Effect of intermittent learning on task performance: a pilot study

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Abstract

We discovered that intermittent training sessions that are separated by short breaks might enhance long-term memory consolidation. The gamma wave power in the frontal lobe was recovered after each break.

Introduction

It is crucial for workers and students to demonstrate the best task performance in a limited period of time. For example, how is it best to allocate time when memorizing words within a given amount of study time? Few studies based on electrophysiological observations have investigated the effect of breaks during learning. In this study, we asked 28 junior high school students to memorize English words for up to 60 min on three types of learning schedule. At the same time, we recorded electroencephalograms (EEGs). In this paper, we report the results of the pilot experiment.

Methods

Experimental scheme

The experimental design is shown in Figure 1. A preliminary test using 75 English words was conducted for 28 participants (12-13 years old) in their first year of junior high school. The participants were divided into 3 groups so that the average score of the preliminary test was equal among the following three groups: a 60-min group (10 persons), a 45-min group (10 persons), and a 15-min×3 group (8 persons). The participants learned a total of 150 English words according to their assigned learning schedules. The 60-min group studied the words continuously for 60 min. The 45-min group studied the same words continuously for 45 min. The 15-min×3 group separately studied the words 3 times for 15 min each, with two 7.5-minute breaks. During the study period, body and eye movements were monitored using video cameras. Immediately after the training, the participants were tested on 75 of the words (day 1). On the next day, they were tested on the remaining 75 words (day 2). After one week, they were retested on 75 words that were randomly selected from the 150 words (day 8).

Human EEG

Two healthy 13-year-old children participated in our EEG experiments. EEG recordings at AF7, Fpz, AF8, F3, Fz, F4, and Cz (following the international 10/10 coordinate convention) were collected at 500 Hz (the right earlobe was used as a reference) with a wireless EEG system (Polymate Mini AP108, Miyuki Giken Co., Ltd, Tokyo, Japan) with pasteless dry electrodes (National Institute of Information and Communications Technology, Japan) (Naruse, 2014). Eye movements and blinks were simultaneously recorded with an electrode put on the left eyelid. The recorded EEG and eye-blink-related signals were saved on a computer using the Mobile Acquisition Monitor Program (NoruPro Light Systems) through a Bluetooth wireless connection. The EEGs were analyzed using the EEGLAB MATLAB toolbox and in-house subroutines written in MATLAB (Delorme and Makeig, 2004). EEGs were continuously recorded during a total period of 105 min that consisted of 15 min of study, 7.5 min of rest, 15 min of study, 7.5 min of rest, and 60 min of study. The raw data were preprocessed offline by linear trend removal and bandpass filtering (1 to 40 Hz). In addition, EEG epochs that contained large potentials were identified by visual inspection and excluded. These noisy epochs were generally due to eye movements and blinks.

Results and Discussion

The time course of the scores on the English word tests is shown in Figure 2. This graph plots the differences in the scores, *i.e.*, the total number of words that could be recalled (the full score = 75 points), on the tests from those on the preliminary test before training. All groups exhibited increased scores after training. However, on days 2 and 8 after learning, the scores of the 15-min×3 groups tended to be higher than the scores of the other 2 groups ($P > 0.05$, two-way ANOVA). The effect of the intermittent learning reached its maximum on day 8. For instance, the mean score improvement of the 15-min×3 groups on day 8 was 18.75%, whereas that of the 60-min group was 16.0%; that is, the effect was 17.2% higher in the 15-min×3 group ($P > 0.05$, Student's *t*-test). This result suggests a possibility that the brief breaks taken by the 15-min×3 group may have a benefit in long-term memory consolidation. It is interesting that a larger effect was obtained despite the fact that the total learning time of the 15-min×3 group was 45 min and was shorter than that of the 60-min group.

No remarkable differences in eye movements or other behaviors were observed among the three groups during learning. Thus, we sought to analyze the EEGs. The gamma waves of the frontal lobe are considered to be involved in concentration. Thus,

we calculated the average value of the gamma waves across all five electrodes that were located on the frontal lobe. In the 60-min group, the power of the gamma band decreased with the passage of time (Fig. 3A), and a sharp drop in the gamma power was observed, especially after 40 min. This fact may indicate that the participants' concentration lasted only for approximately 40 min. On the other hand, in the 15-min×3 group, the gamma-wave power decreased at the initial stage in each block, but the power recovered after every break, and it remained above a certain level during the entire study period.

In conclusion, the present experiment was a small-scale survey, and a larger-scale experiment is necessary to obtain statistically strong results; however, both the test performances and the EEGs produced consistent trends. Therefore, we suggest that short breaks dividing the study time periods contribute to the maintenance of concentration and thereby lead to higher cognitive performance in the long term despite a shorter total duration of learning.

References

Delorme A, Makeig S (2004) EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. J Neurosci Methods 134:9-21.

Naruse Y (2014) Development of mobile wireless EEG system with dry electrode. Proc Life Eng Symp 1:130-132.

Notes

This work is a private study driven by personal interest, and this paper is free from copyrights. We declare no conflict of interest. We are grateful to Benesse Corporation for all the support, including help in recruiting the examinees, providing us with its study rooms, and helping us to conduct the examination. Correspondence should be addressed to Yuji Ikegaya (yuji@ikegaya.jp).

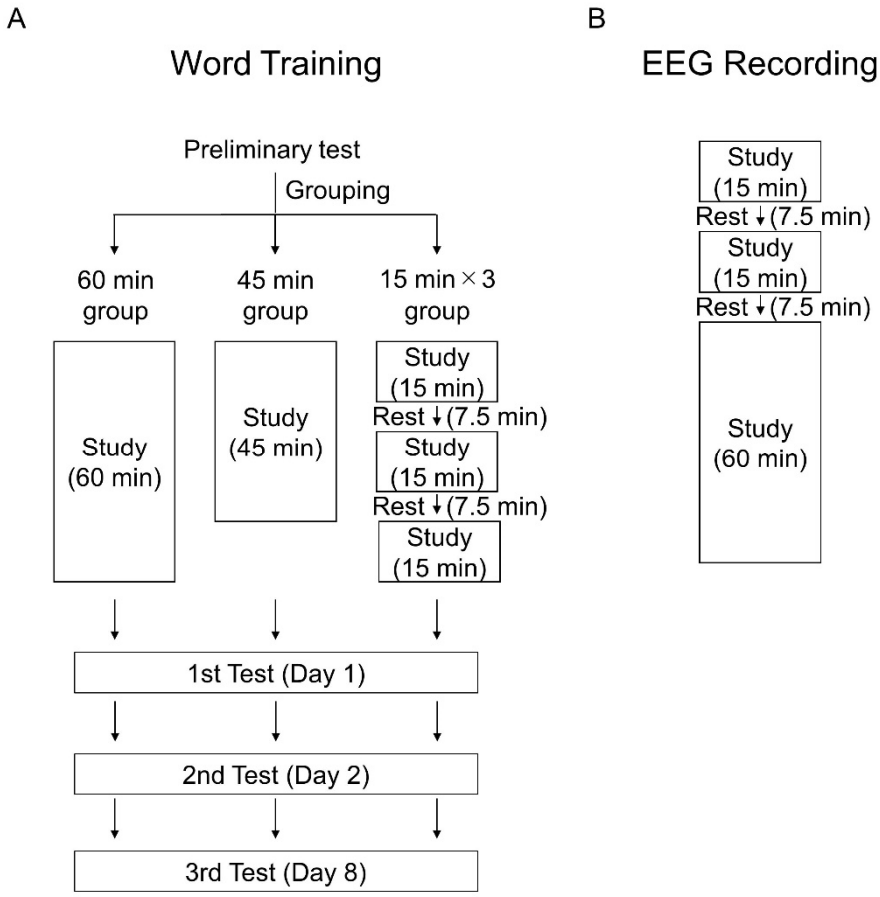

Figure 1 Experimental paradigm A. A total of 28 participants were divided into three groups so that the mean scores in the preliminary test were equivalent among the groups. Different groups studied English vocabulary on different time schedules, and their task performance was assessed by three tests on days 1, 2, and 8. B. EEGs were recorded from two participants.

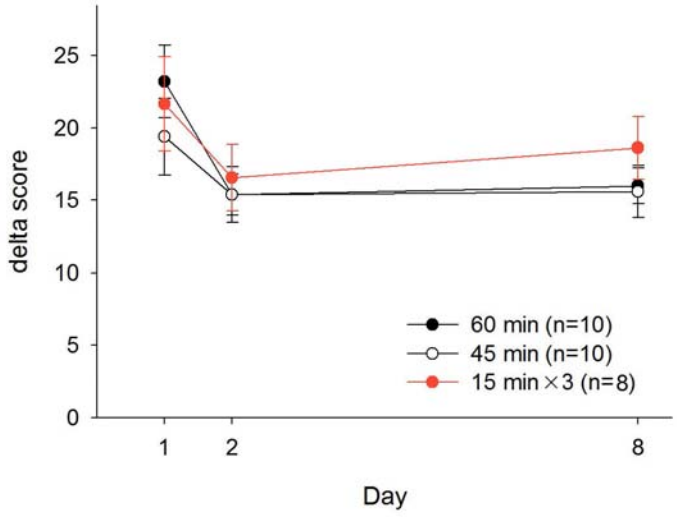

Figure 2 Time course of test scores. Tests were conducted on days 1, 2, and 8. The ordinate indicates increases in the number of correct words relative to the preliminary test. Data are means ± SDs of 8-10 persons.

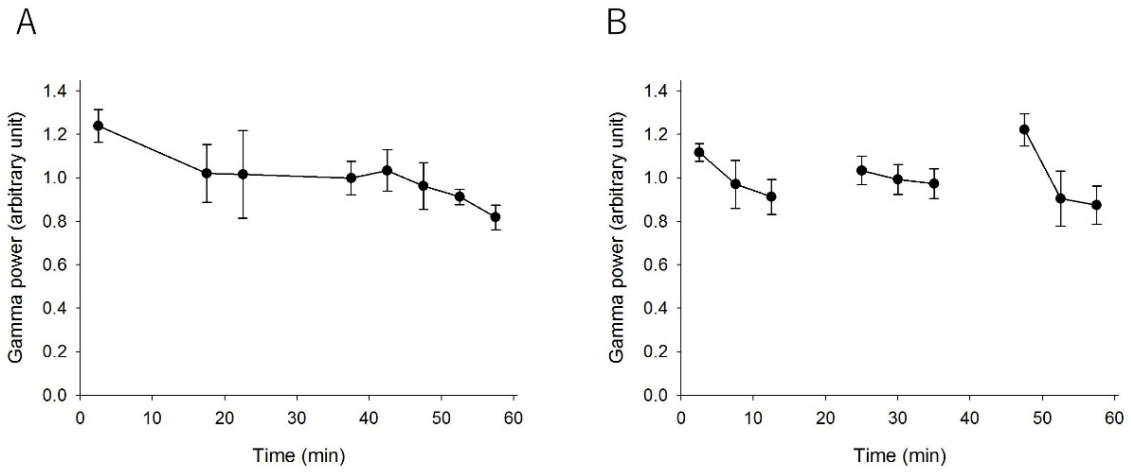

Figure 3 Time course of EEG gamma power in the frontal lobe. A. Time course in the 60-min group. B. The same as A, but for the 15-min×3 group. Data represent means ± SDs of 5 channels.