ELSEVIER

Biological Psychology 46 (1997) 67–71

BIOLOGICAL
PSYCHOLOGY

Brief report

Uninformative symbolic cues may bias visual-spatial attention: behavioral and electrophysiological evidence

Martin Eimer *

Institut für Psychologie, Universität München, Leopoldstr. 13, 80802 Munich, Germany

Received 4 January 1996; received in revised form 17 December 1996; accepted 16 January 1997

Abstract

Event-related brain potentials and response latencies were measured in an experiment where centrally presented arrow cues were followed by left or right visual target stimuli. In one condition, target location was indicated by the cues with 75% validity. In another condition, the precues were uninformative with respect to target location. Faster response times and larger negativities in the ERPs at midline electrodes were measured for targets at cued locations following informative cues, but also with uninformative precues. This indicates that visual-spatial attention may be biased involuntarily by central symbolic precues. © 1997 Elsevier Science B.V.

Keywords: Event-related brain potentials; Response latencies; Uninformative cues; Visual-spatial attention

In many studies on visual-spatial attention, to-be-attended locations are indicated by central symbolic precues (e.g. arrows) that inform subjects about the likely location (left vs. right) of upcoming target stimuli. Responses to stimuli at cued

* E-mail: eimer@mip.paed.uni-muenchen.de.

PII S0301-0511(97)05254-X

(attended) locations are faster and more accurate than responses to stimuli at uncued locations (cf Posner et al., 1978). ERP studies have found enhanced negativities elicited by stimuli at attended as compared to unattended locations (cf Mangun & Hillyard, 1991; Eimer, 1993). This effect that is assumed to indicate the differential processing of stimuli at cued and uncued locations peaks around 160 ms at posterior electrodes (Nd1) and shows a second, broadly distributed maximum between 220 ms and 280 ms (Nd2). In addition, enhanced posterior P1 and N1 components may also be elicited by stimuli at cued locations (Mangun & Hillyard, 1991; but see Eimer, 1994a).

When precues are informative about likely stimulus positions, subjects will shift their attention voluntarily to the indicated location. When they are uninformative (because stimuli are equally likely to appear at cued and uncued positions), there is no incentive for voluntary attention shifts. Nevertheless, the cue may still bias spatial attention. An attentional bias is known to be elicited by uninformative peripheral cues, and has been interpreted as indicating an involuntary capture of attention (cf Jonides (1981) for RT effects, and Eimer (1994b) for ERP effects). Shepherd et al. (1986) reported similar effects in response to centrally presented, uninformative arrow cues (small but significant RT benefits for stimuli at cued locations), possibly indicating an involuntary attentional bias towards cued locations.

The present study investigated behavioral and electrophysiological effects of attentional cueing with informative and uninformative symbolic precues. Ten subjects (7 female, aged 21–35 years), who never participated in this type of experiment before, responded to target letters that were presented for 100 ms 6° to the left or right of fixation (letter M: left response, letter W: right response). At 900 ms before letter onset, a central left- or right-pointing arrow was presented for 200 ms. In the Informative Cue condition, the arrow indicated the location of the target with 75% validity. In the Uninformative Cue condition, targets appeared equally likely at the cued and uncued side. Subjects were informed about these different probabilities. Five subjects (group IU) received 8 blocks with informative cues (60 trials per block) prior to 4 blocks with uninformative cues, and this order was reversed for the other 5 subjects (group UI). EEG was recorded from OL and OR (located halfway between O1 and T5, and O2 and T6, respectively) and from Fz, Cz, and Pz (right earlobe reference; amplifier bandpass 0.1–40 Hz; digitization rate 200 Hz). Trials with eyeblinks or horizontal eye movements identified in the VEOG and HEOG were rejected.

In the Informative Cue condition, RTs were faster for stimuli at cued than at uncued positions (499 ms vs. 527 ms; $F(1,9) = 24.78$, $P < 0.001$). In the Uninformative Cue condition, this effect was smaller, but significant (495 ms vs. 508 ms; $F(1,9) = 17.47$, $P < 0.003$). Fig. 1 shows the ERPs elicited by stimuli at cued and uncued positions at occipital sites (collapsed over OL and OR) and at Cz in the Informative and Uninformative Cue condition and the resulting cued-uncued difference waves. No effect of cueing (cued vs. uncued location) was found for occipital P1 amplitude. An enlarged occipital N1 (measured as the mean amplitude between 160 ms and 210 ms post-stimulus) was found for cued locations ($F(1,9) =$

6.54, $P < 0.031$). Although this effect was significant for informative, but virtually absent for uninformative cues, the relevant cueing × informativeness interaction only approached significance ($F(1,9) = 3.58$, $P < 0.091$). Between 220 ms and 280 ms post-stimulus, this interaction was significant ($F(1,9) = 7.4$; $P < 0.024$), as enhanced occipital negativities for cued locations were only present with informative cues ($F(1,9) = 6.66$; $P < 0.03$). At Cz, qualitatively similar cueing effects were observed for informative and uninformative cues: distinct Nd1-Nd2 effects were also elicited in the Uninformative Cue condition (Fig. 1). Fig. 2 shows the cued-uncued difference amplitudes obtained in the Nd1 (160–200 ms interval) and Nd2 (220–280 ms interval) time windows at midline electrodes for informative and uninformative cues. Main effects of cueing were found in the Nd1 interval for Cz and Pz (all $F(1,9) > 28.6$, all $P < 0.001$) and in the Nd2 interval for all midline electrodes (all $F(1,9) > 5.49$, all $P < 0.044$). No interaction between cueing and informativeness was found in the Nd1 interval. In the Nd2 interval, this interaction approached significance at Fz and Pz (both $F(1,9) > 3.45$, both $P < 0.096$), indicating larger Nd2 effects with informative cues.

While occipital cueing effects were found only for informative cues, faster RTs for cued locations and Nd1-Nd2 effects at midline electrodes were also present in the Uninformative Cue condition. Behavioral and electrophysiological effects can thus be obtained with uninformative symbolic precues. It is however possible that

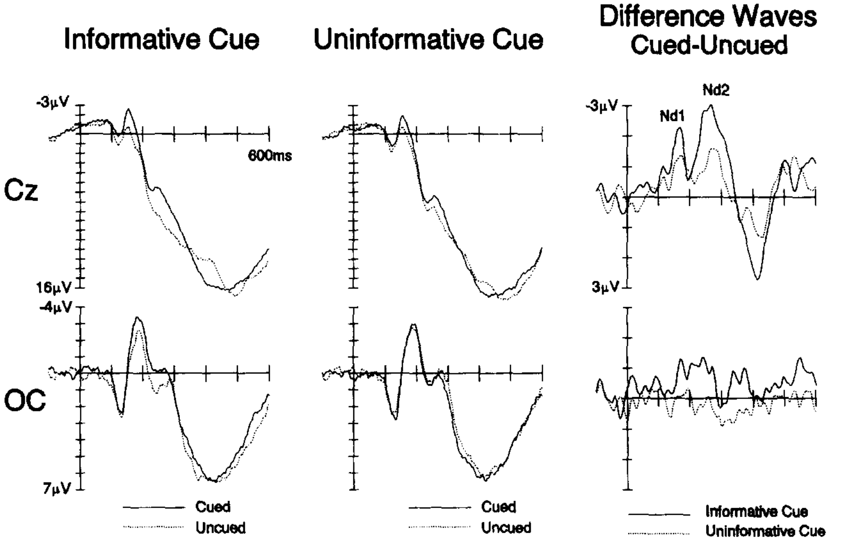

Fig. 1. Grand-average ERPs elicited by targets at cued and uncued locations and difference waves resulting from subtracting ERPs for uncued stimuli from the ERPs elicited by cued stimuli at Cz and occipital sites (collapsed over OL and OR). Left: ERPs elicited by stimuli at cued (solid lines) and uncued locations (dashed lines) in the Informative Cue condition. Middle: ERPs elicited by stimuli at cued (solid lines) and uncued locations (dashed lines) in the Uninformative Cue condition. Right: Cued-uncued difference waveforms for the Informative Cue condition (solid lines) and the Uninformative Cue condition (dashed lines).

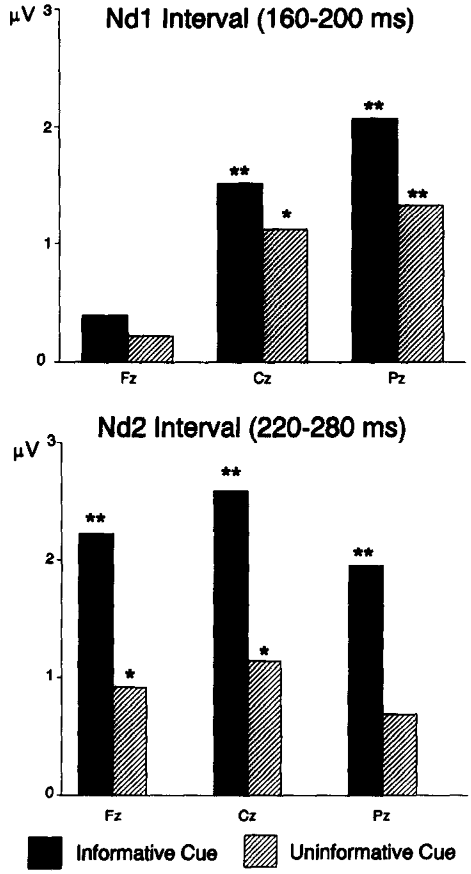

Fig. 2. Mean cued-uncued difference amplitude values at Fz, Cz and Pz for the Nd1 (top) and Nd2 (bottom) time windows together with the significance levels of these differences (**$P < 0.01$; *$P < 0.05$; one-tailed).

these effects simply reflect a generalized tendency to shift attention in the cued direction acquired by those subjects that were first exposed to informative cues. T-tests conducted to compare the effects of uninformative cues for the IU and UI subject groups showed that this was not the case. The RT advantage for cued locations was 13 ms for group IU and 14 ms for group UI ($t(8) < 0.03$), and no significant between-group differences were found for the Nd1-Nd2 effects elicited by uninformative cues (all $t(8) < 1$).

Uninformative symbolic precues may thus bias visual-spatial attention independent of intention. In the literature, the distinction between voluntary and involuntary attention has been closely tied to the difference between orienting processes elicited by symbolic cues and by peripheral onsets. The present results suggest that attention shifts elicited in response to symbolic precues contain both voluntary and involuntary components. Separating voluntary from involuntary attention may thus be more difficult than previously thought.

Acknowledgements

This research was supported by the Max-Planck-Institute for Psychological Research and by a grant from the Deutsche Forschungsgemeinschaft (No. Ei 266/4-1).

References

Eimer, M. (1993). Spatial cueing sensory gating and selective response preparation: an ERP study on visuo-spatial orienting. *Electroencephalography and Clinical Neurophysiology, 88*, 408–420.

Eimer, M. (1994a). 'Sensory gating' as a mechanism for visual-spatial orienting: electrophysiological evidence from trial-by-trial cueing experiments. *Perception & Psychophysics, 55*, 667–675.

Eimer, M. (1994b). An ERP study on visual-spatial priming with peripheral onsets. *Psychophysiology, 31*, 154–163.

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. In L.B. Long and A.D. Baddeley (Eds.), *Attention and Performance* (Vol. IX, pp. 187–203). Hillsdale: Erlbaum.

Mangun, G.R. & Hillyard, S.A. (1991). Modulations of sensory-evoked brain potentials indicate changes in perceptual processing during visual-spatial priming. *Journal of Experimental Psychology: Human Perception and Performance, 17*, 1057–1074.

Posner, M.I., Nissen, M.J. & Ogden, W.C. (1978). Attended and unattended processing modes: the role of set for spatial location. In H.L. Pick and E.J. Saltzman (Eds.), *Modes of Perceiving and Processing Information* (pp. 137–157). Hillsdale, NJ: Erlbaum.

Shepherd, M., Findlay, J.M. & Hockey, R.J. (1986). The relationship between eye movements and spatial attention. *The Quarterly Journal of Experimental Psychology, 38*, 475–491.