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Research Report

Differentiating spatial and object-based effects on attention: An event-related brain potential study with peripheral cueing

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ABSTRACT

Do spatial attention and object attention modulate visual processing in similar ways? Previously we have found a dissociation between these two forms of attention on ERP measures of sensory processing under conditions of peripheral cueing, with spatial attention effects associated with changes over anterior scalp regions and object attention effects associated with changes over posterior regions (He, X., Fan, S., Zhou, K., Chen, L., 2004. Cue validity and object-based attention. J. Cogn. Neurosci. 16, 1085–1097). However, under conditions of central cueing recent data suggest that spatial and object attention have similar effects over posterior cortical areas (e.g., Martínez, A., Teder-Sälejärvi, W., Hillyard, S.A., 2007. Spatial attention facilitates selection of illusory objects: evidence from event-related brain potentials. Brain Res. 1139, 143–152). In the present study we present further evidence for dissociation between spatial and object-based attention under conditions in which spatial attention effects were enhanced by increasing the cue validity and the task load. The data replicated our previous results, with the effects of spatial attention found in an enhanced anterior N1, while the effects of object-based attention emerged in an enhanced posterior N1. Analyses of attention effect maps and current source density maps confirmed the distinct scalp distributions. These results support the proposal that, under peripheral cueing, spatial attention and object attention are associated with activity respectively in anterior and posterior brain structures, and further suggest a distinction between how attention modulates processing under conditions of central cueing and peripheral cueing.

1. Introduction

Attention can select spatial locations (space-based attention) or perceptual objects (object-based attention) that may be formed preattentively. Space-based attention facilitates responses to the stimuli within the selected area of the visual field (Posner, 1980), whereas object-based attention facilitates selection of whole objects (Scholl, 2001). Effects of object-based attention have been confirmed in numerous studies using both divided and directed attention. In a divided attention task, participants have to select multiple attributes for their responses. Performance is typically better when the attributes belong to a single object than when they belong to (and attention is divided across) different perceptual objects (Blaser et al., 2000; Duncan, 1984; Watson and Kramer, 1999). In a directed attention task, attention is cued to a location in

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space. Detection of a subsequent target is typically better when the target falls within the object where attention is cued,

Table 1 – Behavioral results

	Reaction times			Main effect		Pairwise comparisons		Hits	False alarms
	Valid	Intra	Inter	Attention		Spatial attention (valid vs. intra)	Object attention (intra vs. inter)		
	ms			$F(2,30)$	P	P		%	
Experiment 1	344	368	387	22.51	<.0001	<.01	<.0006	98.7	4.0
Experiment 2	549							75.9	0.6

between attention effect and scalp region [$F(5,75)=5.74$, $P<.011$] in an analysis procedure suggested by McCarthy and Wood (1985).

Similar results were obtained in Experiment 2. No attention effect was found for the P1. An effect of spatial attention was evident for the mean amplitudes of the anterior N1, distributed over the centro-parietal region. In contrast, an object-based attention effect was significant in the mean amplitudes of the posterior N1, ranging over the temporo-occipital areas (Fig. 3, Table 2). This differential distribution can clearly be

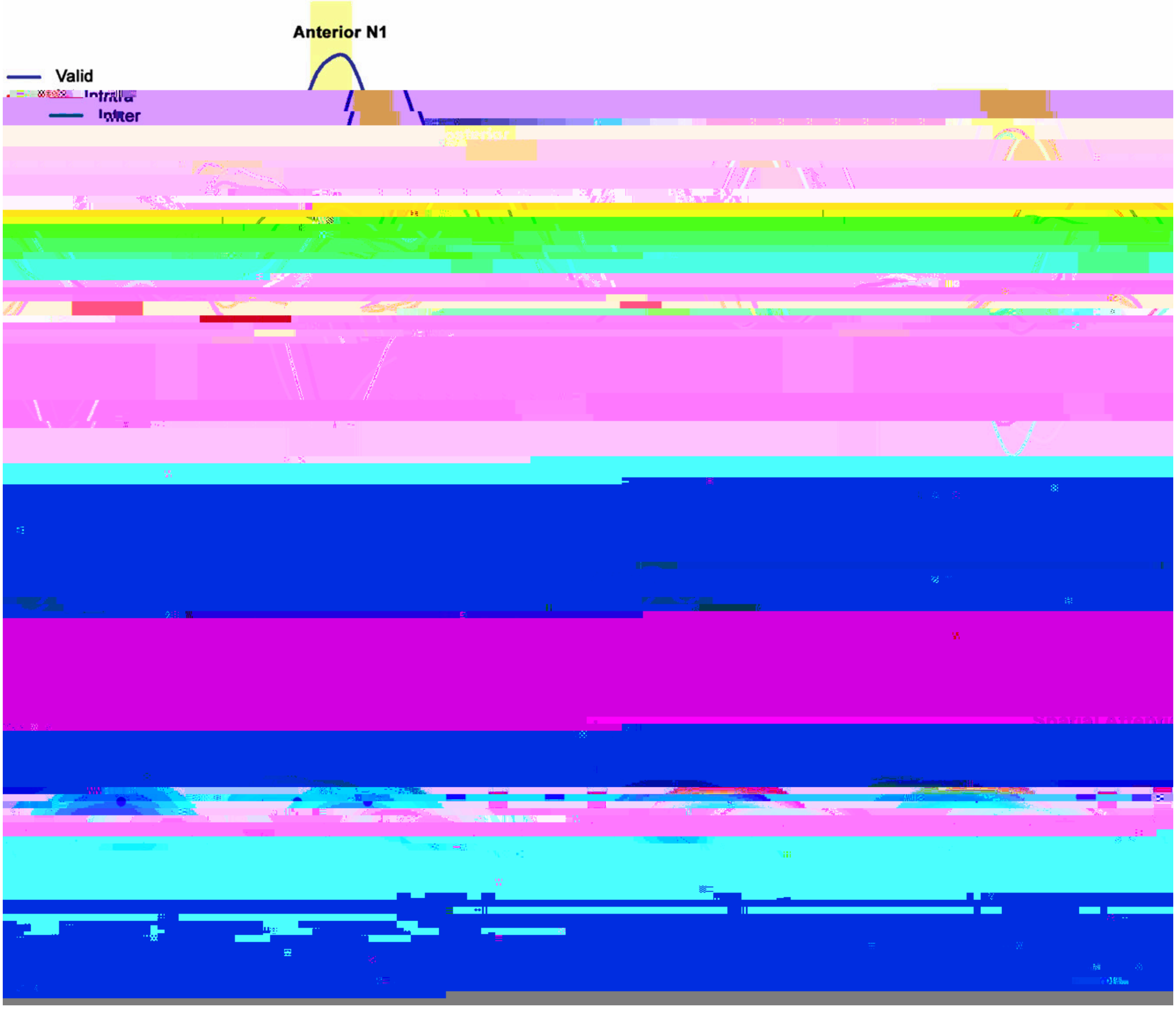

Fig. 2 – ERP results of Experiment 1 (target positions and object layouts collapsed). Spatial attention effect is evident in amplitudes of the anterior N1 maximal over centro-parietal sites (CPz in the illustration). Object attention effect is found in amplitudes of the posterior N1 spreading over temporo-occipital areas (P7 in the illustration). Mean amplitudes were measured within specific windows (yellow rectangles) relative to a 200-ms pre-cue baseline which is not included in the figure. The differential distribution of these two attention effects is also observed in the voltage topographs and current source density (CSD) maps, which are plotted in back view.

witnessed in the voltage and current topograph maps of the spatial and object-based attention effects. The normalization procedure (McCarthy and Wood, 1985) also confirmed the distribution difference between the two attention effects [$F(5,75) = 7.18$, $P < .0004$].

In Experiment 2, a long-lasting spatial effect was evident after the N1 time range. This effect was very strong and could in parietal cortex. These results emphasize the importance of anterior brain structures for voluntary attention, and more posterior structures for reflexive attention. Although the central cueing and/or sustained attention to a location (Mangun and Hillyard, 1991; Luck and Hillyard, 2000). It could be that the CTOAs used in these studies were too short for any posterior effect to build up. This account is not plausible however, because evidence has suggested that a 300-ms stimulus onset asynchrony (SOA) is long enough for spatial attention to affect the posterior N1 (Doallo et al., 2005). Another possible explanation for this discrepancy between our experiments and those of Martínez et al. is that the easy task (simple RT task in Experiment 1) we used would render the posterior N1 much reduced in amplitude (Hopf et al., 2002; Vogel and Luck, 2000), whilst also diminishing any effect of spatial attention (Mangun and Hillyard, 1991). We should note, though, that Experiment 2 here employed a difficult discrimination task and replicated our original finding, which excludes this possibility too. Therefore, we suggest that spatial attention does not modulate the posterior N1 under conditions of peripheral orienting, at least in the present experimental setup. It is noteworthy that the anterior effects of spatial attention that are apparent in the present experiments also differ from the posterior effects found with central cueing (Martínez et al., 2006, 2007a,b), suggesting differences between central and peripheral cueing.

There are grounds to argue that central and peripheral cueing can involve different processes. Attentional effects from central cueing are linked to a voluntary mechanism reflecting an endogenous expectancy which is dependent upon cue validity. In contrast, peripheral cues can capture visual attention in a reflexive (exogenous) manner, while also being used to summon attention endogenously when the cue has high validity (Müller and Rabbitt, 1989; Pashler et al., 2001). Previous studies have indicated that different brain activities can be linked to these two attention mechanisms (e.g. Hopfinger and West, 2006). The present results, however, suggest that there may be a difference in the voluntary attention mechanism invoked by the two cueing methods. In He et al. (2004), the space-based attention effect was modulated by cue validity whereas the object-based effect was not. Therefore we suggested that, under peripheral cueing conditions, space-based attention requires the involvement of voluntary attention while object-based attention is recruited exogenously. This proposal fits with the current argument for distinct space- and object-based attention mechanisms under peripheral cueing conditions, derived here from the contrasting scalp distributions of the effects. Object-based attention, following a peripheral cue, is mediated by ventral visual cortical regions and is associated with changes to the posterior N1. Space-based attention, following the same cue, is mediated by the parietal lobe and is associated with changes in the anterior N1.

Unlike Hopfinger and Mangun's studies (1998, 2001), we did not find any attention effect on P1 under the current peripheral cueing conditions, for either the detection task (Experiment 1) or the discrimination task (Experiment 2). This also differs from data reported by Handy and Mangun (2000), where a P1 effect was evident under conditions of high perceptual load. Comparisons across studies are made difficult by the presence of several differences between experiments, such as the type of cue and the CTOA range used. In addition to this, our specific method for averaging ERPs across different stimulus onset locations, collapsing across contra- and ipsi-lateral electrode sites, could possibly smear the P1 component, which is usually larger at contralateral sites. However, equivalent attentional effects are usually found at ipsilateral and contralateral sites when visual stimuli are presented away from horizontal meridian (e.g., Di Russo et al., pre-cue baseline (i.e., −500 to −300 ms pre-stimulus), and were applied with band-pass filtering (0.1–40 Hz) and artifact rejection (±60 μV criterion). In Experiment 1, EEG activities from all trials were analyzed. In Experiment 2, only standard trials (trials without manual responses) were analyzed.

Because the CTOA was short, the neural responses to the cue overlapped with the responses to the stimulus. However, the adjacent response filter (Woldorff, 1993) could not be employed to remove the differential overlap because the CTOA was kept constant. To rule out the possibility that any differences in early target ERP components might be due to overlapping and distortion from cue ERPs, the ERP waveforms, for each subject, were produced by taking the same number of trials from each location, each layout, and each cue-target relation into the averaging procedure. When this method was applied, the ERP activities generated by the cues and the targets still overlapped each other. However, as a whole the physical stimuli fell at the corners of the rectangles. No matter what cueing condition it was, the stimuli producing the electrophysiological responses were identical. Hence, before the targets/standards were presented, the identical cues would produce almost the same ERP waveforms. Afterwards, when the targets/standards were shown, because of the exactly matched stimuli, the differences between the critical conditions cannot be accounted for by overlapping ERPs but rather by the different attentional status of the stimuli (for detailed analysis, see He et al., 2004, Appendix).

P1, anterior N1, and posterior N1 were quantified as mean amplitudes averaged across electrodes that showed the maximal amplitudes of corresponding components. Because the ERPs were averaged over different stimulus onset locations, data from contra- and ipsi-lateral sites were combined altogether. In this case, the P1 was statistically assessed within mean amplitudes over sites P7, P8, O1, and O2, within time windows around its peak latency (80–100 ms in Experiment 1, 70–90 ms in Experiment 2), relative to the 200-ms pre-cue baseline. Similarly, the anterior N1 was measured as mean amplitudes over C3, C4, and Cz (130–160 ms in Experiment 1, 150–180 ms in Experiment 2), and the posterior N1 over P7, P8, O1 and O2 (150–200 ms in both experiments).

Behavioral and neurophysiological data were put into ANOVAs with Greenhouse–Geisser correction (Jennings and Wood, 1976). If the main effect of attention was significant, the space- and object-based attention effects were further examined with pairwise comparisons, in which the spatial attention effect was revealed by differences between valid and intra conditions, and the object attention effect was identified as differences between intra and inter conditions. Behavioral responses with RTs between 150 ms and 850 ms were recognized as correct hits. RT medians of correct hits in Experiment 1 were analyzed with a two-way ANOVA (3 attention × 2 object layout). Mean ERP amplitudes were analyzed with one-way ANOVAs, in which the object layout factor was dropped because there was a limited amount of data.

Scalp distribution of spatial and object attention effects in the N1 complex was statistically compared with the normalization method suggested by McCarthy and Wood (1985). Sixteen main electrode sites (FC3/4, C3/4/z, CP3/4/z, P3/4/z, P7/8, O1/2/z) were chosen and grouped into six scalp regions. Mean amplitudes across electrode sites within each region were measured at time points when the spatial/object attention effects reached their maxima (Experiment 1: 164 ms/176 ms, Experiment 2: 172 ms/184 ms), and then put into a two-way ANOVA (2 attention effect × 6 scalp region).

Egly, R., Driver, J., Rafal, R.D., 1994. Shifting visual attention between objects and locations: evidence from normal and parietal lesion subjects. J. Exp. Psychol. Gen. 123, 161–177.

Eimer, M., 1994. “Sensory gating” as a mechanism for visuospatial orienting: electrophysiological evidence from trial-by-trial cuing experiments. Percept. Psychophys. 55, 667–675.

Fink, G.R., Dolan, R.J., Halligan, P.W., Marshall, J.C., Frith, C.D., 1997. Space-based and object-based visual attention: shared and specific neural domains. Brain 120, 2013–2028.

Fu, S., Greenwood, P.M., Parasuraman, R., 2005. Brain mechanisms of involuntary visuospatial attention: an event-related potential study. Hum. Brain Mapp. 25, 378–390.

Handy, T.C., Mangun, G.R., 2000. Attention and spatial selection: electrophysiological evidence for modulation by perceptual load. Percept. Psychophys. 62, 175–186.

He, X., Fan, S., Zhou, K., Chen, L., 2004. Cue validity and object-based attention. J. Cogn. Neurosci. 16, 1085–1097.

Hillyard, S.A., Münte, T.F., 1984. Selective attention to color and location: an analysis with event-related brain potentials. Percept. Psychophys. 36, 185–198.

Hopf, J.-M., Vogel, E., Woodman, G., Heinze, H.-J., Luck, S.J., 2002. Localizing visual discrimination processes in time and space. J. Neurophysiol. 88, 2088–2095.

Hopfinger, J.B., Mangun, G.R., 1998. Reflexive attention modulates processing of visual stimuli in human extrastriate cortex. Psychol. Sci. 9, 441–447.

Hopfinger, J.B., Mangun, G.R., 2001. Tracking the influence of reflexive attention on sensory and cognitive processing. Cogn. Affect. Behav. Neurosci. 1, 56–65.

Hopfinger, J.B., Maxwell, J.S., 2005. Appearing and disappearing stimuli trigger a reflexive modulation of visual cortical activity. Cogn. Brain Res. 25, 48–56.

Hopfinger, J.B., West, V.M., 2006. Interactions between endogenous object-based attentional modulation of brain potentials. J. Cogn. Neurosci. 10, 137–151.

Vecera, S.P., Farah, M.J., 1994. Does visual attention select objects or locations? J. Exp. Psychol. Gen. 123, 146–160.

Vogel, E.K., Luck, S.J., 2000. The visual N1 component as an index of a discrimination process. Psychophysiology 37, 190–203.

Watson, S.E., Kramer, F.A., 1999. Object-based visual selective attention and perceptual organization. Percept. Psychophys. 61, 31–49.

W160doneTR8(Watso1?Tj788-1.335TJ1.601-1.335a.)Tstnk.hor8(and)-28hysa dERPy