Interactions between spatial attention and global/local feature selection: an ERP study

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Received 31 May 2000; accepted 14 June 2000

The present study examined the interaction between spatial attention and global/local feature processing of visual hierarchical stimuli. Event-related brain potentials (ERPs) were recorded from subjects who detected global or local targets at attended locations while ignoring those at unattended locations. Spatial attention produced enhanced occipital P1 and N1 waves in both global and local conditions. Selection of local features enhanced posterior P1, N1 and N2 waves relative to

MATERIALS AND METHODS

Subjects: Fifteen graduate students (10 females) ranging in age from 20 to 26 years participated in this experiment as paid volunteers. The subjects were neurologically normal and had normal or corrected-to-normal vision. Informed consent was obtained after the situation was explained.

Stimuli: White compound letters on a black background were presented on a computer-controlled video monitor 57 cm from the participant's eyes. A ®xation cross, subtending $0.3 \times 0.2°$ of visual angle, was continuously visible in the center of the monitor. The stimuli were ¯ashed in either the LVF or the RVF in random order. Each stimulus consisted of a global letter (H or E) made up of local letters (H or E) in 7×7 matrix, as shown in Fig. 1. The global and local letters subtended an angle of $3.3 \times 5.6°$ and $0.4 \times 0.6°$, respectively. The distance between the ®xation cross and the center of each compound stimulus was 2.9°. Stimulus duration was 200 ms. Interstimulus intervals were randomized between 600 and 1000 ms.

Procedure: Subjects were verbally instructed to attend to one hemi®eld prior to each block of 100 trials and to press a key with the right thumb to the designated global or local target (H or E) in the attended hemi®eld. Forty practice trials were presented prior to testing. A total of 800 trials in eight blocks were presented in global and local conditions, respectively. Accordingly, there were four blocks of trials f trials and821(weJ28.668(f)-65aS.668 / F8 1 Tf2f)-38atter

ERP components were de®ned as positive or negative de¯ections between the following time windows over parietal / occipital / temporal electrodes: P1 (80±140 ms), N1 (130±190 ms), P2 (200±280 ms), N2 (250±350 ms) and P3 (320±600 ms). Behavioral data were analyzed with ANOVA with factors being hemi®eld (stimuli were presented in the LVF or the RVF), global / local feature selection (attend to the global or local levels of the hierarchical stimuli), and consistency (global and local letters were consistent or inconsistent). The ANOVAs of ERP mean peak amplitudes and peak latencies were computed with hemi®eld, spatial attention (attended or unattended), global / local feature selection, consistency, and hemisphere (electrodes on the left or right hemisphere) as factors.

RESULTS

Performance: A global precedence effect was obtained: reaction times (RTs) to global targets were faster than those to local targets ($F(1,14) = 30.78$, $p < 0.001$; Table 1). RTs were also faster when the global and local letters were consistent than when they were inconsistent ($F(1,14) = 8.25$, $p < 0.02$). This was due to an interference effect on RTs in local but not global conditions, which produced a signi®cant interaction between global / local feature selection and consistency ($F(1,14) = 30.49$, $p < 0.001$). RTs were also faster to RVF than LVF targets ($F(1,14) = 11.90$, $p < 0.004$). However, no interactions involving hemi®eld reached signi®cance. Accuracy measures were consistent with the RT effects but showed less sensitivity to global / local differences. False alarm rates were 0.49% and 0.05% for local and global conditions, respectively. Subjects responded correctly to 95.7% of global targets and 98.0% of local targets, with no signi®cant effects of hemi®eld, global / local feature selection, or consistency.

ERPs: The grand average ERPs recorded at occipito-temporal sites in response to non-target global and local stimuli are shown in Fig. 2. The measures of ERP amplitudes of each component are presented in Table 2. The effect of global / local consistency and its interaction with other factors were not signi®cant for any component, and are therefore not reported below.

There was a signi®cant effect of spatial attention on the P1 ($F(1,14) = 8.96$, $p < 0.01$). Stimuli at attended locations evoked larger P1s than those at unattended locations. The effects of spatial attention were more pronounced for stimuli presented in the LVF than in the RVF ($F(1,14) = 5.36$, $p < 0.04$).

However, modulations of the N1 by global / local feature selection did not differ between spatially attended and unattended locations ($F(1,14) = 1.17$, $p > 0.2$). Global / local feature selection also delayed the N1 peak latencies in local (161 ms) relative to global conditions (156 ms; $F(1,14) = 26.54$, $p < 0.02$).

The P2 amplitudes were larger at electrodes contralateral to the stimulated hemi®elds than at ipsilateral sites ($F(1,14) = 8.04$, $p <$

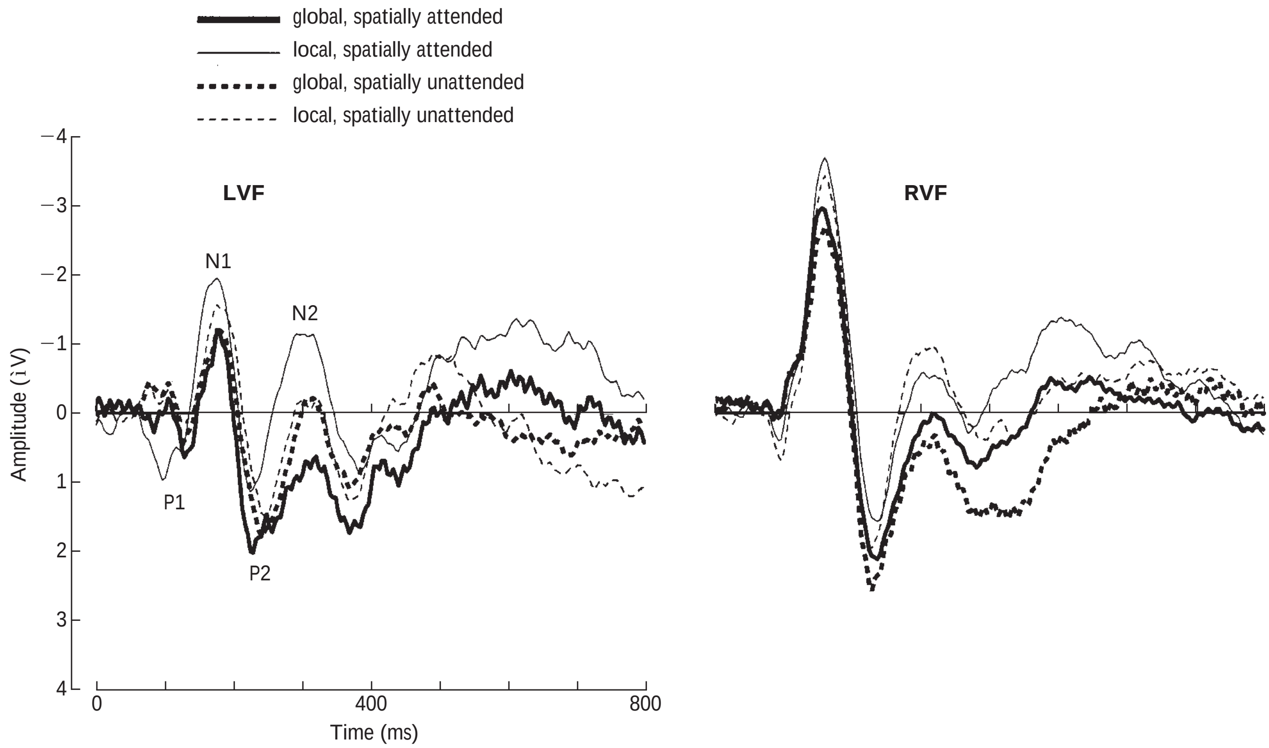

Fig. 3. ERPs recorded at O1 eliciRPs]TJ/F1 2(d)75.757 474. EXq438.718r/F14 1 Tf0.833 3. 3.. EXq438

attended hemi®eld. The RTs showed a global precedence effect, which was similar for targets presented in the LVF and the RVF.

The effects of spatial attention on ERPs replicated the ®ndings of previous work [1]. The amplitudes of the P1 and N1 were enhanced to stimuli in spatially attended locations. This effect was stronger for stimuli presented in the LVF than in the RVF, possibly re¯ecting a right hemisphere dominance in directing spatial attention [13±15].

Global / local feature selection produced effects on both early and late ERP components. Both P1 and N1 components were enlarged when attention was directed to local relative to global levels of the compound letters. The P1 effect corroborates the ®ndings of previous studies in which hierarchical stimuli were presented in the center of the visual ®eld or were presented peripherally with spatial attention equally allocated to the two hemi®elds [9±11]. Since the present study showed that the P1 was modulated by both spatial attention and global / local feature selection and previous work has localized the spatial attention-modulated P1 to early prestriate cortical regions [2,3], it is possible that the P1 effect associated with global / local processing in the current experiment also re¯ects the modulation of processing in prestriate visual cortices. This is consistent with brain imaging study which showed metabolic activation of prestriate occipital cortex associated with local and global tasks [16]. Note that the P1 could be larger in global relative local conditions when the global precedence effect was absent in RTs [8]. The contrast between these studies suggest that the initial differential sensory-perceptual processing contributes to the global precedence effect observed in behavioural data.

Modulations of longer-latency ERP components were also associated with global / local feature selection in the current study. The P2 was larger in global than local conditions while the N2 was enhanced in local relative to global conditions. These are in agreement with previous studies [7,10,11]. The results indicate that global / local feature selection modulates brain activities at multiple levels of visual information processing, from early sensory processing to late target perception.

More important, the present study provided electrophysiological evidence for the interaction between spatial attention and global / local feature selection. The earliest sign of this interaction was observed in the P1 component. There was a P1 enlargement related to local feature selection when spatial attention was directed to the LVF, whereas the P1 did not differ between global and local conditions when spatial attention was directed to the RVF. Similarly, the modulation of the N2 by global / local feature selection was also contingent upon the direction of spatial attention. Spatial attention to the LVF enlarged the enhancement of the N2 in local relative to global conditions, while spatial attention to the RVF reduced the N2 enhancement. This interaction was true even when the hierarchical stimuli were located in the unattended hemi®eld.

This asymmetric pattern of interaction between spatial attention and global / local feature selection possibly resulted from the asymmetric role played by the two hemispheres in global and local feature processing. Patient