein distance.

Fig. 1. Effect of sleep duration on delayed LD error. LD, Levenshtein distance. Covariates appearing in the model are evaluated at the following values: sleep duration = 1.35.

Several factors have been identified to be able to strengthen memory, resulting in people's ability to remember words, which is an important part of the language learning process. One of these factors is sleep. Recent studies have focused a lot on sleep as an important factor. The effect of sleep on language learning has been examined with several contents such as lexical learning [4], speech recognition [13], the role of sleep in the consolidation of newly learned data's [14], and so on.

Sleep deprivation is also one of the most important problems that can cause functional disorders in people and children's concentration, as a fundamental issue in schools [15-17]. Effects of sleep deprivation are usually ignored as they are usually partial and end with sleep. The duration of sleep deprivation and its recurrence over a short period of time can increase the burden of problems. Buxton et al. [18] have shown that sleeping between sessions can enhance inter-session learning. They found that this method could be a simple and reliable method to achieve a long reading and reminder with less time for study. In their study, results of reading in two turns (after one week and after six months) were evaluated and the optimal effect of sleep on reading was proven [19], which was in line with results of the present study showing that the number of recalled words in the second stage of the second group showed a very significant difference in new words recall after night session in comparison with morning session.

Effects of sleep on learning and memory have been proven by demonstrating structural changes using non-invasive neuroimaging methods in the brain which emphasizes the effect of sleep on memory processes [20], consistent with results of the present study showing that the sleep process plays a role in vocabulary recall. Additional studies are needed to investigate relationships of memory stabilization stages with short-wave sleep and REM sleep periods. In some studies, the effect of early and late sleep on visual memory has been investigated. SWS waves have been effective in early sleep and REM memory in late sleep. Visual memory is more affected by early sleep and in fact, the formation of visual memory is more simultaneous with SWS waves [8]. Due to the lack of polysomnography documents in the current study, it is not possible to provide comparable results with the above-mentioned study.

A previous study by Kurzdo and Spencer [6] on the relationship between sleep and memory has shown that volunteers who take the first three phases of the test at night and the fourth phase 12 hours later (and at least 6 hours after a nap) can recall more words than volunteers who have completed the first three steps at 8 AM and completed the fourth step 12 hours later without a nap. Results of the present study are in line with the study on the role of sleep in learning words with lexical similarity by Dumay and Gaskell [4]. They emphasized that words learned at 8 pm after 12 hours (after a night's sleep) could induce vocabulary competition correctly and that subjects could memorize words in the medium term and long term. However, when here is no night-time sleep after learning, this process was transferred to 24 hours later (after establishing a night-time sleep period) [4]. In line with these findings, some studies have carefully examined effects of insomnia on learning a new language. For example, Pilcher et al. [21] have conducted a study on non-English speak-
ners using several cognitive and linguistic tests and found that sleep deprivation has a negative impact on linguistic abilities.

Results obtained in the present study are somewhat in line with results reported previously, especially those using Pittsburgh sleep quality indicators. Of course, the above studies are different in terms of inclusion criteria and implementation method, including the degree of difficulty of words and observing the exact hours of sleep, sample size, age of subjects, length of delayed reading time, and so on. However, most studies have observed a significant effect of adequate sleep on memory stabilization. Differences in results are partly due to differences in implementation methods and human errors or the boredom of candidates in answering questions of the questionnaires which are unavoidable in human studies.

Conclusion

Overall, based on results of this study, it seems that having a good night’s sleep is effective in improving and stabilizing memory. Mental quality of sleep, delay in falling asleep, duration of sleep, and quality of sleep can also have a significant impact on this process. Analytical analysis of PQSI questionnaire results showed that people with enough sleep (more than 5 hours and 45 minutes of sleep) a night have a much better ability to read delayed than people with insufficient sleep. This shows the effect of sleep on memory stabilization. Our findings support the hypothesis that more second language words can be recorded in immediate and delayed memory along with adequate sleep time. We recommend the use of results of the present study to non-native language teaching institutions in order to improve the practicality of educational results.

Limitation

This study is a human-based research study. We had some limitations about controlling the whole issue especially when tests were done in their home. Thus, we tried to have phone consultation for running the test using the right methodology.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Author Contributions


Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Funding Statement

None

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