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Stimulus context determines whether non-target stimuli are processed as task-relevant or distractor information

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Abstract

Objective: The P300 event-related brain potential (ERP) was elicited using a visual three-stimulus oddball paradigm (standard 0.70, target 0.15, non-target 0.15) to examine how target/standard stimulus context affects non-target processing.
Methods: Target/standard discrimination difficulty (easy or difficult) and non-target /target similarity (similar or dissimilar) were manipulated orthogonally. Participants ($N = 13$) were instructed to respond to each infrequent target stimulus by pressing a button.
Results: Target stimuli in all task conditions elicited P3b, which was affected only by the difficulty of target/standard discrimination. When target/standard discrimination was easy, the amplitude of non-target P3 was larger for similar than for dissimilar non-target. In contrast, when target/standard discrimination was difficult, non-target stimuli elicited P3a, the amplitude of which was larger for dissimilar than for similar non-target. Thus, the P300 component for non-target stimuli and the pattern of the effect of target similarity on each P300 component varied as a function of the target/standard stimulus context.
Conclusions: The target/standard stimulus context influences the attentional set for stimulus processing such that it determines whether non-target stimuli are processed as task-relevant or distractor information.
Significance: The present results are important for understanding the mechanism of cognitive modification in non-target processing.

Keywords: Event-related potential; Stimulus context; P3a; P3b; Non-target; Three-stimulus oddball paradigm

1. Introduction

Various events occur in the external environment and they may have significant meaning for an organism. Therefore, the appropriate evaluation of events is crucial for successful adaptation to the external environment, and this cognitive process underlies a broad range of human behavior. Furthermore, flexible cognitive modification is also important for survival in a changing environment. Actually, some studies have reported that whether a successful exclusion of irrelevant information from perception occurs (i.e., early selection) or a failure to exclude irrelevant information from perception occurs (i.e., late selection) are dynamically modified by the level of perceptual load of relevant information processing (Lavie, 1995, 2005; Lavie and Tsal, 1994). It is assumed that the context in addition to the physical attributes of events also strongly affects the response to the events. However, the mechanism of cognitive modification in the event evaluation process has not yet been elucidated because this process is complete immediately after the event is detected and interacts with various psychological factors. Event-related brain potential (ERP) is one of the most suitable measurements for investigating such a cognitive mechanism because it has notable temporal resolution and each component has been associated with specific psychological factors (e.g., Otten and Rugg, 2004).

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1.1. P3b and P3a

One of the most widely studied ERP components is P300 or P3. This component is usually obtained with the so-called "oddball paradigm", which is based on the random occurrence of infrequent stimuli that are embedded in a train of frequent standard stimuli. In a classical oddball paradigm, or "two-stimulus" oddball paradigm, a participant has to respond to each infrequent target stimulus by pressing a button or by silent counting. In ERP, target stimuli elicit "P3b", which is a large positive-going potential that has a maximum amplitude over parietal electrode sites with a peak latency of about 300–600 ms, depending on the stimulus modality and task difficulty (Katayama and Polich, 1996a; Picton, 1992). This component has provided a great deal of information about the neural activity that underlies fundamental cognitive operations; e.g., its amplitude reflects the allocation of attentional resources (Humphrey and Kramer, 1994; Kok, 1997, 2001; Wickens et al., 1983), and its peak latency reflects the stimulus classification time (Kutas et al., 1977; Magliero et al., 1984; McCarthy and Donchin, 1981).

One variant of the oddball paradigm, the "three-stimulus" oddball paradigm, presents the participant with an additional infrequent non-target stimulus that is inserted into the sequence of target and standard stimuli. When "typical" (i.e., not novel, easily recognized) non-target stimuli are presented, they also elicit a P300 component that is smaller in amplitude than the target P300, and its latencies and morphologies are similar to those of the target P300 (Katayama and Polich, 1996b, 1999; Pfefferbaum et al., 1980). In contrast, when perceptually "novel" (e.g., colorful, unrecognizable slide) non-target stimuli are presented in a series of more typical (e.g., simple figures) stimuli, they elicit a large positive component that is different from P3b. This component is called "novelty P3" or "P3a", which has a shorter latency than P3b and has a frontal/central amplitude distribution (Courchesne et al., 1975; Friedman et al., 1993; Squires et al., 1975). This component can be elicited by auditory (Squires et al., 1975), visual (Courchesne et al., 1975), and somatosensory stimuli (Yamaguchi and Knight, 1991). P3a is considered to reflect the capture and orientation of attention towards deviant distractor information, and its amplitude reflects the attentional resources that are allocated for such orientation processing (Berti et al., 2004; Escera et al., 2000; Friedman et al., 2001; Schröger and Wolff, 1998), therefore the amplitude increases as a function of stimulus deviancy (Berti et al., 2004).

1.2. Stimulus context

As mentioned above, it has been considered that stimulus novelty is a critical determinant of P3a generation. However, Katayama and Polich (1998) reported that P3a generation could be dynamically modified by the target/standard stimulus context. The difficulty of perceptual discrimination between target and standard stimulus was manipulated in an auditory three-stimulus oddball paradigm using "typical" tone stimuli. For the condition in which target/standard discrimination was easy, P300 for a deviant non-target was similar in latency and morphology to that elicited by the target, but showed an appreciably smaller amplitude. In contrast, for the condition in which target/standard discrimination was difficult, P300 for a deviant non-target had a shorter latency and larger amplitude over the frontal/central location compared to target P3b. This component was considered to be "P3a", which has been reported when "novel" non-target stimuli were used (Courchesne et al., 1975; Friedman et al., 1993). Importantly, the degree of non-target deviation from the standard was the same between the easy and difficult conditions. These results showed that the target/standard stimulus context is also a critical factor of P3a generation for non-target. Comerchero and Polich (1999) reported that the target/standard stimulus context determines P3a generation for a typical non-target in the visual modality, and Polich and Comerchero (2003) showed that a deviant typical non-target and novel non-target produced robust and highly similar P300 components when target/standard discrimination was difficult.

1.3. Present study

The above previous studies have shown that the target/standard stimulus context determines whether or not non-target stimuli elicit P3a. Thus, these findings imply that the target/standard stimulus context affects the processing of non-target. However, the underlying mechanism, in particular the interplay between non-target processing and the target/standard stimulus context, is as yet unclear because previous studies have mainly focused on the issues of stimulus context and P3a generation.

The main purpose of the present study was to clarify how stimulus context affects non-target processing. We hypothesized that the target/standard stimulus context influences the attentional set for stimulus processing such that it determines whether non-target stimuli are processed as task-relevant or distractor information. To examine this hypothesis, the difficulty of target/standard discrimination (easy or difficult) and non-target/target similarity (similar or dissimilar) were manipulated orthogonally. Target/standard discrimination difficulty is a critical determinant of the target/standard stimulus context. Non-target/target similarity could provide information about how non-target stimuli are processed. If non-target stimuli are processed as task-relevant information, they would elicit a target-like P300 and *target-similar* non-target stimuli would elicit larger amplitude than *target-dissimilar* non-target stimuli (Azizian et al., 2006; Watson et al., 2005). In contrast, if non-target stimuli are processed as distractor information, they would elicit P3a and *target-dissimilar* non-target stimuli would elicit larger amplitude than *target-similar*