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4286 EVENT-RELATED POTENTIALS OF THE FRONTO-PARIETAL NETWORK FOR MULTI-TARGET SPATIAL WORKING MEMORY PROCESSING: INDEPENDENT COMPONENT ANALYSIS

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Neuroimaging studies have shown that the prefrontal cortex (PFC) and the posterior parietal cortex are activated during spatial working memory processing as well as spatial attention (Kastner and Ungerleider 2000). However, how these areas process relevant information is still unknown. Recently, Tanaka (2002) proposed that the PFC circuit can perform fundamental cognitive operations with multiple target locations. To get more insights into the processes, we studied the dynamics of the cortical network by analyzing the event-related potentials observed from human brains. Scalp electroencephalographs were recorded from five healthy, normal subjects with a 64-channel system (NeuroScan). Subjects sat in front of a computer monitor with a keyboard. They pressed keys in their right hands (all of them are right-handed). All the tasks were delayed matching-to-sample tasks. According to the numbers of samples and targets, the tasks were devided to three types: Task A: Single sample single target task, Task B: Multi-simulataneous-sample multi-target task, and Task C: Multi-sequential-sample multi-target task. The match-nonmatch comparisons of these data showed negative peaks at around 250-300 (200-350) ms. This would indicate that, in non-match conditions, the response had a larger positive component of the potential. Judging from the latency, this component corresponds to P3a. The largest negative deviation was seen in the central or centro-parietal portion. Our independent component analysis, however, revealed that the frontal cortex exhibited two P3a components (one peaked at 315 ms and the other 330 ms) for the match conditions. We did not find such components for the non-match conditions. The P3b components were observed posteriorly and were not match-nonmatch dependent. The results are argued in comparison with recent computer simulations (Miyashita et al. 2003; Tabuchi and Tanaka 2003; Tanaka 2003).

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Event-related potentials of the fronto-parietal network for multi-target spatial working memory processing: Independent component analysis

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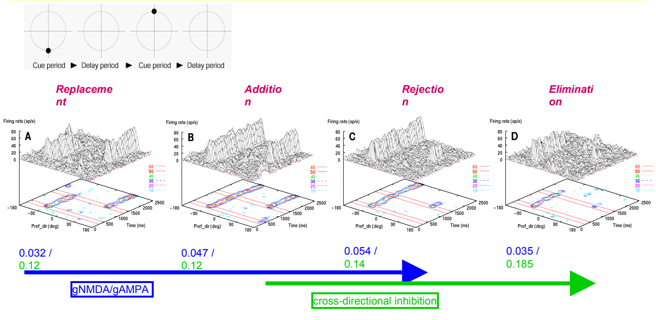
1. Introduction

Neuroimaging studies have shown that the prefrontal cortex (PFC) and the posterior parietal cortex (PPC) are activated during spatial working memory processing as well as spatial attention (refs). However, how these areas process relevant information is unknown yet. Recently, Tanaka (2002) proposed that the PFC circuit can perform fundamental cognitive operations with multiple target locations. Tanaka (2003) analysed dynamics of the PFC-PPC network via computer simulation with a model PFC-PPC network. These computational studies suggest that regulation of dopamine level in the PFC is critical for the cognitive operations and that the feedforward and feedback corticocortical connections have various roles in the processing of spatial working memory. To investigate such complicated behavior of the network, we analyzed event-related potentials (ERPs) in human during performing spatial working memory tasks.

Cognitive operations of multi-target working memory controlled by dopamine



2. Methods

2.1. Event-related potentials

Scalp electroencephalographs were recorded from five healthy, normal subjects (four men, one women, age range: 18 to 23 years) with a 64-channel system (NeuroScan). The data were sampled and digitized at a rate of 1 kHz. ERPs were obtained by averaging individual artifact-free potentials time-locked to the onset of the stimulus. The numbers of superposition are 40-100.

2.2. Behavioral tasks

Subjects sat in front of a computer monitor with a keyboard. They pressed keys in their right hands (all of them are right-handed). All the tasks were delayed matching to sample tasks, but, according to the numbers of samples and targets, the tasks were devided to three cases.

(i) Task A: Single-sample-single-target task

Subjects fixated a central small spot of light on the monitor (the fixation point). A sample was displayed during the cue period of 0.5 s. The sample was a small spot of light on the monitor, the location of the spot was chosen randomly from eight locations. A delay period of 2 s followed the cue period. After the delay period, a target was displayed for 0.5 s. The subject push the button 1 if the target was in the same location with the sample or push button 2 if not. Another delay period followed this, then another target was displayed. Each session had five trials. Each subject performed 36 sessions (or 180 responses) during 540 s.

(ii) Task B: Multi-simulataneous-sample-multi-target task

This task was essentially the same with Task A, but the numbers of samples and targets were both two. The subject push the button 1 if both targets were in the same locations with the samples or push button 2 otherwise. Each session had five trials. Each subject performed 36 sessions (or 180 responses) during 540 s.

(iii) Task C: Multi-sequential-sample-multi-target task

This task was essentially the same with Task B, but the display of samples were not simultaneous but sequential with the interval of 0.5 s. The subject push the button 1 if both targets were in the same locations with the samples or push button 2 otherwise. The length of the sessions were variable. Each subject performed 60 sessions with 406 responses during 1165 s.

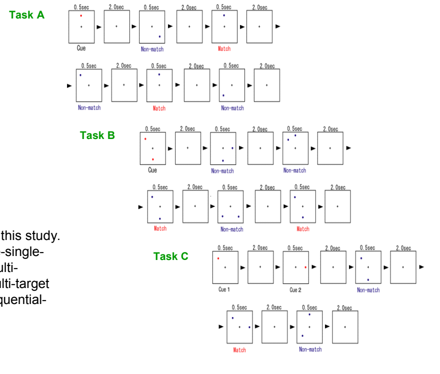


Fig. 1. Tasks employed in this study. (A) Task A: Single-sample-single-target task. (B) Task B: Multi-simulataneous-sample-multi-target task. (C) Task C: Multi-sequential-sample-multi-target task.

3. Results

3.1. Between-task comparisons

We analyzed the ERP data obtained by subtracting one of Task B from one of Task A:

(i) Sample (Task A) – Sample (Task B)

(ii) Match (Task A) – Match (Task B)

(iii) Non-match (Task A) – Non-match (Task B)

In all of these, the results show significant, single positive peaks at around 200 ms from the onset of stimuli (p = 0.0155, 0.0187, and 0.0349, respectively). Figure 2 shows the results for these cases.

Match (single target) – Match (two targets)   Non-match (single target) – Non-match (two targets)

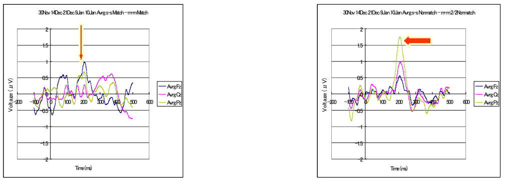
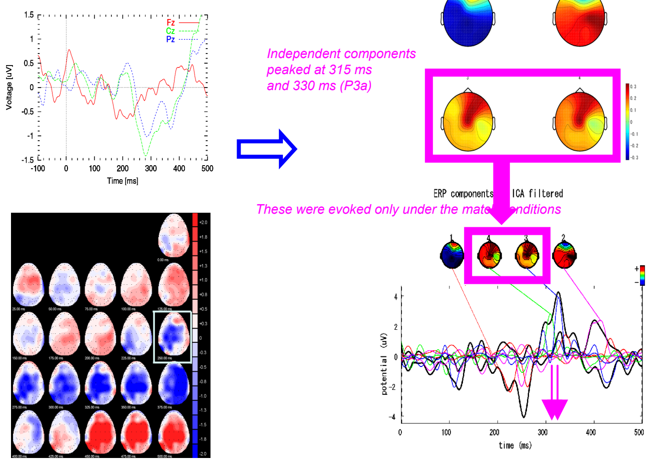


Fig. 2. Subtracted event-related potentials responding to one or two targets depending on the tasks. The potentials are locked to the time at which the stimuli were presented. (A) Match (Task A) – Match (Task B). (B) Non-match (Task A) – Non-match (Task B).

ICA (independent component analysis)

Task B: Match – Non-match



The match-nonmatch comparisons of these data showed negative peaks at around 250-300 (200-350) ms. This would indicate that, in non-match conditions, the response had a larger positive component of the potential. Judging from the latency, this component corresponds to P3a. The largest negative deviation was seen in the central or centro-parietal portion. Our independent component analysis, however, revealed that the frontal cortex exhibited two P3a components (one peaked at 315 ms and the other 330 ms) for the match conditions. We did not find such components for the non-match conditions. The P3b components were observed posteriorly and were not match-nonmatch dependent. The results are argued in comparison with recent computer simulations (Miyashita et al. 2003; Tabuchi and Tanaka 2003; Tanaka 2003).

4. Discussion

In the between-task comparisons, all cases showed significant positive peaks at around 200 ms. This means that Task B had larger negative potentials (N200) than Task A. The N200 is considered to occur as a result of higher visual processing. Because Task B has two samples and two targets, Task B would have required higher load of the processing.

Match-nonmatch comparisons showed negative peaks at around 250-300 ms. This would indicate that, in non-match conditions, the response had larger positive component (or subcomponent) of the potential. Judging from the latency, this subcomponent may correspond to P3a (Knight 1997). This subcomponent is not generated solely by the parietal cortex but more frontal portions. Actually, our ICA analysis indicates (right) prefrontal activation during 300-350 ms. This is reasonable because the PFC is thought to play central roles in higher cognitive functions, such as judgement. Recent computer simulation of the prefrontoparietal network showed similar concurrent activation of the prefrontal cortex and the posterior porietal cortex (Tanaka 2003: Neurocomputing).

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