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# The Effects of Selective Attention on ERPs Elicited by Visual & Auditory Deviant Stimuli

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**Abstract** The effects of deviant visual and auditory stimuli on event-related potentials were investigated in an intermodal oddball task. Tones of different pitch were used as auditory stimuli (standard: 1 000 Hz,85 %, deviant 800 Hz. 15 %) and various single Chinese words and simple geometric figures were used as visual stimuli. Auditory and visual stimuli were presented sequentially to subjects at randomized ISI of 700～1 300 ms. The subjects were instructed to attend visual channel and ignore the auditory in one block and to attend auditory and ignore visual in the other with key-responses to the current attended stimuli. Results showed the deviant auditory stimuli elicited similar mismatch negativity (MMN) in both attended and unattended conditions. MMN's independence of attention in auditory modality may reflect the automatic processing of auditory sensory inputs. In the visual modality, the deviant stimuli elicited no MMN or MMN-like component in both conditions because of the parallel processing system of visual modality and its difficulty of establishing the memory trace. The enhanced P300 elicited by the auditory and visual deviant stimuli in active condition may reflect the representation updating of work memory. The results were consistent with Naatanen's observation on MMN.

**Key words** Oddball paradigm; ERPs; MMN; P300; N2; P200; N2b; P3a

## 0 Introduction

The mismatch negativity (MMN) component was first isolated from N2 by Naatanen and his co-workers in 1978[1] by using the oddball paradigm under passive and active conditions which usually occurs at a latency of 100～200 ms from stimulus onset. The MMN can be measured from a difference wave by subtracting the ERPs to standard stimulus from the ERPs to deviant stimulus, and it can be similarly elicited by the deviant auditory stimuli in both attended and unattended conditions. Naatanen interpreted the MMN as a response to the relation between consecutive

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stimuli, and as reflecting automatic processing of sensory stimulus features because of its independence of attention. In active condition, the deviant stimuli usually elicit a wave complex called "N2-P3a"[2]. This N2 is probably composed of MMN and a further negative component called N2b. The N2b usually overlaps the later part of mismatch negativity. The N2(N2b) is considered to be a correlate of stimulus categorization[3] and N2b and P3a might be closely related to the orienting response[4]. In the visual modality, Naatanen stated that no MMN would occur due to the difference between two modalities. It might be related to the chiefly sequential nature of auditory processing compared to the visual sense, which can be characterized as a parallel-processing system[5].

The present paper examines the ERPs elicited by visual deviant stimuli and the ERPs by deviant pitch with an intermodal oddball paradigm. Because of the highly focused attentional state produced, the experiment provided a test of Naatanen's proposal that the auditory MMN is independent of attention and it questioned the existence of the MMN-like in visual modality. In the experiment, ERPs to deviant pitch were elicited in both active and passive conditions. As reviewed by Naatanen[5], the N1 component appears to be a response to individual stimuli and the MMN is a response to the relation between consecutive stimuli. We proposed that there was no difference in N1 elicited by the deviant pitch between active and passive condition. In both modalities, we also proposed a larger P300 to visual or auditory deviant stimulus in active conditions.

## 1 Methods

Eleven university students (aged 18～26, all male and right-handed with normal hearing and corrected or normal vision) were instructed to key-respond to an intermodal oddball task. At last, four subjects were rejected because of too many EEG/EOG artifacts and response failure.

The auditory stimuli consist of a train of tone pips (standard: 1 000 Hz, 55 db, 20 ms, 85 %; deviant: 800 Hz, 55 db, 20 ms, 15 %) presented to the two ears at a random ISI of 700～1 300 ms. Eighteen simple geometric figures such as square, triangle and 40 simple single Chinese words (all in same size of 2 cm ×2 cm, yellow in black background) were randomly presented to the monitor at random ISI of 700～1 300 ms. The distance between subjects and the monitor is 2.0 m.

In one block, subjects were instructed to attend visual stimulus, ignore the auditory channel and comfortably touch different sensitive buttons to response to different visual stimuli (standard and deviant, we call them frequent and infrequent stimuli) with different hands. In the other block, subjects attended to auditory stimulus with correspondent key-responses and ignored all the visual stimuli while their eyes still fixed on the monitor all the time. The experiment epoch is 700 ms and prestimulus baseline is 50 ms. To avoid the artifacts from the key-response, we used two indicators in auditory (a click, 100 μs, 18 db) and visual (a dot, 0.13 cm ×0.13 cm) modalities. The subjects were instructed not to touch the button until the indicator randomly presented after the recording epoch. Thus, the subjects couldn't predict when the indicator would be presented,

they must keep high attention on the current attended channels to get correct response. Before each run, the subjects practiced to key-respond correctly up to 95 % within 30 s.

Brain electrical activity was recorded using Ag/AgCl electrodes placed at 6 scalp sites (Fz, Cz, Pz, Oz, P3, P4) of the international 10～20 system, all referred to both mastoids. The EEG was amplified with a band pass of 0.1～100 Hz. ERPs were averaged offline. Electro-Ocular Activity (EOG) was also recorded from the left of the left eye to enable artifact rejection of trials with blinks and other eye movements.

Averaged ERPs were obtained to auditory and visual stimuli when attended and unattended. Mean amplitudes of ERP waveforms, relative to the baseline were measured across windows-visual: V1 (80～160 ms), V2 (160～280 ms), V3 (280～380 ms) and V4 (380～600 ms); auditory: A1 (60～130 ms), A2 (130～210 ms), A3 (210～280 ms), A4 (280～400 ms). Latencies and amplitudes of MMN to deviant stimuli were measured from difference waves by subtracting ERPs to standard from ERPs to deviant in each conditions in two modalities. These ERPs data were entered into separate repeated-measure analyses of variance (ANOVA).

## 2　Results

### 2.1　ERPs for Auditory Stimuli in Attend and Ignore Conditions

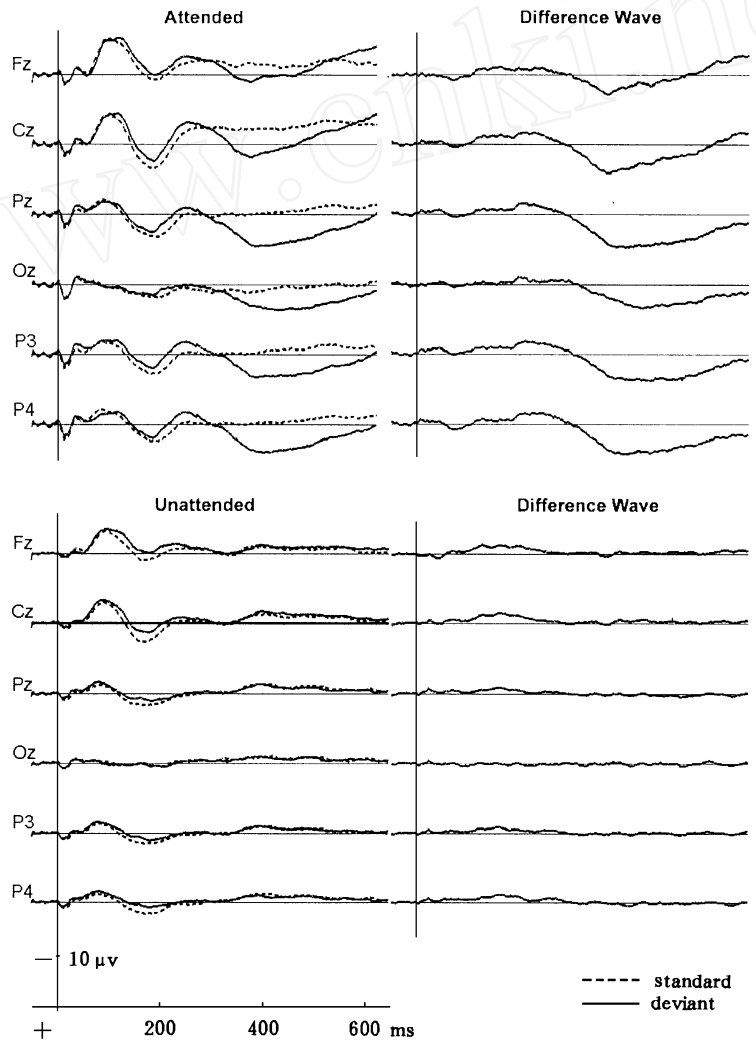
Figure 1 shows the ERPs elicited at Fz, Cz, Pz, Oz, P3 and P4 by the deviant tones when they were attended or unattended, superimposed on the ERPs to the corresponding standard tones.

The comparison between the ERPs elicited by the deviant versus standard tones can be seen more clearly in the difference waves. In the upper part of Figure 1, in the range of window A1, the deviant elicited a negativity larger than the standard at P3 ($F(1,6) = 8.607$, $P < 0.05$). In the window A3, the deviant elicited a larger negativity at P4 ($F(1,6) = 7.335$, $P < 0.05$). In the range of A4, the deviant elicited a significantly larger positive at all sites ($F(1,6) = 6.22$ for Fz, 9.965 for Cz, 14.891 for Pz, 16.114 for Oz, 10.974 for P3 and 10.017 for P4, $P < 0.05$). In the lower part of the figure, in the unattended conditions, the deviant elicited no significant components in windows from A1 to A4. For both attended and unattended tones in different blocks, a negative difference was evident in the deviant ERPs relative to the standard ERPs. The negative differences started from 100 ms and lasted to 280 ms at Fz (mean amplitude [deviant/standard]: - 2.59 μv/ - 2.33 μv), Cz (- 3.04 μv/ - 2.41 μv), Pz (- 2.34 μv/ - 1.74 μv), Oz (- 1.60 μv/ - 1.00 μv), P3 (- 2.196 μv/ - 1.68 μv) and P4 (- 2.51 μv/ - 1.84 μv). Their mean amplitudes were no significant difference in unattended conditions and in the attended conditions at all sites. The different positives in the attended conditions in window A4 were significantly larger than in the unattended conditions (mean amplitudes, $F(1,6) = 12.46$, 13.49, 18.46, 11.88, 15.46 and 10.45, $P < 0.05$). There was also no difference of the deviant N1 components between two modalities.

### 2.2　ERPs for Visual Stimuli in Attend and Ignore Conditions

Figure 2 shows the grand ($N = 7$) average ERPs for visual standard (85 %) and deviant

(15 %) stimuli. In the upper part of Figure 2, in the attended conditions, the deviant visual stimuli elicited larger positives in window V2 and V4. The peak amplitude of the positive in V2 by the deviant was dominant in all sites except Oz( $F(1,6) = 80.732$ for Fz, 43.69 for Cz, 8.395 for Pz, 37.314 for P3 and 14.166 for P4, $P < 0.01$). In window V4, the deviant elicited significant larger peak amplitudes than the standard did at all sites ( $F(1,6) = 17.183$ for Fz, 18.90 for Cz,

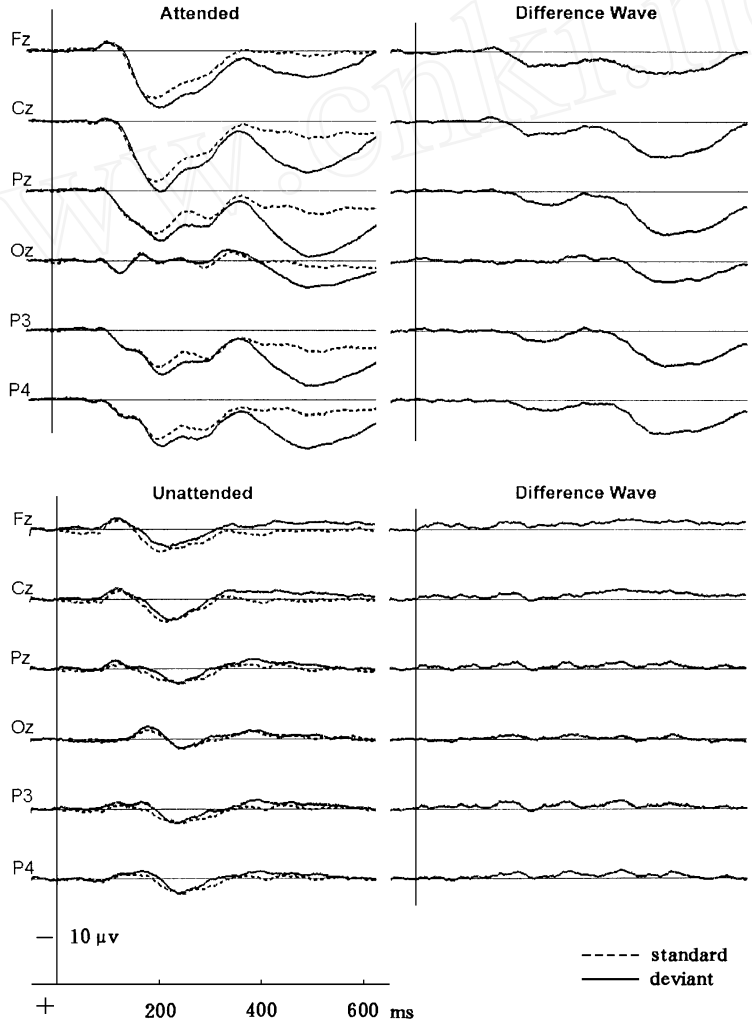



ERPs difference waves (ERPs to deviant-ERPs to standard) in attended and unattended conditions at six scalp sites (Fz, Cz, Pz, Oz, P3, P4)

**Fig. 1 The grand (N = 7) average ERPs for auditory standard (85 %) and deviant (15 %) pitch**

40.085 for Pz, 20.551 for Oz, 29.347 for P3 and 29.397 for P4, $P < 0.001$). From the lower part of the figure, in the unattended conditions, there was a significance in window V1 at P3, P4 ( $F(1,6) = 7.465, 8.634$, $P < 0.05$), V2 at Fz ( $F(1,6) = 12.58$, $P < 0.01$) Oz, V4 at P3

($F(1,6) = 8.828$, $P < 0.05$). In the right part of the figure, the deviant visual stimuli elicited a significant different positives in the range of 360～600 ms when they were attended than that when they were ignored ($F(1,6) = 29.21$ for Fz, 31.979 for Cz, 51.644 for Pz, 22.568 for Oz, 50.306 for P3 and 63.089 for P4, $P < 0.002$). There were no significant differences in window V1 and V3 in attended and ignored condition.




ERPs difference waves (deviant-standard) in attended and unattended conditions at six scalp sites (Fz, Cz, Pz, Oz, P3, P4)

**Fig. 2　The grand (N = 7) average ERPs for visual standard (85 %) and deviant (15 %) stimuli**

## 3　Discussions

In the present experiment, the attended deviant tones elicited a negative difference wave which started at 100 ms and lasted to 280 ms with its peak amplitude (- 3.04 μv at Cz) at the peak latency of 160 ms and followed by a positive component at 330 ms. The deviance negativity

could be identified as the typical mismatch negativity that overlapped the N2b component and followed by a P3a component due to the higher task difficulties in active condition. In the passive condition, we also distinguished a deviance negativity at the latency range of 100 ms to 250 ms (mean amplitude = -2.41 μv at 168 ms at Cz) without a following of P3a or N2b components. The onset, peak latencies, wave shape and distribution of the waves were similar in both attended and unattended conditions if subtracting the overlapping N2b from the attended deviance negativity in attend condition. As described in the methods, both the auditory and visual stimuli repeated to present in the exchanged position (condition) of attention, and the tasks for subjects were highly focused with key-responses with no time for the subject to switch attention between two modalities. It could not be explained as controlled processing in unattended condition because of the highly focused primary visual tasks. The similarity of unattended MMN and attended MMN could reflect its independence of attention and could be interpreted as automatic processing of auditory sensory inputs. Due to the fact that the intensities of the tones in different conditions were both the same 55 db, the similar N1 component elicited by the auditory deviant in attended and ignored conditions may reflectits correlation with physical features of individual stimulus but not the relation between stimuli.

In the visual ignore condition, however, the visual deviant elicited no mismatch negativity-like components in the corresponding latency range in comparison with the standard ERPs at all sites. In active condition, MMN is always overlapped with a N2b component in auditory modality according to Naatanen's interpretation[5]. From the upper of the figure 2, there is no N2b component or an enhanced N2 component within the corresponding latency. We can also conclude no MMN component occurred in the active condition in visual modality. Naatanen claimed that no MMN could occur in visual modality. He accounted the difference between two modalities to the different processing nature of visual and auditory sensory that there exists a parallel processing system in visual modality and a sequential processing system in auditory. And the duration of auditory sensory memory is several seconds, whereas the duration of visual iconic memory is less than half a second or may not exist. Naatanen considered sensory memory as the information basis of MMN[5]. In this experiment, the difference between the standard and deviant visual stimuli is the meaning of the word that could be explicitly expressed as the familiar or regular structure of the words or other physical features. It is difficult to produce an invariable iconic memory due to the sequentially presentation of repeated and varied words and figures. So it is impossible to establish a memory trace[5] that could be reflected by MMN which could reflect the automatic processing of sensory stimulus as in auditory modality. Due to the variance of the visual stimuli, the N1 amplitude is much smaller in both conditions.

In the attended condition, both visual and auditory deviant stimuli which elicited larger P300 than that by the standards, especially in the visual modality. That the P300 amplitude to targets is attenuated with increased target probability is studied in selective dichotic-listening[6]. P300 latency and amplitude for targets might reflect the further processing of to be attended stimuli[5].

The deviant stimuli elicit P300 when the stimulus sequence is to be attended but no P300 or smaller when the stimulus sequence is to be unattended[7]. Donchin[8] proposed a hypothesis of context updating to interpret the means of P300 may reflect the representation updating of work memory. In the present experiment, the visual sequence consists of various Chinese words and simple geometric figures. The subjects responded to the different physical features of words and figures, their different properties of structure, but also the categorization of stimuli, that is, the difference between serial meaningful words and meaningless figures. It couldn't be explained only by the probability of the stimulus because too many words and figures occurred in the sequence and to each word and figure that each probability was rather low. The context updating theory may explain the enhanced P300 in this experiment. Thus the representation updating of work memory may describe the enhanced P300 by the change of the deviant figures in the sequence of the Chines words.

In summary, in the intermodal oddball task, the auditory deviant stimuli which elicited similar MMN in both the attended and unattended conditions may consist with Naatanen's conclusion that MMN's independence of attention reflects automatic processing of sensory stimulus. The attended auditory MMN overlapped the N2b and followed by a P3a component in active condition that might be related to activation brain events and the orienting response[3]. In the visual modality, a sequence of various single Chinese words and simple geometric figures were used that appeared the deviant visual stimuli elicited no MMN-like components in both attended and unattended conditions. The visual deviant stimuli elicited a larger P300 may reflect the inner categorization of visual stimuli and may be interpreted by the context updating theory proposed by Donchin[8].

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# 视、听偏差刺激选择性注意的 ERPs 研究

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**摘 要** 本实验采用了视听双通道伪同时呈现的 oddball 模式,以汉字和简单几何图形为视觉刺激,1 000 Hz 和 800 Hz 的纯音为听觉刺激,使用注意通道(注意和非注意条件)×刺激概率(偏差刺激概率均为 15 %,标准刺激的概率均为 85 %)的 2×2 因素设计,来研究视觉和听觉偏差刺激在注意和非注意条件下诱发的事件相关电位(ERPs)。实验中视觉和听觉刺激随机序列地呈现给被试(刺激间隔 ISI 为 700～1 300 ms),被试被要求注意某一通道如视觉通道,而相应地忽视另一通道即听觉通道,以左右手触键反应,如左手反应视觉偏差刺激,右手反应视觉标准刺激。结果表明,听觉偏差刺激在注意和非注意条件下均诱发了类似的不匹配负波(MMN);而视觉偏差刺激在注意和非注意条件下没有诱发 MMN 或类似 MMN 的成分,这是因为视觉系统的平行加工特性和难以对视觉影像产生记忆痕迹。听觉偏差刺激在注意条件下重迭了 N2b 成分并跟随了 P3a 成分,这种重迭和跟随反映了选择注意中的定向反应。注意条件下听觉和视觉的偏差刺激诱发了较大波幅的 P300 成分,反映了工作记忆中的表象更新。本实验的结果支持 Naatanen 对 MMN 所做的观察,听觉偏差刺激所诱发的 MMN 与注意条件的无关性反映了听觉通道中感觉刺激特征的自动化加工。

**关键词** Oddball 模式; ERPs; MMN; P300; N2; P200; N2b; P3a
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