Influence on brain activity during and after a study break using different types of music

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Abstract

Effective relaxation methods during and after a break from “study” (i.e., an experimental task involving a rock-paper-scissors game requiring concentration) were investigated in terms of prefrontal cortex and parasympathetic nervous system activity. Prefrontal activity was determined from changes in oxy-hemoglobin (Hb) and deoxy-Hb measured by 10-channel wearable optical topography, and parasympathetic nervous system activity was analyzed by high frequency components (HF) of fluctuations in instantaneous heart rate (IHR). In this study, we hypothesized that subjects would relax or experience reduced mental stress when prefrontal activity became inactive and/or the HF decreased. Relaxation tasks were used during the study breaks were as follows: (1) just resting (doing nothing); (2) deep breathing; (3) listening to an uplifting song; (4) listening to relaxing music; (5) listening to classical music. During study breaks in which subjects listened to three kinds of music, particularly uplifting songs, both prefrontal and parasympathetic nervous system activity tended to become inactive compared with a study break in which subjects did nothing or engaged in deep breathing. Furthermore, when the study task was performed a second time after a break involving doing nothing or listening to classical music, prefrontal activity tended to become more active in comparison with activity during the first study task.

Keywords: prefrontal activity, NIRS, parasympathetic nervous system activity, relaxation method.

1. Introduction

Concentration is required for effective studying and to achieve positive results on various tasks. Since concentration depends on personal ability and is difficult to maintain in the long term, individuals often must rest before starting the next task. Effective relaxation methods vary for different types of tasks (e.g., strenuous or light physical work, routine work, sports, listening, watching, consideration, imaging while studying). In this study, we focused on effective rest methods and attempted to investigate which tasks are best for a study break and for maintaining concentration. Previous research indicated that listening to music was an effective task to ensure better rest⁽¹⁾.

As is well known, the relationship between emotions and brain activity has been investigated by electroencephalogram (e.g. ²). More recently, blood flow of the frontal lobe has been determined using near infrared spectroscopy (NIRS), representing a comparatively simple method of measuring brain activity (e.g. ³). It is also well known that parasympathetic nervous system activity can be determined from heart rate fluctuations (HRF) in order to estimate whether a nervous condition is rest⁽⁴⁾. Therefore, we attempted to investigate which relaxation task (and especially which type of music) is the best rest method for a study break in terms of changes in blood flow and HRF.

2. Experimental methods

2.1 Experimental Procedure

To simulate a study task requiring concentration, subjects were instructed to lose at a “rock-paper-scissors” game that they played against a random displayed hand at a 1-sec throwing interval. Subjects were also given the following five study break relaxation tasks: (1) just resting (doing nothing; i.e., the control task); (2) deep breathing (as a classic, effective rest method); (3) listening to their favorite uplifting song (selected by each subject); (4) listening to their favorite relaxing song (selected by each subject); and (5) listening to classical music (in order to compare with the two aforementioned types of music); the first 1 min of *Spring* from *The Four Seasons* by Vivaldi was chosen because this music was reported to include a 1/f fluctuation (i.e., pink noise) which people find comforting⁽⁵⁾. The duration of the study task was 2 min; the duration of each relaxation tasks as 1 min; subjects were instructed to keep their eyes open during these tasks. The first 30 sec of the procedure consisted of a rest period; subjects then completed the 2-min study task and then rested; each rest period involved a 1-min relaxation method. Afterwards, subjects repeated the 2-min study task and took a 30-sec rest. Subjects repeated this procedure with the different five relaxation methods at adequate time intervals. This experimental procedure was shown in Fig. 1.

Fig. 1. Experimental procedure and example of Janken task.

As the study task was completed twice, if prefrontal activity in the second study task increased or was maintained at the same level, this implied that the relaxation task effectively maintained the concentration level attained during the first study task.

During this procedure, instantaneous heart rate (IHR) and oxy-hemoglobin (Hb) concentration in the prefrontal area were measured simultaneously. The five conditions were measured three times each on separate days. The five relaxation tasks were conducted with an order randomized.

As each relaxation task was repeated three times, there were 33 measurements in total. Statistical analyses were not conducted because we felt that a sample size of 33 was inadequate for statistical analysis; qualitative comparisons are thus described in this report.

2.2 Brain Activity

Activity in the prefrontal area was investigated by measuring changes in oxy- and deoxy-Hb concentrations determined by 10-channel (CH)-wearable optical topography (WOT-100, Hitachi High Technologies Ltd.,) with NIRS at a sampling frequency of 5 Hz. If oxy-Hb increased and deoxy-Hb decreased, this indicated that the corresponding region of the prefrontal area is active compared with the previous condition. When oxy-Hb decreases and deoxy-Hb increases, prefrontal activity is inactive (summarized as Table 1). In this study, if Hb in the regions surrounding the CHs involved in the study task changed during the study break as per the above definition of inactivity, we proposed that the subject was taking a rest in the current task compared with previous task.

Table 1. Brain activities determined from changes of

oxy-Hb and deoxy-Hb		
Change of oxy-Hb	Change of deoxy-Hb	Brain Activity
↑	↓	Active
↓	↑	Inactive
↑	↑	
↓	↓	

↑: increase ↓: decrease

2.3 Parasympathetic Nervous System Activity

Autonomic nervous system activity was analyzed by the frequency component ratio determined from a power spectrum of HR fluctuations. IHR was determined from time intervals of adjacent R waves of an electrocardiogram (RAC-3502, Nihon Koden Ltd.). The IHR power spectrum was calculated every 30sec using a discrete Fourier transform algorithm. The low frequency (LF) range was 0.04 to 0.15 Hz and the high frequency (HF) range was 0.15 to 0.4 Hz. High frequency components (%HF), which represent the ratio of HF component to HF + LF, is used as an index of parasympathetic nervous system activity^(4, 6-7). Although HF is often used for a parasympathetic index, %HF, which means a normalized index, was adopted in order to emphasize a change of parasympathetic nervous system activity and reduce an influence from very low frequency

component in this research.

3. Results and Discussion

Simultaneous measurements of blood flow in the prefrontal cortex and heart rate (HR) were conducted in eleven subjects (healthy students aged 19–21 years; eight males and three females). We investigated which regions of the prefrontal become active during the study task. The study task, that is, rock-paper-scissors, is roughly the equivalent of “Janken” in Japanese, which was the task used in the current study.

Fig. 2 shows the proportion of each CH that became active during the first Janken task results indicated that active rates in CH 8 and CH 14 of the right and left prefrontal cortices, respectively, were higher than other channels. Of course, the regions activated by study tasks depend on the difficulty of the task or the level of concentration required. The Janken task, which required a quick judgment and a quick hand motion, involved to the areas around CH 8 (right prefrontal cortex) and CH 14 (left prefrontal cortex). Thus, in the current study, we focused on prefrontal activity around CH 8 (i.e., CHs 7, 8, and 10) and CH 14 (i.e., CHs 13, 14, and 16) when investigating effective relaxation after the Janken task.

Fig. 2. Active rates in % during the Janken task of each channel (CH) of the prefrontal cortex. The listed values indicate the rates at which each area became active per total number of measurements ($n = 33$).

Fig. 3 shows an example of the simultaneous measurement of the degree of change in Hb concentration of CH 8 and change in IHR during Janken tasks and rest periods (doing nothing). The dotted vertical line indicates that the subject started the next task. The solid line depicts changes in oxy-Hb concentration and gray dotted line indicates those of deoxy-Hb. Each black dot indicates a heartbeat. This subject was 20 years old, healthy, and right-handed. In this

example, oxy-Hb increased and deoxy-Hb decreased during the first and second Janken tasks, indicating the initiation of prefrontal activity at CH 8 during the Janken task. Meanwhile, the prefrontal activity of CH 8 became inactive and the IHR decreased during rest periods.

Fig. 3. An example of the degree of Hb changes and IHR through one set of the experimental protocol. The upper panel shows the degree of change at 8CH. The lower panel depicts changes in IHR.

Rates of prefrontal inactivity in each brain area during the five relaxation tasks performed after the first Janken task are shown in Fig. 4A (left prefrontal cortex; CHs 13, 14, and 16) and Fig. 4B (right prefrontal cortex; CHs 7, 8, and 10). Colored bars represent the five relaxation tasks: doing nothing, deep breathing, listening to a favorite uplifting song, listening to a relaxing song, listening to classical *Spring* by

Fig. 4. Rates of prefrontal inactivity in each brain area during the five relaxation tasks performed after the Janken task.

Vivaldi. All measured channels of the prefrontal cortex tended to be inactive while the subject listened to music in comparison with doing-nothing and deep breathing. However, rates of inactivity were not significantly different among the various types of music.

As shown in Fig. 5, rates of prefrontal activity during the second Janken task after resting and listening to classical music (*Spring*) tended to be higher than those of other tasks, although these differences were not statistically significant.

Fig. 5. Rates of prefrontal activity during the second Janken task after the five relaxation tasks.

We investigated the changes between average %HF of the first Janken task and that of each relaxation task. The increase in average %HF from the first Janken to the relaxation tasks indicates the subject's decrease in static stress during the study break. Although the difference was not statistically significant, the %HF of the three music relaxation tasks (listening to a favorite uplifting song, favorite relaxing song, or classical music) tended to be higher than the other two tasks (Fig. 6)

Fig. 7 indicates the rate at which the subject rested or experienced reduced stress during the study break in terms of both prefrontal activity and parasympathetic nervous system activity. Subjects tended to be more well rested when listening to all three types of music compared to other relaxation tasks; the rate of prefrontal inactivity when listening to the subject's favorite uplifting song was the highest among the three types of music, and when listening to the subject's uplifting song, it was four times higher than

that of the just resting (doing nothing) condition. Interestingly, subjects selected their own favorite songs, uplifting songs were different songs. Regardless of whether the selected songs were same or not, subjects were the most relaxed after listening to their favorite uplifting songs. This finding indicates that subjects can have a mental refresh or not could more influence on it.

Fig. 6. The increase rate of average %HF from the first Janken to the relaxation tasks.

Fig. 7. The condition rates of both prefrontal inactive and high average %HF during the relaxation tasks.

Satisfying both conditions indicates the possibility that subjects were relaxed both in terms of both brain activity and static stress.

4. Conclusions

Effects of relaxation tasks during and after a study break on parasympathetic nervous system activity and prefrontal activity were examined in 11 Kosen (Our institute, National College of Technology is called Kosen) students. In this study, we focused particularly on the difference among

types of music (uplifting song, relaxing song, and classical music) because many Kosen students answered that they listened to music during their study breaks. The Janken task, which was used as a study task, activated CHs 8 (right prefrontal cortex) and 14 (left prefrontal cortex). All three types of music tended to decrease subjects' prefrontal activity during the study break and rest period (doing nothing) and classical music activated the areas in the next Janken task. From the viewpoint of parasympathetic nervous system activity, all relaxation tasks tended to result in subjects being well rested; the %HF when listening to music was slightly higher than that when resting and or engaging in deep breathing. In terms of both prefrontal activity and parasympathetic nervous system activity, music, especially uplifting songs, induced better relaxation during a break from the Janken task. Importantly, however, these tendencies depended on the individual and were attributed only to our Janken tasks.

The effects of these relaxation methods on other study tasks (e.g., easy/difficult mental calculations, memorizing words/sentences, deep consideration of physical phenomena) should be investigated in subsequent studies. In addition, since listening to music appears to be a good relaxation technique for use during study breaks, further experiments under different conditions (e.g., differing listening durations, types of music, and tempos) are required. This experiment was conducted in healthy Kosen students aged 19–21 years (i.e., young adults). Different results might be found among younger students or those from different cultures.

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Additional statements

This research was approved by the Life Ethics Committee of NIT, Hakodate College.

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