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Brief report

The time course of spatial orienting elicited by central and peripheral cues: evidence from event-related brain potentials

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Abstract

To study differences in the time course of attentional orienting triggered by salient peripheral events and by central symbolic precues, event-related brain potentials (ERPs) were recorded in response to letter stimuli following spatially informative symbolic or peripheral precues after a cue-target interval (CTI) of either 200 or 700 ms. Stimuli at cued (attended) locations elicited an enhanced negativity relative to stimuli at uncued locations. With short CTIs, these effects started around 150 ms post-stimulus for peripheral cues. They were delayed by about 100 ms for central cues. This latency difference is assumed to reflect fast exogenous orienting elicited by peripheral, but not by central cues. Beyond 200 ms post-stimulus, attentional negativities were larger with long CTIs than with short CTIs for both cue types, presumably related to the gradual build-up of endogenous orienting triggered by spatially predictive events. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Visual–spatial attention; Event-related potentials; Exogenous orienting; Endogenous orienting

The time course of visual–spatial orienting depends on the type of attentional cue. Exogenous orienting triggered by salient stimuli in the periphery of the visual

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field produces maximal selective effects on visual processing at short cue-target intervals (CTIs), while effects of endogenous orienting elicited by spatially informative cues build up more gradually (Müller and Rabbitt, 1989). Spatially informative peripheral cues trigger a fast but transient exogenous orienting process as well as a slower endogenous orienting process. Central symbolic cues elicit only endogenous orienting (Müller and Findlay, 1988). The present study investigated these differences by comparing effects of informative central symbolic and peripheral cues on ERPs elicited by target stimuli presented after short (200 ms) and long (700 ms) CTIs. If exogenous orienting was faster than endogenous orienting, attentional ERP modulations should be delayed with short CTIs for central relative to peripheral cues. With long CTIs, attentional effects should depend on endogenous orienting alone and should therefore be similar for both cue types.

Central or peripheral cues (100 ms duration) were followed by letter stimuli (M and N; 100 ms duration) that appeared with equal probability in one of the four corners of a continuously present grey background square (subtending a visual angle of $6° \times 6°$). Subjects had to maintain central fixation and to press a button when the target letter N appeared at the cued location. Twenty-eight paid volunteers participated in the study. Four of them had to be excluded because the averaged HEOG in response to cues on the left and right side revealed poor eye fixation control in the CTI (residual HEOG deviation larger than ± 2 μV). Of the remaining subjects (ten female, aged 18–42 years), twelve were assigned to the central cue condition, where a centrally presented digit (1, 2, 3, or 4) indicated the relevant location for the target-nontarget discrimination (upper right, lower right, lower left, or upper left). The other twelve subjects were assigned to the peripheral cue condition, where the relevant location was cued by a transient illumination of one corner segment of the background square. Twenty-four blocks were run. CTI was varied between blocks, with twelve successive blocks with long and short CTIs, counterbalanced across subjects. Each block consisted of 64 trials. In 48 trials, non-targets were presented equiprobably at cued locations (valid trials) and uncued locations (invalid trials). In the remaining 16 trials, target letters were presented with equal probability at cued and uncued locations. EEG was recorded from OL and OR (located halfway between O_1 and T_5, and O_2 and T_6), and from Fz, Cz, and Pz (linked earlobe reference; amplifier bandpass 0.1–40 Hz; digitisation rate 200 Hz). Trials with eye blinks or lateral eye movements identified in the VEOG and HEOG were rejected. ERPs were analysed for non-target trials only.

Mean reaction times (RTs) to targets at cued locations were 609 and 560 ms in the central and peripheral cue conditions, respectively, but this difference was not significant. With short CTIs, responses tended to be faster for peripheral cues than for central cues ($t(22) = 2.0$; $P < 0.06$). Figs. 1 and 2 show grand-averaged ERPs elicited in valid and invalid trials with long and short CTIs for the central and peripheral cue groups. Fig. 3 shows the corresponding valid-invalid difference waveforms. Attention was reflected in enhanced negativities for valid relative to invalid trials. With peripheral cues, these effects started around 150 ms post-stimulus for both CTIs. With central cues, they were reduced in amplitude and delayed for short CTIs. This difference was reflected in a cue type × CTI × validity interaction for ERP mean amplitudes between 140 and 200 ms post-stimulus ($F(1,22) = 5.9$; $P < 0.02$). CTI × validity interactions were present for the central cue group ($F(1,11) = 6.5$; $P < 0.03$), but not for the peripheral cue group. Subsequent paired t-tests revealed that with central cues, attentional modulations were reliable at all sites with long CTIs (all $t(11) > 2.3$), but failed to reach significance at any site with short CTIs. With peripheral cues, significant attentional modulations were obtained for all sites and both CTIs (all $t(11) > 2.4$). Attentional effects were further analysed in two subsequent time intervals (200–260 and 260–320 ms post-stimulus). For both cue types, CTI × validity interactions were observed in these intervals (all $F(1,11) > 5.5$; all $P < 0.04$), reflecting larger attentional effects with long CTIs. In the central cue group, validity effects were significant at all sites in both time windows with long CTIs (all $t(11) > 2.2$), but only emerged in the 260–320 ms interval with short CTIs (all $t(11) > 2.9$). In the peripheral cue group, validity effects were reliable at all electrodes for long and short CTIs in both time windows (all $t(11) > 2.4$). To estimate the onset of attentional modulations for each combination of cue type and CTI, valid and invalid ERPs were compared with paired t-tests conducted successively for each sampling point in the 300 ms time interval

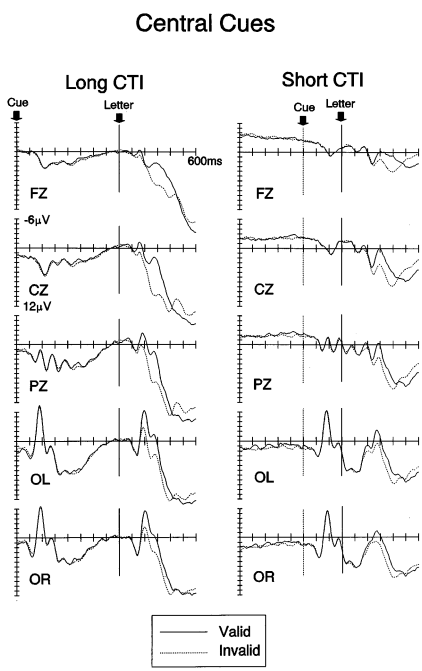

Fig. 1. Grand-averaged ERPs at midline and lateral occipital electrodes recorded for the central cue group in valid trials (solid lines) and invalid trials (dashed lines) with cue-target intervals (CTIs) of 700 (left) and 200 ms (right). Waveforms are displayed between −800 and +600 ms relative to the presentation of non-target letter stimuli (solid vertical lines). Cues were presented at −800 ms in the long CTI condition, and at −300 ms (dashed vertical lines) in the short CTI condition. Amplitude values are relative to a 100 ms baseline prior to letter onset.

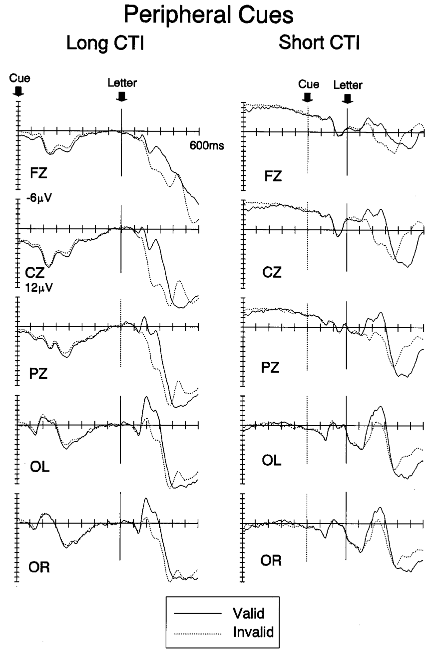

Fig. 2. Grand-averaged ERPs at midline and lateral occipital electrodes recorded for the peripheral cue group in valid trials (solid lines) and invalid trials (dashed lines) with cue-target intervals (CTIs) of 700 (left) and 200 ms (right). Waveforms are displayed between −800 and +600 ms relative to the presentation of non-target letter stimuli (solid vertical lines). Cues were presented at −800 ms in the long CTI condition, and at −300 ms (dashed vertical lines) in the short CTI condition. Amplitude values are relative to a 100 ms baseline prior to letter onset.

following letter onset. To avoid α errors, a significant t-value was only accepted as reliable if t-values remained significant for eight successive sampling points. Table 1 shows the resulting onset estimates, which correspond well with the difference waveforms in Fig. 3.

Differences in the time course of attentional orienting processes triggered by central symbolic and peripheral cues were reflected in systematic differences in the onset of attentional ERP modulations. With short CTIs, these effects were delayed for central relative to peripheral cues. This latency difference is likely to reflect the impact of fast exogenous orienting processes triggered by peripheral cues. In addition, it may also be related to differences in the time required to decode central and peripheral cues (Eriksen and Colegate, 1971), resulting in a faster onset of endogenous orienting in the peripheral cue condition. Beyond 200 ms post-stimulus, attentional effects were larger with long CTIs than with short CTIs for both types of cues. This difference is likely to reflect the gradual rise time of endogenous orienting processes elicited by spatially informative events. Overall, the present study demonstrated how differences between attentional orienting processes triggered by central and peripheral cues can be studied with ERPs.

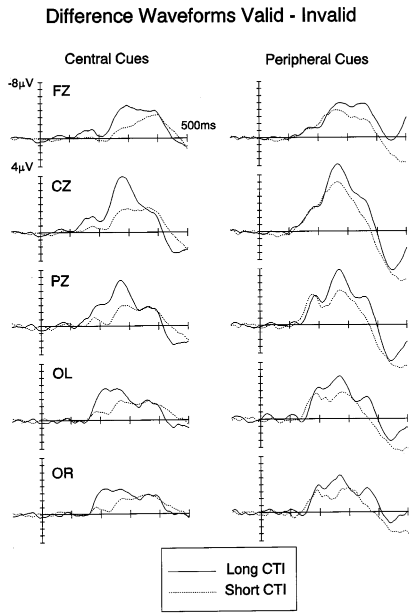

Fig. 3. Difference waveforms obtained in the 500 ms interval following letter onset at midline and lateral occipital electrodes for the central cue group (left) and the peripheral cue group (right) by subtracting ERPs to invalid trials from ERPs to valid trials, separately for long CTIs (solid lines) and short CTIs (dashed lines). Waveforms are presented relative to a 100 ms baseline preceding letter onset.

Table 1
Estimated onset of attentional ERP modulations (in ms post-stimulus)

	Central cue		Peripheral cue	
	Long CTI	Short CTI	Long CTI	Short CTI
FZ	140	270	190	155
CZ	135	240	140	150
PZ	165	250	155	150
OL	175	245	165	160
OR	175	240	165	180

Acknowledgements

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