NOTES

Brain dynamic mechanisms on the visual attention scale with Chinese characters cues

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Abstract **The temporal dynamics in brain evoked by the scale of visual attention with the cues of Chinese characters were studied by recording event-related potentials (ERPs). With the fixed orientation of visual attention, 14 healthy young participants performed a search task in which the search array was preceded by Chinese characters cues, "大, 中, 小" (large, medium, small). 128 channels scalp ERPs were recorded to study the role of visual attention scale played in the visual spatial attention. The results showed that there was no significant difference in the ERP components evoked by the three Chinese characters cues except the inferoposterior N2 latency. The targets evoked P2, N2 amplitudes and latency have significant differences with the different cues of large, middle and small, while P1 and N1 components had no significant difference. The results suggested that the processing of scale of visual attention was mainly concerned with P2, N2 components, while the P1, N1 components were mainly related with the processing of visual orientation information.**

Keywords: event-related potential, visual spatial attention, scale, cues of Chinese characters.

In the process of correct cognition of objective world, the information from the outside and the inmost world must be selected by human brain, and be processed in different levels. Furthermore, it influences human's perception and behavior. It is the attention mechanism of brain's advanced function that plays the role of selection. As an important part of it, visual attention is set emphasis constantly in the field of psychological study. This selective function of attention could be conducted from different factors such as location scale, feature of the subject, criteria of discrimination, etc. The previous study on visual attention was mainly started from the aspect of spatial location, i.e. where the target stimuli appear, while it was soldom related to the attention scale. ERP is an effective method to study the question of attention, which can concisely reflect the dynamic mechanisms of information processing in brains[1]. This experiment tried to study the unique mechanism of visual information processing in the different attention scales by this method.

From the experimental model, the cue paradigm is the most frequently used paradigm in the ERP study on the visual attention location, i.e. cues information is presented before target stimuli appear[1—4]. The cues could be divided into two main kinds——symbolic cues and location cues. Symbolic cues suggest the direction or location the target will present through the abstract symbol, such as arrow. For example, symbolic cue experiment of Mangun and Hillyard[2] suggested the location where the target will appear through an arrow at the fixation. Location cues show the location where the target stimulus will appear directly by flashing. For another example, the recent experiment of Hopfinger and Mangun[5] adopts the typical peripheral flashing cues. In the ERP studies with these two types of cues, the P1, N1 amplitude evoked by cued target stimuli were larger than by uncued target stimuli[1,4]. Generally speaking, the ERP study of the visual attention in the past 20 years showed that the attentive information had a "gain control"[1—5], i.e. the attentive information evoked P1, N1 amplitude was larger than the inattentive information evoked. This effect was found through comparing the attention and inattention condition, especially in the study of attentive location factor. Therefore, the gain control of P1, N1 reflected the difference between attention and inattention. But whether that effect could be gotten in the mechanism on visual scale? In addition, the two models mentioned above implied the roles of attention scale in some degree, because while defining the attention location, the attention scale was diminished. For example, when it reminds of attention of the left visual field, it contracts half of the attention scale. As mentioned above, the outcome of the precious studies on visual attention location may involve the influence of the attention scale factors. Therefore, further study on the attention scale mechanism is very necessary.

Up to now, there are some behavioral studies on visual attention scale[6,7], but there is few relevant ERP study on it, and the discussion about the brain mechanism is very limited. In 2001, Luo et al.[8] investigated the brain mechanism through visual attentive spatial scale factor for the first time, and found that target stimuli evoked P1 amplitude enlarged the later amplitude of N1 components decreased; cues induced later amplitude of N1 components increased with the enlargement of scale of cues. As the location where the cues appear is random, the experiment will be influenced by the spatial location factors. Therefore, it is necessary to have more concisely experimental designs for attention scale, so that brain mechanism of spatial attention could be discussed further.

This experiment uses the new experimental model to separate attention scale and attention location from the two aspects, cues evoked attention type, and purified attention scale factors. First, the classification methods of spatial attention scale were improved through fixing the spatial location of attention scale, in order to rule out the effect of spatial location factors and have the effect of purifying attention scale. Second, Chinese characters were presented in the fixed location as cues of attention scale, for the character, as a kind of advanced abstract symbols, is fit for cues in the studies on the brain mechanism of visual attention. There is no ERP study reported on this aspect at present. Through analyzing cues evoked ERP and target evoked ERP, we discuss the temporal and spatial variety of brain activity in different attention scales and interval times between cues and target stimuli (ISI). Furthermore, the brain dynamic mechanism of visual attention scale and the features of attention scale information processing with the cues of Chinese characters are also discussed.

1 Methods

(ⅰ) Subjects. 14 healthy young participants (7 males and 7 females, 18—20 years old, an average of 17.8 years old) attended the electrophysiological experiment for the first time. They were right-handed, and have normal and corrected visual acuity.

(ⅱ) Stimuli. A stimuli trail included "background-cue-target". As shown in fig. 1(a), the background was a white circle with visual angle of 13°, and there was a little black cross at the center as the attention point. At the same time 3 black circles of different sizes were presented and their centers were located at the center of screen, their diameter visual angles were 11.4°, 7.6° and 3.8°, respectively. Cue was one of three Chinese characters, 大 or 中 or 小 (meaning large or medium or small, visual angle was 0.91°×0.91°) randomly presented at the circle's center, and they represented three attention scales. After cues, there presented 11 crescents (visual angle is 0.92°×0.76° each). One vertical crescent was the target, and its concave was the left or the right randomly; in addition, 10 horizontal crescents were distractors, and their concaves were up and down randomly. All the places where crescent appeared were random, and there was no overlap between them. Except the 10% outside, the rest of them appeared within the scale of cues. The ISI between cues and targets were divided into two groups: short (400—600 ms) and long (600—800 ms) and they presented randomly.

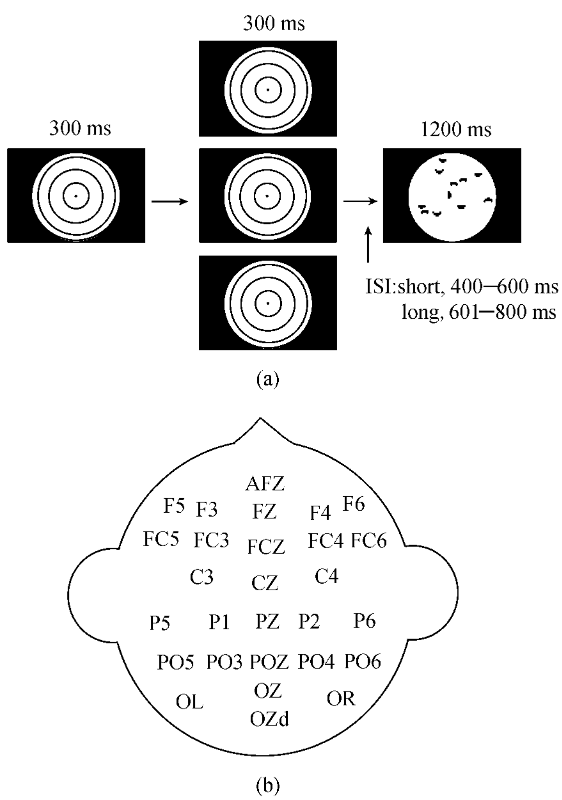

Fig. 1. The procedures of experiment (a) and the electrodes location on the scalp (b).

(ⅲ) ERP recording. The electroencephalogram (EEG) was recorded from 128 scalp sites using tin electrodes mounted in an elastic cap (NeuroScan ERP workstation), with the reference on the left and right mastoids. The vertical electrooculogram (EOG) was recorded with electrodes placed above and below the left eye. All inter-electrode impedance was maintained below 5 kΩ. The EEG and EOG were amplified using a 0.1—40 Hz band-pass and continuously sampled at 500 Hz/channel for off-line analysis. ERPs were averaged over a 500-ms epoch including a 100-ms prestimulus baseline. Trials with EOG artifacts (mean EOG voltage exceeding ±100 μV) were excluded from averaging.

(ⅳ) Procedure and task. At first the background was presented for 300 ms, then one of the three Chinese characters, as a cue of different attention scale, was presented randomly for 300 ms. After cues disappear, target and distractors were presented simultaneously for 1200 ms to make sure of enough recognition time (fig. 1(a)). The possibilities of the 3 kinds of cues appearance were the same. The tasks of subjects were to recognize whether the concave of target was to the left or to the right, and press the buttons with the thumb of the left or right hand. But there should be no response to the target outside the scale of cues. The request for subjects was both correct and quick.

(ⅴ) ERP data analysis and statistics. After EEG was classified and overlapped, 3 kinds of cues of characters evoked ERPs and 6 kinds of correct targets evoked ERP between different ISIs and different attention scales were available. The following 28 sites were chosen for statistical analysis (fig. 1(b)): AFZ, FZ, FCZ, CZ, F3, F4, F5, F6, FC3, FC4, FC5, FC6, C3 and C4 (the 14 sites for anterosuperior); PZ, POZ, OZ, OZd (down to the OZ), P1, P2, P5, P6, PO3, PO4, PO5, PO6, OL (down to the PO5), and OR (down to the PO6) (14 sites for inferoposterior).

Topography map was recorded from 128 scalp sites. In accordance with the general average figure and seniors' experience, the anterosuperior and the inferoposterior were analyzed using the analyses of variance (ANOVA) respectively. Cue evoked ERPs were analyzed at the anterosuperior scalp in 90—160 ms (N1), 160—220 ms (P2), 220—290 ms (N2); target evoked ERP in 50—120 ms (N1), 120—260 ms (P2), 260—360 ms (N2). Cue evoked ERPs were analyzed at the inferoposterior scalp in 50—160 ms (P1), 160—210 ms (N1), 200—250 ms (P2), 240—290 ms (N2); target evoked in 60—130 ms (P1), 130—200 ms (N1), 200—240 ms (P2), 240—320 ms (N2). The latencies and amplitudes (peak-to-peak value, the difference between the present and the former peak value)[9,10] of the above ERP components were analyzed by three-way repeated measures analyses of variance (ANOVAs). The ANOVA factors were attention size (3 levels: small, medium, large), ISI (2 levels: short, long) and electrode site (14 sites each for anterosuperior and inferoposterior components respectively). The P values of multi-factors ANOVAs were corrected using the Greenhouse-Geisser method, and the scalp distributions of the data were normalized to control.

2 Results

(ⅰ) Cue evoked ERP components. As shown in fig. 2, there was no main effect of the attention scale for

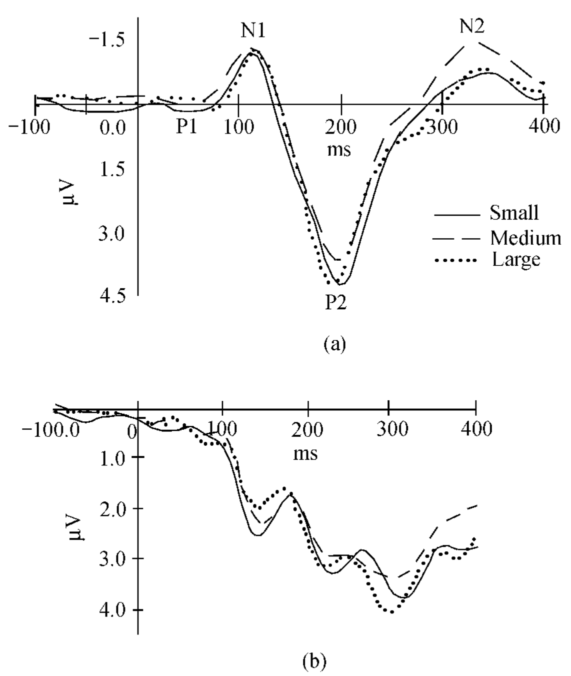

Fig. 2. The cue evoked ERP. (a) The prefrontal area (FZ site); (b) the parietal area (PZ site).

the P1, N1 components. There was the only significantly main effect of electrode site in the later P1 amplitude and latency. The shortest latency was at left post-occipital region (OL, (118±7.5) ms), $F_{13,169}$ = 3.6, P < 0.05; the largest amplitude was at the medium of occipital region (POZ, (3.2±0.4) μV), $F_{13,169}$ = 9.2, P < 0.001. There was the main effect of electrode site in the anterior N1 amplitude, $F_{13,169}$ = 4.0, P < 0.01. There was also only main effect of electrode site in the later of latency, and the shortest latency was at the left post-occipital region (OL, (169±2.1) ms), $F_{13,169}$ = 3.5, P < 0.05.

The anterior N2 latency decreased gradually as attention scales increased (small, medium and large), i.e. (261±6.2), (259±6.1), (251±6.4) ms, $F_{2,26}$ = 6.8, P < 0.05. Its largest amplitude was at the center of frontal region (FCZ, (4.1±0.8) μV), $F_{13,169}$= 3.1, P < 0.05.

(ⅱ) Target evoked ERP components. An explicit posterior P1 component was evoked by target, and its latency is (112±2.6) ms. There was only the main effect of electrode site in latency for the posterior N1, $F_{13, 169}$ = 3.5, P < 0.05; the latency was the shortest at the bilateral post-parietal lobe (P1, (156±2.5) ms; P2, (156±3.0) ms). However, the shortest latency of the anterior N1 was at the right center (C4, (69±5.3) ms), $F_{13,169}$ = 7.7, P < 0.01. But there was no main effect of the attention scale in P1, N1 components, and there was no significant difference between each two of the three attention scales. In addition, there was no significant cross effect between the attention scale and electrode site (table 1).

Table 1 With small, medium and large attention scale, the target evoked P1, N1 amplitude and F value of attention scale factor

		Small (M±SE)/μV	Medium (M±SE)/μV	Large (M±SE)/μV	F
Anterior	N1	1.3±0.2	1.1±0.3	1.2±0.2	0.5
Posterior	P1	2.5±0.5	2.8±0.4	2.7±0.6	0.4
	N1	4.5±0.9	4.5±0.9	4.4±1.0	0.0

The largest posterior P2 amplitude was at the central occipital region (POZ, (5.4±0.7) μV), $F_{13,169}$ = 4.9, P < 0.01; the largest anterior P2 amplitude was at the central frontal region (FZ, (9.4±0.7) μV; FCZ, (9.3±0.9) μV), $F_{13,169}$ = 5.3, P < 0.01. The shortest latency of anterior N2 is at the right occipital region (C4, (294±4.0) ms), $F_{13,169}$ = 9.4, P < 0.001; the largest amplitude was at the central frontal lobe (FZ, (7.8±0.5) μV), $F_{13,169}$ = 4.6, P < 0.01 (fig. 3).

There were the main effects of attention scales in latency and amplitude of P2, N2 components. In general, latency extended with the increase of attention scales, and amplitude increased with the increase of the attention scale (tables 2 amd 3).

In addition, comparing the target evoked ERPs under short ISI with that under long ISI on the same visual attention scale, there was significant difference between the amplitudes of anterior N1 and posterior P1 (fig. 4, table 4).

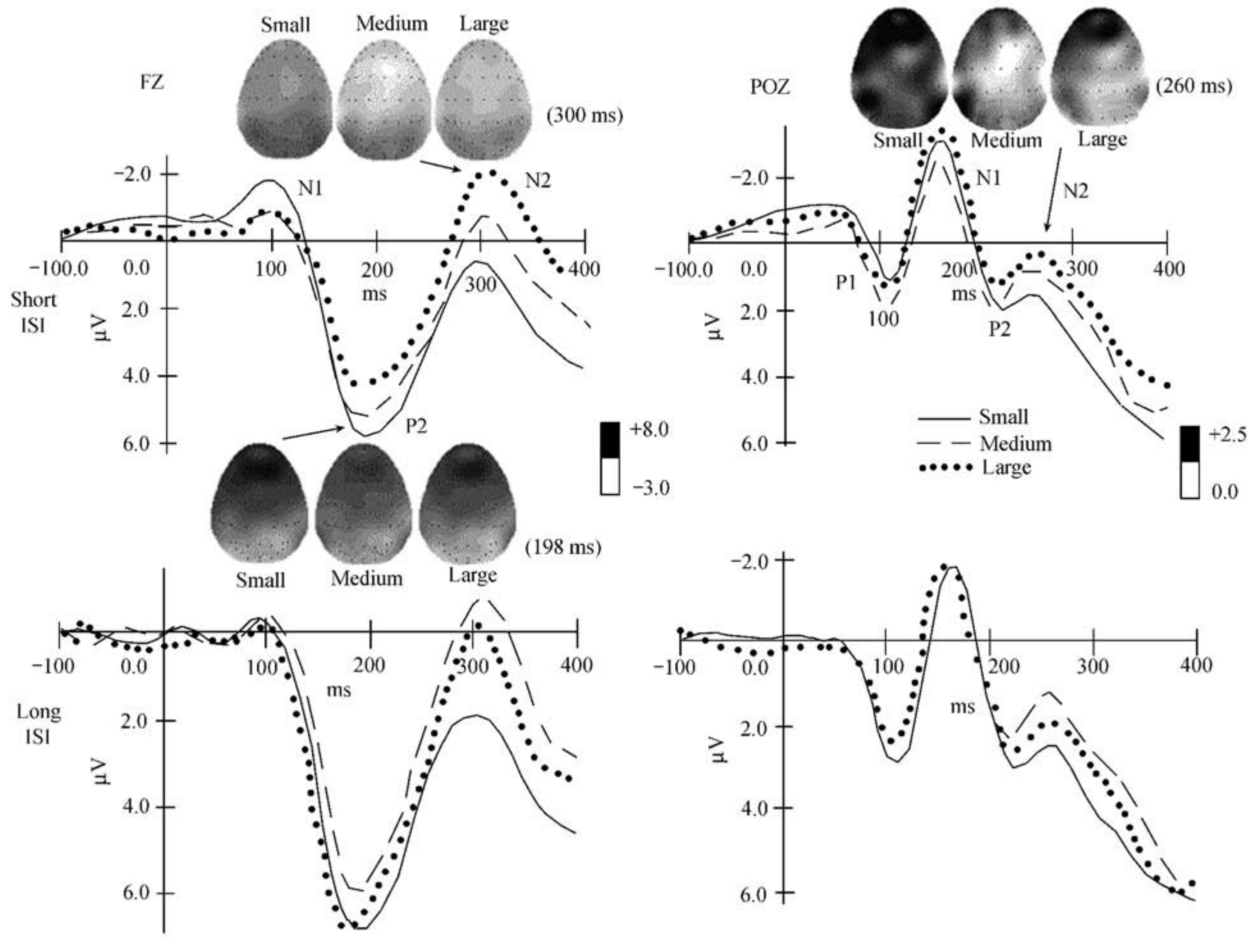

Fig. 3. The target evoked ERP and topography map with three different attention scales, short ISI (upper) and long ISI (lower).

Table 2 With small, medium and large attention scale, the target evoked P2, N2 amplitude and F value of attention scale factor

		Small ($M\pm$SE)/μV	Medium ($M\pm$SE)/μV	Large ($M\pm$SE)/μV	F
Anterior	P2	8.8 ± 0.8	7.8 ± 0.7	8.7 ± 0.6	4.1^{*}
	N2	5.9 ± 0.6	7.2 ± 0.5	7.5 ± 0.4	10.0^{**}
Posterior	P2	5.1 ± 0.8	4.6 ± 0.8	5.1 ± 0.6	1.3
	N2	1.7 ± 0.5	2.8 ± 0.6	3.1 ± 0.7	5.2^{*}

* $P < 0.05$, ** $P < 0.01$.

Table 3 With small, medium and large attention scale, the target evoked P2, N2 latency and F value of attention scale factor

		Small ($M\pm$SE)/ms	Medium ($M\pm$SE)/ms	Large ($M\pm$SE)/ms	F
Anterior	P2	202 ± 4.1	203 ± 5.3	210 ± 4.8	2.1
	N2	292 ± 5.0	311 ± 4.1	310 ± 3.8	21.2^{***}
Posterior	P2	225 ± 3.1	219 ± 2.8	223 ± 3.0	6.9^{**}
	N2	264 ± 4.9	272 ± 5.6	281 ± 6.1	10.1^{**}

** $P < 0.01$, *** $P < 0.001$.

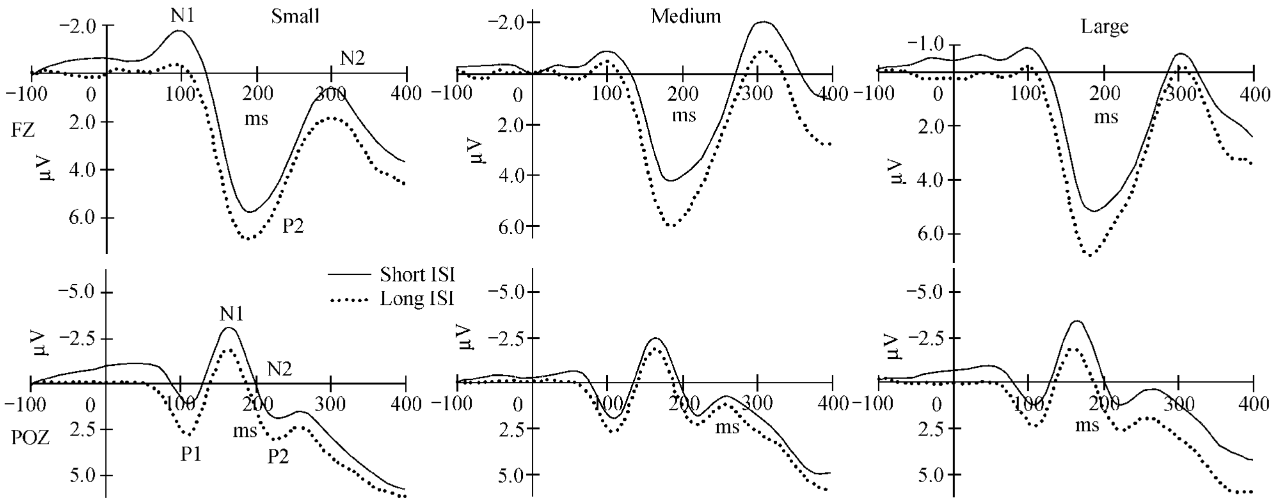

Fig. 4. The target evoked ERP with two kinds of ISIs, the prefrontal area (FZ site, upper) and the post-parietal area (POZ site, lower).

Table 4 With long and short ISIs, the target evoked P1, N1 amplitude and F value of attention scale factor

		Short ISI ($M\pm$SE)/μV	Long ISI ($M\pm$SE)/μV	F
Anterior	N1	1.8 ± 0.2	0.6 ± 0.2	26.2***
Posterior	P1	1.8 ± 0.4	3.5 ± 0.6	10.7***

*** $P < 0.001$.

3 Discussion

Except the latency of N2 component with the Chinese characters "小、中、大" (small, middle, large), the cue evoked ERP components had no significant difference, especially the early components of P1 and N1 were not influenced by the change of cues. The result is expected for the design of the experiment, i.e. reducing the influence of cues. Because the physical natures of the three Chinese characters were similar, the early components of ERP had no significant difference. And in the related research of linguistic processing[11,12], the linguistic processing demanded of participation of more advanced brain area, and the negative amplitude near 400 ms in latency may be related to the processing of characters, which was in line with the features of cues of characters evoked ERP in this study.

In the present ERP experiment paradigm, it adopted cues of characters to research the brain mechanism of visual spatial attention, which was not found in the previous studies on visual attention, and achieved an important outcome: target evoked early components of P1 and N1 with the cues of Chinese characters were not influenced by the attention scale factor, i.e. the early activity of visual cortex was not regulated significantly by the attention scale; while the relatively late components of P1 and N2 were closely related to the factors of attention scale. In the previous studies on visual attention, the target evoked P1, N1 with the cues of symbols and characters both had the gain control effect[1,2,5], however, the difference presented in this study reflected the features of ERP of information processing of attention scale. The locations of three kinds of the visual cues of attention scale in the experiment's background were fixed, which were presented at the center of the screen, and abolished the influence of the spatial location, thus the change of ERP reflected the influence of the factors of attention scale, but not the factors of the attention location. Under this condition, there was no gain control effect of P1, N1 in the present study, but the adjusting effect for P2, N2. Therefore, the result suggested that P1, N1 did not reflect the information processing of attention scale, but reflect the information processing of attention location; it was the component of P2, N2 that was related to the information processing of visual attention scale.

Compared with other attention studies, there is something else worthwhile thinking that the gain control effect of P1, N1 was achieved from the comparison between the attention and inattention condition, i.e. this effect reflected the difference between the attention and inattention. While the comparison among the three kinds of cue scale in the study was on the basis of the comparison among different attention levels, and there was no comparison between the attention and inattention condition. Therefore, it could be deduced that the adjusting phenomenon of P2, N2 reflected the regulation mechanism of quantitative change of attention scale, which is dissimilar to the difference between the attention and inattention condition reflected by the gain effect of P1, N1.

In the present study, the target evoked ERP under the condition of the long ISI and the short ISI was positive, and the difference of peak-to-peak amplitude was mainly on the early components (late P1, early N1), which suggests that the factors of ISI influences ERP mainly in the early period. In addition, according to the outcome of previous studies[1,13,14], N2 mainly reflected the processing of recognizing the features of target (e.g. the directions of the crescent's concaves). In this study, the subject's tasks were the same with the different scale's cues, so the difference of N2 was due to different cues' scale, i.e. the recognition of target was influenced significantly by the attention scale. And, some researchers suggested that the more negative the late components, the heavier the mental load may be[11,15]. Because the different resources consumed to search and recognize within different scales, N2 amplitude increased when the attention scale enlarged. In addition, starting from P2, the amplitude and latency were influenced by the attention scale, which maybe suggested that the information processing of attention scale began in this period.

4 Summary

Compared with the previous studies[4,5,8,16,17], the present study purified the effect of attention scale and got rid of the effect of spatial location, consequently separated the effects of two factors on ERPs. The results of this study suggested that P1 and N1 components were related to the process of the spatial attentive location, hence the conclusion that the visual attention had a close relation with P1 and N1 components should be aimed at the factor of attentive location, furthermore, the "gain control" of P1 and N1 components reflects the distinguish between attention and inattention. However, P2 and N2 components were related to the process of attention scale, and the P2 and N2 effect reflects the quantitative change of attention within the attention level.

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