Dream Drill: Learning Application

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CHI'12, May 5–10, 2012, Austin, Texas, USA.
ACM 978-1-4503-1016-1/12/05.

Abstract
Some evidence indicates that sleep supports memory consolidation. Items studied before sleeps are memorized more efficiently than those not followed by sleep. Consequently, we propose a learning management system based on these findings. The system includes an alarm clock, whose alarm is set only if a user answers some questions. The user also has to answer the same questions once the clock has awakened him or her in the morning. We implemented a prototype and conducted a user study with five participants to evaluate the effectiveness of the system.

Keywords
sleep; memory; learning; study; Android application; Google App Engine

ACM Classification Keywords
H.5.2 [Information Interfaces And Presentation]: User Interfaces

General Terms
Design, Experimentation, Human Factors

Introduction
The effects of memory consolidation by sleep have been demonstrated many times. Memory is generally categorized as sensory memory, short-term memory, and long-term memory [1]. Sensory memory stores

sound or image information. Short-term memory holds information for several tens of seconds. In contrast, long-term memory is assumed to retain it until death, unless the brain's ability to do so is impaired. Long-term memory is classified into two types: non-declarative memory and declarative memory. The former contains information that we have learned or know and the latter the procedures, expertise, and techniques that we have mastered. It is well-known that both declarative and non-declarative memories are consolidated by sleep [2].

Much research shows that sleep consolidates declarative memory, but no systems have as yet utilized this finding in everyday life. Setting an alarm before going to bed is one of the nightly routines of our daily lives. In our research, we focused on it, assuming that this action could be utilized for effective learning. The alarm clock designed for our system provides a practice opportunity when a user sets the alarm at night and turns it off in the morning.

To make this method effective, we had to find responses to several questions:

- What kinds of practices are involved in this system?

- What kinds of information should the system give to users before sleep (questions, hints, or answers)?

- What kinds of incentives are effective?

- How hard and how long should a user practice before sleep?

As the first step, we conducted English word memorization experiments on several Japanese participants. We expected to learn how to refine our methods for further experiments.

Sleep & Memory

Since the theory that memory consolidation is enhanced by dreaming [3] was published in 1791, many studies have been conducted on the relationship between sleep and memory. In recent years, the importance of sleep in memory reactivation has been shown neuro-scientific and cognitive scientific research [4].

Some alarm clocks are employed not only to wake up but also to learn. The TWIST Desktop Digital Alarm Clock [5] displays a formula on the LCD when its alarm sounds. To stop the alarm, the user has to complete the formula by twisting its body. This technique is based on the idea that forcing a user to use his brain and body will help him to wake up easily. However, this technique does not employ sleep effects to promote memory consolidation.

A variety of devices and applications have been developed for learning support. For example, MicroMandarin [6] is a location-based application program for language learners whose first language is not Chinese. It provides Chinese word quizzes that correspond to the location of users.

Those devices or application programs do not provide any systematic way to make users practice before sleeping. In this paper, in order to incorporate effectively the promotion of memory consolidation by sleep, we propose the Dream Drill, a ubiquitous learning system that utilizes the time before sleep.

Design of Dream Drill

Dream Drill is a system that supports daily learning before sleep for people whose first language is not English. We used smart phones as mobile terminals and built the server using the Google App Engine. The system includes an alarm clock function and the opportunity to perform language exercises before and after sleep. It offers English word quizzes to users before they set alarms and after they turn them off. We chose an English word quiz, since many people want to memorize English words. The system displays one English word and four choices for its meaning in Japanese; users select one of them as an answer (Figure1-a). With a correct choice, the system displays "correct", and, with an incorrect one, "incorrect" and the correct answer. At the end of a turn, the system displays on the display the number of correct answers, a list of answers, and the time taken to answer each question (Figure1-b). Users are able to set the alarm after the quiz (Figure1-c).

On the server side, the database of the system holds information on each user, such his or her name, a list of question words, correct response rate, the choices, the time taken to answer, and the date and time of each turn. At the beginning of each turn, the mobile terminals fetch the words from the server. At the end of each turn, the mobile terminals send data to the server (dashed arrow). The server selects words at random for each user. Therefore, the set of words for each user will be different.

(a) (b) (c)

Figure 1. (a)Question Screen, (b) Result Screen, (c) Set Alarm Screen.

Experimentation

Using this system, we performed an experiment to explore an effective way to learn before sleep. We selected difficult English words so that were all new to participants. The participants learned the words just by answering the questions asked by the system, that is, they learned the words giving the meaning of a foreign (English) word in a native (Japanese) word from the choices and then seeing if an answer was correct. We asked the participants to take these tests three times a day--after waking up, in the daytime, before bedtime--and we compared the results. When a participant finished a test, he or she could set the time for the next test by using the alarm function of the system. In this way, we evaluated if our mobile phone based learning system successfully encouraged the consolidation of memories.

Participants

We asked five native Japanese participants (two males and three females, aged 22 years to 56 years) to join the experiment. Their self-reported English language skills were diverse; one of them was "novice high," one "intermediate low," two "intermediate mid," and one "intermediate high."

All the participants were familiar with the mobile devices, such as the SAMSUNG Nexus S, on which we had installed our system and which we have lent to them during the experiment.

Method

The participants were asked to use this system for four days. In order to explore effective exercise time for memory consolidation, we designed the experiment as follows: We chose 55 English words for the experiment and assigned 35 randomly selected words from them to each participant. We divided the 35 words assigned to each participant into seven groups of five words each, which we named groups EM, AE, MA, EO, MO, S1, and S2. In each exercise, the participants were challenged by three of the seven groups, that is, by 15 words. Table 1 is the exercise schedule for the four day experiment and shows when a participant was challenged by each group. The first column represents the name of the group (EM to S2), while the first line represents the test days and the second line the time of the experiment. Letter M represents the morning (after waking up), letter A the afternoon (daytime), letter E the evening (before going to bed). For example, participants were challenged by groups EM, AE, and EO before going to bed on the first and second day.

Each participant was challenged by ten exercises of three groups of words during the four days, as shown in Table 1. The exercise times of groups EM to MO scheduled from DAY1-M to DAY3-M were the essence of the experiment plan. Each group had a specific time, that is, EM was scheduled in the evening and morning, AE in afternoon and evening, MA in the morning and afternoon, EO in evening only, and MO in morning only. Both groups S1 and S2 were dummy exercises that were prepared to equalize the number of groups per exercise to three; thus, there was no regularity in the timing. By comparing the total scores for each group, it was possible to discover the time of study most effective for memory consolidation. The final exercises

	DAY1			DAY2			DAY3			DAY4		
	M	A	E	M	A	E	M	A	E	M	A	E
EM			○	○		○	○					○
AE		○	○		○	○					○	
MA	○	○		○	○					○		
EO			○			○					○	
MO				○			○					○
S1	○				○					○		○
S2	○	○					○			○	○	

Table 1. Test schedule. First column shows group name. First row shows the day of the experimentation. Second row shows timing: M = morning, A = afternoon and E = evening.

for groups EM to MO were scheduled on Day 4, each coming about 40 hours after the previous exercise, considering that the interval between each exercise is roughly equal (8 hours). Scores of the final exercise on Day 4 indicated the long-term learning performance for the timing of groups EM to MO.

Hypotheses

We would like to focus first on the results of groups EM, AE, and EO. These three groups are expected to have consolidated memories during sleep more successfully than the other groups, since the participants in them were challenged before going to bed. Second, by comparing the results of group EM and group AE, we reveal the effect of repeating the memorization after waking up. Third, if the results of group EM and group EO are close, we would conclude that the scheduling of group EO is the best learning time, since the participants in it learned same number of words with half the effort.

Result and Discussion

Figure 2 shows the results of the experiments, where the X-axis represents the timing of the exercises and the Y-axis the score and the number of correct answers for groups EM, AE, MA, EO, and MO. The maximum score is 25, since five participants were challenged by the five words in each group.

Figure 3 shows the growth of those scores, where the X-axis is the same as Figure 3, and the Y-axis represents the difference from the first score of each group.

The scores significantly improved for all groups in this four day experiment, but the difference between them is unclear. We do not perform any statically analysis at this point, since the total number of exercises is not yet sufficient. However, we have some hints of the results.

Let us focus on the scores of the last exercise on the last day. For each group, about 40 hours, which is long enough to forget many words, had passed since the previous exercise. Comparing the scores of the last and the previous exercises, groups EM and MO have lost several points, group MA a slight number of points, and groups AE and EO have gained some points. The previous exercises were done in the morning for both groups EM and MO, in the afternoon for group MA, and in the evening before sleep for groups AE and EO. These results may imply that the exercise performed before sleep was more effective than those in the morning or afternoon. We agree that this result could be accidental, but it helps to investigate the hypothesis.

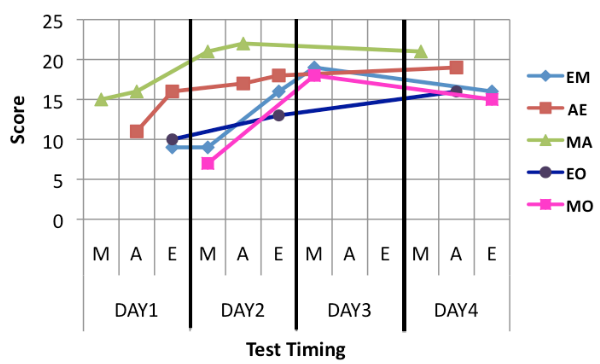

Figure 2. Results of experiments

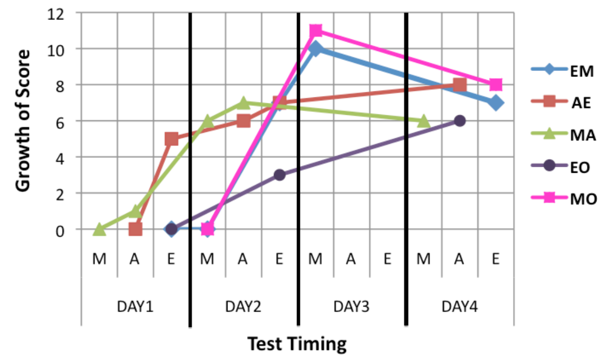

Figure 3. Growth of scores

To clarify the difference in the groups, it might be necessary to eliminate the effect of flukes. We asked participants to memorize the correct answer after each question, but the experiment was not designed to test if they really tried and succeeded in memorizing it during the exercise. For the next experiment, we are planning to try a method to test if they do so. For example, if a question (word) is repeated more than two times in an exercise until the user chooses the correct answer two times successively, we will be able to assume that he or she has really tried and succeeded in memorizing it at least during the exercise.

We also found that the difficulty of questions may not have not sufficiently equal. If the questions are equally difficult and unknown to the participants, the rate of choosing a correct answer will be around 25%. However, the rate for group MA was 60% (15 in 25). We need to consider how to prepare more equitable questions.

Some participants said that they tended to see only the choices in answering the questions. They memorized the correct answers but not the English words. Therefore, the tasks did not seem useful to them and, hence, spoiled their motivation. In addition, because the choices were presented in Japanese, the mother language of the participants, it is possible that some choices were easier to memorize than others. This problem may be solved to some extent if the system presents question words in Japanese and choices in English.

This was the first trial of experiments to measure the effectiveness of Dream Drill. We will improve the experimental method and gather much more data in the future.

Conclusion

While it is difficult to promote consciously long-term memory consolidation, our application unconsciously affects it. This paper is intended as practical guideline for designing a learning system that is used before bedtime. In the future work, we are planning to experiment with a wider variety of conditions, such as changes in the number, appearance, and timing of questions.

We would like to measure the effects of other kinds of learning before sleep. Some reports suggest the importance of sleep in the consolidation of declarative memory and others suggest its key roles in "inspiration"[7]. Learning before sleep is not only effective in simple memorization, but it may be deployed in a variety of learning situations.

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