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EFFECTS OF RAPID ATTETION SWITCHING ON THE N1-P2 AMPLITUDE OF THE VISUAL EVENT-RELATED POTENTIALS

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Letters, a number and a checkerboard pattern were presented using a LED matrix. One of them was designated as a target. The subject was required to count the numbers of the target in a block. EEG electrodes were placed at F3, F4, C3, C4, Cz, O1 and O2 referenced to right and left ears. Event-Related Potenitial (ERP) was obtained by averaging 40 EEG responses. Session 1 was composed of 17 blocks of 24 trials including about 8(±2) trials of the same target (short stimulus run). Session 2 was composed of two blocks of 143 trials including 41 trials of the same target (long stimulus run). In session 1 the target was alternated in every other block. The P3 amplitude was significantly larger to the target than to the nontarget in seeion 1 and 2. The vertex N1-P2 amplitude was significantly larger for the target than for the nontarget in session 1, whereas that amplitude was not different between the target and nontarget in session 2. These results were interpreted in terms of match-mismatch process between sensory inputs and short-term memory.

DESCRIPTORS: ERP, VEP, Selective attention. Short-term memory.

Introduction

When a subject is required to select targets in the sequence of large number of stimuli (targets and non-targets), it is well known that the amplitudes of vertex N1 (or N1-P2) and P3 components which are evoked by target are larger than those evoked by nontargets (Sutton, Braren, Zubin, and John, 1965: Sutton, Tueting, Zubin, & John 1967: Hillyard, Hink, Schwent & Picton 1973).

So, we might be able to say that both components are sensitive, in a similar fashion, to selective attention. But the amplitudes of N1-P2 and P3 components did not change similary depending on the experimental variables such as inter-stimulus-interval (ISI), probability of target occurrence, and task difficulty in these selective attention situations. We may deduce these two kinds of ERPs represent the different aspects of selective attention processes. For example, the enhancement of the N1 amplitude occurrs when ISI is shorter than one second. This is a marked contrast to the P3 enhancement, which occurs when ISI of any values (longer than 400msec) (Wood, Hillyard, Courchesne, &

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Galambos 1980: Schwent, Hillyard, & Galambos, 1976 a, b: Donchin, Ritter, & McCallum, 1978). Second, the enhancement of the N1 component occurred at any probabilities of the target occurrence. (Donald & Young 1980: Donald & Little 1981) The P3 enhancement, on the contrary, occurred at low probabilities of the target occurrence (Tueting, Sutton & Zubin 1970).

Hillyard and Picton (1979) have reviewed these findings and hypothesized that there are two kinds of selective attention mechanism. One based on the stimulus-dependent selection at the early stage of the information processing, named the stimulus set selective attention, which passes signals to the advanced processing stages based on simple physical cues. The other is based on the memory-dependent selection at the later stage of the information processing, named the response set selective attention. The N1 and the P3 are supposed to reflect the stimulus set and response set selective attention, respectively. Hillyard and Picton (1979) have suggested that in some dichotic listening situation requiring the target detection, these two modes of the selective attention operate in a hierarchical fashion. A human subject first selects one of two channels, and there after, select the targets among stimuli presented within the selected channel. The evidence for the sequential selection is that the enhancement of the N1 amplitude occurs not only for the target but also for the nontarget stimuli presented in the attended channel. whereas the enhancement of the P3 occurs only for the target.

In Furutsuka's study (Furutsuka 1982), the subject was required to estimate tone duration exactly and to count the numbers of tones with medium duration presented in the sequence of the three kinds of tones with long (1200msec), medium (600) and short (300) durations. His findings were (1) P3 enhancement was occurred by the offset of target tone, (2) P3 enhancement was also occurred by the offset of short duration tone (nontarget), if subjects become to be able to expect timing of tone offset of target with a preliminary practice, and (3) the vertex N1-P2 of the ERP to the tone onset, as significant cue to estimating the duration, decreased rapidly in amplitude with repetition. Whereas the N1-P2 amplitudes of tone offset, as this was the significantly task-relevant cue, progressively increased in amplitude. This third result can be interpreted as suggesting that subject makes internal working model with which he analyses the task, and then he takes more efficient strategy depending on this model. Namely, at the tone onset, he starts to estimate the duration of the tone, and to focus his attention to tone offset as more critical cue of this task. In earlier trials, subject focuses attention to several cues of task-relevant stimulus, but, with increasing practices, he makes decision to attend to fewer more critical cues for the economies of attentional capacities.

These results may mean that two modes of attention sets do not operate in a hierarchical fashion. Rather, I think that both sets operate concurrently. And with increasing practice, subject shifts the shares of his processing capacities from stimulus set to response set. Broadbent (1979), who was the first to differentiate the selective attention into the stimulus set and response set attention, has suggested this shift.

Inability of the vertex N1-P2 to discriminate between the within-channel target and nontarget stimuli has been reported by some studies on the ERP correlates of selective attention (Hillyard, Hink, Schwent, & Picton, 1973; Schwent, Hillyard, & Galambos, 1976 a, b). In these studies the same target stimuli are presented with low probability among several hundreds stimuli. A large number of the target and nontarget trials may allow the subject to change allocation of his processing capacity. His processing may be in the stimulus set mode at the early part of the long stimulus run. However, after the practices of stimulus discrimination his stimulus set mode attention may be automatically operated with least allocation of the processing capacity at the later part of the stimulus run. On the average across the long stimulus run his attentiveness may be less in the stimulus set mode but more in the response set mode. This may reduce the ability of the N1-P2 to discriminate between the within-channel target and nontarget stimuli.

The stimulus set selective attention may be more active in the short stimulus run. If the subject detects the target among the stimuli in the active stimulus set mode, the vertex N1-P2 may discriminate the target from the nontarget stimuli presented in the same channel. Using tone pips presented in a series of short runs (25 tones per run), Wilkison and Lee (1972) have shown that the vertex N1-P2 amplitude is larger for the counted tones than for the ignored ones within the same channel. The effects of run length on the N1-P2 responsiveness to the within-channel target and nontarget stimuli must be analyzed further.

In the present experiment, visual pattern stimuli were used to analyze the run length effect on the N1-P2 responsiveness. Two kinds of the target stimuli were used each in alternate stimulus blocks of 24 trials including 8(+2) trials of the same target. Because of short stimulus run for each target, the subject may allocate his processing capacity more to the stimulus set selective attention. Two long runs of 143 trials each including 41 trials of the same target were also run as the control.

METHOD

Subjects

Eight students of Hokkaido University (5 males and 3 females; age 20-23) served as the paid subjects. All had the normal or corrected normal visions. They had no EEG experience prior to this experiment. The subject seated in the reclining chair in the soundproofed (−60 dB) electrically schielded room. The room was dimly lit, so he could see around a stimulus field.

Stimuli

The stimuli were presented by the visual display which was made up with the matrix of the Light Emitting Diodes (LED). It was at the center of black board (70×70 cm) with distance of 90 cm from the subject's eyes. The display was made of the 9×9 matrix of red square LEDs (side length of unit, 4 mm). Each LED was controlled by the PS-80 (TEAC) micro computer. All LEDs of the matrix were always lit except one LED for a fixation point. The stimulus, for example alphabet " H ", was created by offset of some LEDs (see Fig. 1). The fixation point was one LED at the raw 2 column 5. this LED was off during the inter-stimulus interval (ISI). Stimuli were alphabet " M ", checker board pattern " checker " and the Arabic numeral " 2 " in the first session and " J ", " F " and " H " in the second session (see Fig. 1). Their duration was 495 msec. The ISI were randomized between 0.9 and 1.7 sec (mean=1.3 sec). The probability of occurrence of three stimuli was same(1/3).

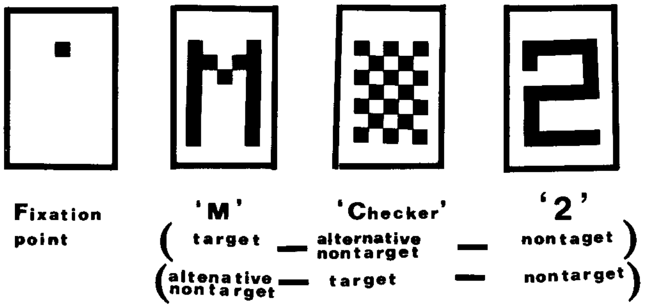

FIGURE 1 The visual display constructed by the matrix of the LEDs used. the stimuli in the first session were presented in a random order with the duration of 495 msec. The probability of occurence of each stimuli was 1/3. The Inter-Stimulus-Interval (ISI) was randomized from 0.9 to 1. 7 sec (mean of 1.3).

Procedare

Each subject participated in the two sessions for about one hour. The first session was divided into the 17 blocks of 24 trials (the rapid alternate session). At each block, either letter " M " or the checkerboard was assigned as the target alternately across blocks. The number " 2 " was the nontarget in all blocks. The subject was asked to count the numbers of the target occurrence in mind. After the end of the block, he was asked to report the numbers. Namely, the subject was instructed at the start of the first session: " Three kinds of stimuli will be presented. You must count the " M " (or " checker-board ") and after the end of this block, please report the number of the occurrence." And at the second block of 24 trials. he was instructed " Next, you must count the occurrence of the " checker " in spite of the " M " and at the end of this block, tell me the number of occurrence." At the third block, target changed alternately to alphabet " M ".

The second session was composed of two blocks of 143 trials. In the first block of the second session, the alphabet " F " was the target, and the " H " and the " J " were the nontargets. In the second block the alphabet " H " was the target, the " F " and the " J " were were nontarget.

Recording of EEG and ERP analysis

The EEG was amplified by the SAN-EI DC1117. Time constant was 3 sec and low pass filter was set at 100 Hz(−3 dB). The Ag/AgCl electrodes (Beckman miniature electrode) were attached to the F3, F4, C3, C4, Cz, O1 and O2 in the international 10-20 system. Each electrode located at the left hemisphere was referred to the left ear lobe (A1). And each located at the right hemisphere including Cz was referred to the right ear lobe(A2). Eye movements also monitored. The electrode attached on the chin was connected to the ground. The amplified EEGs were stored to the FM data recorder (TEAC SR-70 DC-350 Hz) and analyzed by the minicomputer (HP 1000 system). The analysis time for ERP was 500 msec from stimulus onset with 256 point/sec. The EEG contaminated by the eye movements or other artifacts was rejected from analysis. The number of averaging was 40.

As the targets were changed alternately across blocks, the EEG responses were sorted into two groups depending on what was the target. One was the 〈target M〉 group and the other was 〈target checkerboard〉 group. In the 〈target M〉 group. the ERPs of three kinds of stimulus (target " M ", alternate nontarget " checker " and always nontarget " 2 ") were analyzed. And in the 〈target checkerboard〉 group, the ERPs for target " checker," the alternate nontarget stimuli " M " and the always nontarget " 2 " were analyzed. The identifications of N1, P2 and P3 components were made with the following procedures. The N1 was the negative wave peaking between 100-200 msec. The P2 was the most positive peak between 150 msec and 250 msec. The P3 was the most positive peak between P2 latency and 500 msec. The amplidudes of N1-P2 were the distance between these peaks. The P3 amplitude was the distance between a base line (average amplitude during 100 msec interval from the stimulus onset) and P3 peak.

RESULTS

The grand averaged Event-Related Potentials (ERPs) obtained from the vertex had the sequences of peaks, which contained N1(latency was 127 msec), P2(236 msec) and P3(405 msec). The grand averaged ERPs from anterior scalp(F3, F4, C3 and Cz) had the similar morphologies of those from vertex. While the grand averaged ERPs from the posterior locations (O1 and O2) were not similar to those from the anterior scalp. These ERPs were characterized by the sequences of peaks of P1(118 msec), N1(168 msec), P2(260 msec) and P3(388 msec).

There were no significant asymmetries of the morphologies of ERPs between the right and the left hemisphere and the morphologies of the grand average ERPs obtained among frontal, central and occipital locations. So the statistical analysis were restricted to the vertex and the left occipital potentials.

The effects of the rapid change of the target (the first session)

The grand averaged ERPs across subjects for three stimuli at the " count ' M ' " blocks are drawn in the Fig. 2. The grand averaged ERPs of three stimuli at the " count ' checker ' " block were drawn in the Fig. 3. The N1-P2 amplitudes for the target ' M ', the alternate nontarget ' checker ' and always nontarget " 2 " at the vertex were significantly different (for the target " M " 11.3±2.1uV ; alternate nontarget " checker " 9.5±0.6uV ; always nontarget 8.2±1.8uV ; $F(2, 6)=5.2$ $p<0.05$). The P3 amplitudes at the vertex were also significantly different (for the target " M " 12.6±1.8uV ; alternate nontarget " checker " 8.6±1.3uV ; always nontarget " 2 " 7.1±1.8uV ; $F(2, 6)=17.2$ $p<0.001$). These tendencies that the N1-P2 amplitude was the largest for the target, intermediate for the alternate nontarget and the smallest for the always nontarget were seen at the all electrode locations.

At the " count 'checker' " block, the N1-P2 amplitude was the largest for the target " checker " (11.3±2.5uV), intermediate for the alternate nontarget " M " (9.4±2.0uV) and the smallest for the always nontarget " 2 " (8.7±2.5uV). The amplitude differences across stimulus condition were not significant ($F(2, 6)=3.84$ n. s.). The P3 amplitude had a significant difference across target and nontarget condition in the count

" checker " block (for the target " cheker " 13.8±3.9uV ; alternate nontarget " M " 7.2±1.5uV ; always nontarget " 2 " 8.4±1.8uV ; F(2, 6)=10.3 p<0.001). Only the enhancement of the P3 amplitude for the target was significant. There were no difference between alternate and always nontarget stimuli.

The N1-P2 amplitudes at O1 location did not show the attention effects, but showed the effects of physical difference of three stimuli (target " M " block : for the target " M " 11.1±2.0uV ; numeral " 2 " 9.9±2.5uV ; checkerboard 4.3±2.6uV ; F(2, 6)=36.84, p<0.001) (target ' checker ' block : alphabet " M " 7.5±3.0uV ; numeral " 2 " 8.7±2.3uV ; checkerboard 4.7±3.0uV ; F(2, 6)=17.25, p<0.001). The N1-P2 amplitude of the stimulus ' checker ' was smallest in spite of target change across blocks.

The effects of the slow change of the target (the second session)

Fig. 4 shows the grand averaged ERPs for the target and two kinds of nontarget stimuli in the first (count " F "). we could identify the N1(latency in 137.7 msec), P2

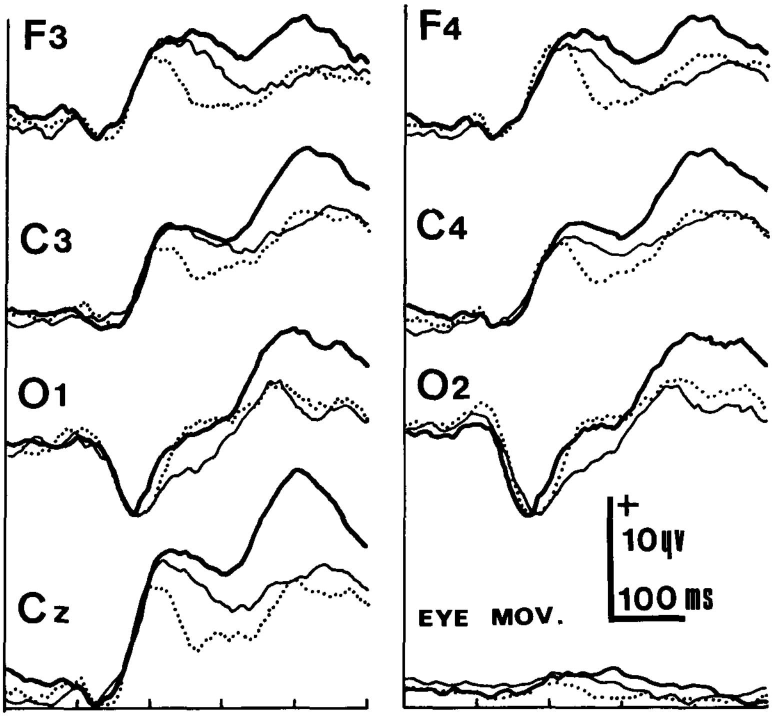

FIGURE 2 Grand Averaged Evoked Potentials(GAEP) over 7 subjects at the " count M " blocks in the first session. Left frontal(F3), central(C3), occipital(O1) and vertex(Cz) GAEPs are shown in the left column, right frontal(F4), central(C4) occipital(O2) GAEPs and EOG in the right column. The BAEP for the target ' M ' drawn with thick solid line, the GAEP for the alternate nontarget " checker " with thin solid lines, the BAEP for the always nontarget ' 2 ' with dotted line, were superimposed at each electrode sites. The enhancement of the N1-P2 amplitude for the target and for the alternate nontarget occurred at F3, C3 and Cz. The enhancement of the P3 amplitude occurred only for the target at all electrode locations.

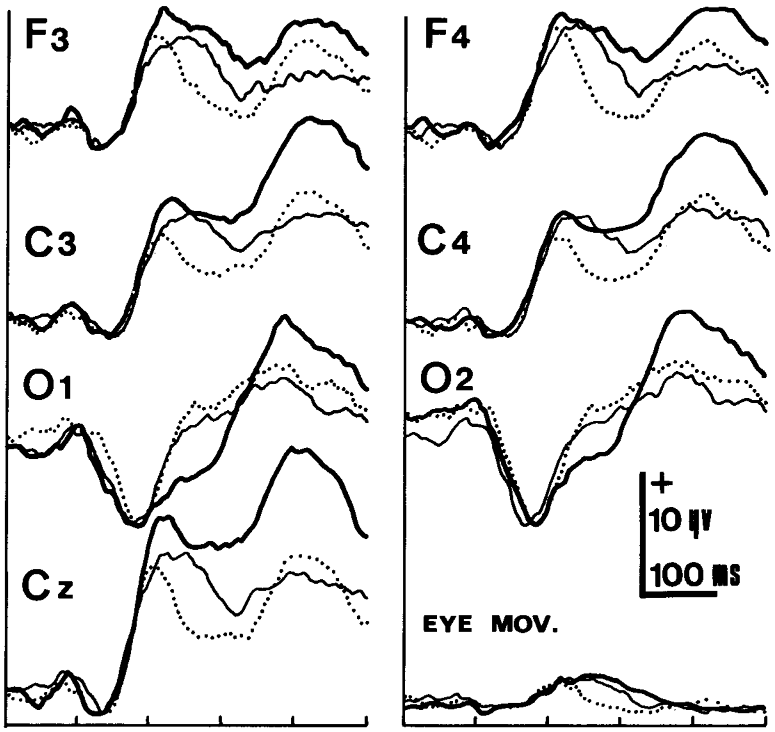

FIGURE 3 The GAEPs in the "count (checker)" block in the first session. The GAEP for the target 'checker' was drawed by the thick solid line. The GAEP for the alternate nontarget 'M' was thin solid lines. and the GAEP for the always nontarget '2' with dotted line. The enhancement of the N1-P2 amplitude for the target occurred at C3, C4 and F4. Other details are the same as those in Fig. 2.

(231.7 msec) and P3(431.9 msec). The P3 component for the target from the vertex had larger amplitude than the P3 for the nontargets (count "F" blocks: for the target "F" 13.9±2.1uV; nontarget "J" 10.1±1.8uV; nontarget "H" 7.8±1.9uV; F(2, 6)=12.61 p<.001:: count "H" blocks; for the tareget "H" 11.8±2.0uV; nontarget "J" 5.1±1.6uV; nontarget "F" 5.1±1.8uV; F(2, 6)=13.2 p<.001). But the N1-P2 amplitudes for the three kinds of stimuli from the vertex were not different from each other (count "F" blocks: for the target "F" 10.8±2.3uV; nontarget "J" 10.1±2.3uV; nontarget "H" 7.8±2.4uV; n. s. :: count "H" blocks:: for the target "H" 8.1±2.2uV; nontarget "J" 9.8±1.6uV; nontarget "F" 9.1±1.8uV; n. s.).

DISCUSSION

In session 1 (short stimulus run) and in sesion 2 (long stimulus run), the P3 enhancement was observed only for the target. But the N1-P2 behaviors in session 1 was different from those in session 2. The N1-P2 in session 1 was the largest in amplitude for the target, intermediate for the alternate nontarget, and the smallest for the always nontarget. There were no amplitude differences between the N1-P2 components to these stimuli in session 2. The finding of the P3 and N1-P2 behaviors in session 2 seem to confirm the results in some studies of the ERP correlates of selective attention (Hillyard

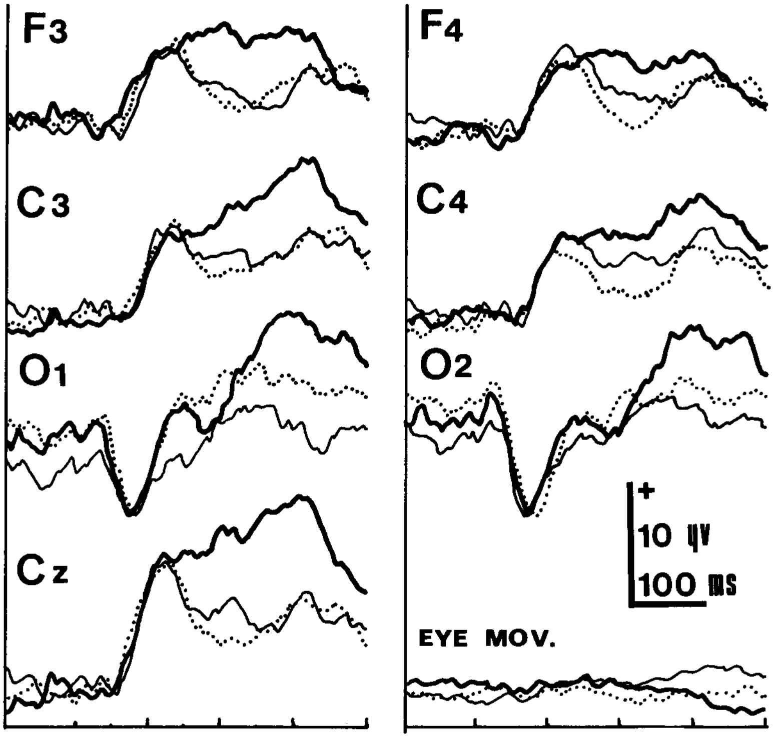

FIGURE 4 The GAEPs at "count (H)" block in the second The GAEPs for the target 'H' were drawn with the thick solid line, the GAEPs for the nontargets 'F' and 'J' were drawn with the thin solid line and the dotted line. No enhancement of the N1-P2 amplitude for the target occurred. The enhancement of the P3 amplitude for the target occurred.

et al., 1973; Schwent et al., 1976a, b) demonstrating that the P3 can discriminate, while the N1-P2 can not do, between the target and nontarget stimuli, when they were presented with bong ISI.

Wilkinson and Lee (1972) have shown that the vertex N1-P2 enhancement can be observed for the counted tones, but not for the ignored ones. The N1-P2 behavior in session 1 in the present study confirmed their data and further demonstrated that the N1-P2 amplitude can discriminate the present target and the ex-and post target. These results confirmed the hypothesis that the vertex N1-P2 can discriminate between the target and nontarget stimuli only when the stimulus rus is short.

Printz (1977) has proposed the importance of memory representations in the visual search. Target detection is the comparison of stimulus input with memory representations of the target. If the numbers of the targets to be detected are small, the search speed is not reduced with practices. If these numbers are large, however, the search speed is reduced drasitically with practices (Neisser, Novic, & Lazer, 1963). Schneider and Shiffrin (1977) have shown that the practice does not reduce the search speed if the targets are changed across the trials and mixed with distractors. Visual search for the target may be not simple match-mismatch process between sensory inputs and solid target memory such as template. As has been proposed by Naatanen (1982) the target selection may be selective rehearsal. The subject must maintain the attentional trace in his short-term memory as a vivid mental image through the rehearsal using external stimuli corresponding to the attentional trace. If the stimulus run is short and the target is alternated in every other run, maintaining momory representation of the target in the short-term memory requires focal attention to the stimulus input (Neisser, 1967). Practices are not effective to reduce attention allocation to the stimulus set attention mode.

Boddy (1981) required the subject to make a judgement of positive or negative instance between words and a previously presented category. He has demonstrated that the positive instance can produce larger amplitude of the vertex and parietal N1-P2 than the negative instance. The vertex N1-P2 behavior in session 1 observed in the present experiment can be interpreted as showing the N1-P2 reflection of within-category structure of the target memory (the present and the ex-and post-targets).

Boddy's data showed complex effects of the narrow and wide categories on the separate N1 and P2 amplitudes. Any proposals on the relationship between the memory representation and the vertex N1-P2 must be tentative. However, the findings in the present study seem to support the hypothesis that the N1-P2 can reflect maintaining process of the target memory trace in the short-term working memory. The N1-P2 ceases this reflecting, after the working memory is consolidated into the long-term memory.

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