Evaluating the Attention Devoted to Memory Storage Using Simultaneous Measurement of the Brain Activity and Eye Movements

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Abstract. Our study indicates that combined measures of brain activity and eye movement are useful parameters for quantifying the attention devoted to memory storage. We measured eye movements with an Eye Tracker and prefrontal cortex activity using a wearable Optical Topography in 18 participants performing a visual working memory task. We used these measures to calculate a combined index of brain activity and eye movement, which revealed that increased brain activity and higher fixation counts were related to improved task performance.

Keywords: memory, attention, eye movement, brain activity.

1 Introduction

Eye movements can indicate where others direct their gaze and focus their atten-tion, but they cannot indicate whether an item is stored into memory. Therefore, we used simultaneous measurements of brain activity and eye movement to develop an index that quantifies the attention devoted to memory storage. Our index is a useful parameter for optimizing memory-learning systems and for designing advertisements.

2 Methods

Participants. Eighteen subjects (twelve male and six female: mean age 37.2 years) participated in this study. All subjects provided informed consent after they received an explanation of the experiments.

Measurement Settings. The WOT-220 system (Hitachi) measured changes in cerebral blood volume at 22 positions (channels) in the prefrontal cortex [1]. Eye movements were measured with the TX300 eye tracker system (Tobii). WOT system had a black rubber sheet that shaded light from the eye tracker system.

Task Paradiam. Participants performed a working memory task that was similar to those used in previous studies [2]. A single task trial was performed in three periods:

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memorization, maintenance, and retrieval (Fig. 1). In the memorization period, the participants memorized four pictures that were presented simultaneously on a display for 8 s. In the maintenance period, the participants had to maintain in memory the contents and positions of the four pictures for 4 s. In the retrieval period, a colored target appeared at one of the four previous picture positions (target picture), and the participants were allowed 5 s to correctly select the corresponding picture from four pictures presented at the bottom of display. Each participant performed 20 task trials, with a 20-s rest period between each trial. During the rest period, the participants were instructed to push a keyboard button according to a left or right arrow presented on the monitor. The arrows appeared every 0.5 s with a 1-s duration. Eye movements, brain activity, reaction time, and task response were recorded for each participant. The pictures presented in the task were randomly selected from 32 pictures for each subject. The eye tracker system was calibrated for each subject prior to beginning the task.

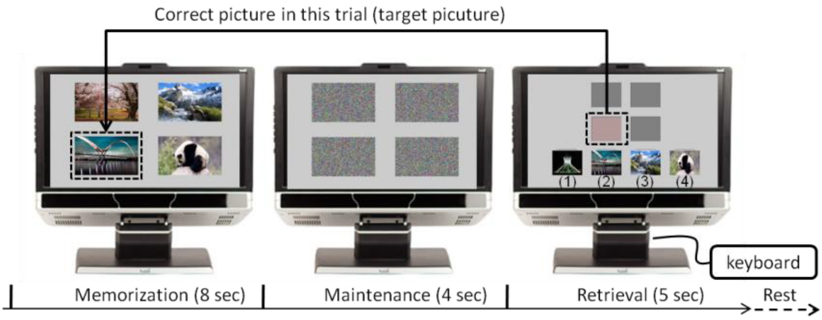

Fig. 1. Task paradigm

3 Results and Discussion

The time, duration, and locations of gaze fixations, as well as the number of fixa-tions counted (fixation count), were calculated for the target picture in the memoriza-tion period by using Tobii Studio. The fixation count was used as an index for eye movements. The WOT signals were translated into oxy- and deoxy-hemoglobin (Hb) signals by Platform for Optical Topography Analysis Tools [3]. Six channels (3 on each side) were excluded because of the noise from the analysis. We corrected the Oxy-Hb signal with a three-degree fitting, channel exception (over 0.3 mM*mm in one sampling or over 0.8 mM*mm in maximum amplitude), band pass filtering (high pass: 0.02 Hz, low pass: 0.80 Hz), and by averaging over an 18-s period that began 5 s before each task trial. We confirmed significant changes in brain activity in each participant by comparing the rest and task periods with t-tests (Fig. 2-1). The index of brain activity was determined by the average activity across the channel that showed the most significant change from the rest period.

The correct task rate was determined for each participant from the answers they provided during the task. All trials were divided into four groups on the basis of the fixation count and Hb averages. The four groups were as follows: high brain activity, high fixation number (H:brain-H:eye); high brain activity, small fixation number (H:brain-S:eye); low brain activity, large fixation number (L:brain-H:eye); and low brain activity, small number of fixation (L:brain-S:eye). Criteria for determining high or low activity or high or small numbers were based on the percentile among all trials: the upper 25% were considered high and the lower 25% were considered low or small. After the trials were categorized, we compared the correct rate among the four groups. We found that the high brain activity and the high fixation number group (H:brain-H:eye) demonstrated the highest correct rate (Fig. 2-2). This suggests that the combination of brain activity and eye movement is useful in quantifying the amount of attention devoted to memory storage, more so than eye movement or brain activity alone. Our future studies will aim to validate this combination index.

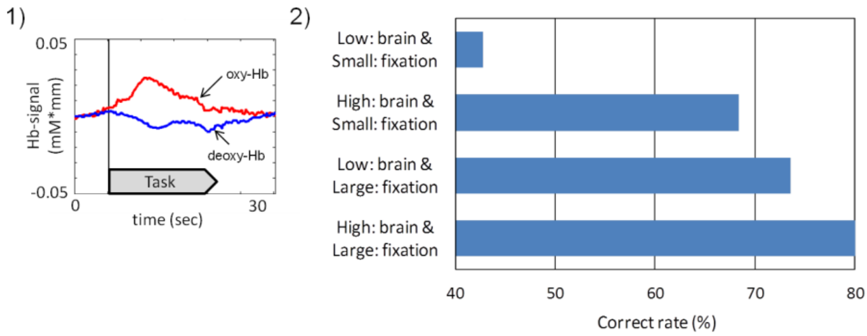

Fig. 2. Data analysis and correct rate for the four trial groups

1) Time course of Hb-signals (red:oxy-Hb, blue: deoxy-Hb).

2) Correct rate for each trial group.

4 Conclusion

We examined the relationship between brain activity and eye movements in sub-jects performing a working memory task. A high correct rate in the task was related to a combined index that revealed high brain activity and a high fixation number.

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