Different Effects of Exogenous Cues in a Visual Detection and Discrimination Task: Delayed Attention Withdrawal and/or Speeded Motor Inhibition?

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Abstract

■ Several studies examining spatial attention have found a discrepancy regarding the effects of exogenous cues on reaction times in visual detection and discrimination tasks. Namely, across a wide range of cue–target intervals, responses are slower for targets at cued than at uncued locations (inhibition of return) in detection tasks, whereas responses are faster for targets at cued than at uncued locations (facilitation) in discrimination tasks. Two hypotheses were proposed to account for this discrepancy. First, attention may dwell much longer on the exogenously cued location in discrimination tasks because stimuli have to be identified (i.e., the delayed attention withdrawal hypothesis). Secondly, due to increased motor preparation in detection tasks, cue-induced motor inhibition may rise much faster in these tasks than in

discrimination tasks (i.e., the speeded motor inhibition hypothesis). We examined to what extent these hypotheses can account for effects of exogenous cues in a detection and discrimination task on the extrastriate P1 component, and the onset of motor activation, as indexed by the lateralized readiness potential. Some support was found for the delayed attention withdrawal hypothesis, as task-dependent cueing effects were found on the P1 component. Other aspects of our data, however, indicate that motor inhibition is also involved. Based on these findings, we propose that effects of exogenous cues in detection and discrimination tasks are determined by the interplay between two mechanisms, of which the time courses of activation may be modulated by the specific setting. ■

INTRODUCTION

Sudden visual events in our surrounding space attract our attention automatically, allowing appropriate interactions with our environment. This automatic attraction of our attention to a location in visual space independent from the locus of our eyes is commonly denoted as covert exogenous orienting. In experimental psychology, exogenous orienting is often studied with the Posner paradigm (e.g., Posner & Cohen, 1984). In this paradigm, participants fixate a location while targets occur at other locations, for example, to the left or right from fixation. After cueing one of the target locations at random, for example, by abruptly presenting an irrelevant stimulus near a possible target location, a target that occurs often has to be detected by pressing a key. With short delays (stimulus onset asynchronies [SOAs]) between cue and target onset of about 150 msec, responses are commonly faster for cued than for uncued targets. This facilitatory effect for cued targets on reaction time (RT) is ascribed to attention being directed towards the cued location. With longer SOAs, however, this facilitatory effect reverses to inhibition, that is,

responses to uncued targets become faster. Posner and Cohen (1984) labeled the latter effect as inhibition of return (IOR), referring to the interpretation that there is a tendency to attend to novel (i.e., uncued) locations.

Recently, it has become clear that the presence of facilitation or IOR due to exogenous orienting is highly dependent on the type of task (e.g., Klein, 2000; Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997; for related findings, see Tanaka & Shimojo, 1996, 2000). Lupiáñez, Milán, et al. (1997) compared exogenous orienting effects in visual detection tasks, requiring a simple button press upon target arrival, and discrimination tasks, requiring a choice response on the basis of target identity. They noticed that the crossover point, the SOA between cue and target at which facilitation turns to IOR, occurred much later in discrimination tasks (at about 500 msec) than in detection tasks (200 msec or even earlier, e.g., see Klein, 2000). In another study by Lupiáñez, Miliken, Solano, Weaver, and Tipper (2001), it was shown that the crossover point was additionally later in go/no-go tasks, which also require identification, as compared to detection tasks. Thus, in tasks requiring identification, facilitation has been found across SOAs up to 500 msec, whereas in detection tasks, IOR has already

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been found for SOAs as short as 200 msec. Two explanations may be proposed for these different effects of exogenous cues, which we denoted as the delayed attention withdrawal hypothesis and the speeded motor inhibition hypothesis.

According to the delayed attention withdrawal hypothesis, the later emergence of IOR in discrimination and go/no-go tasks is due to the increased relevance of the identification process in these tasks (Lupiáñez, Miliken, et al., 2001; see also Klein, 2000, p. 141). Specifically, attention may dwell longer on the exogenously cued location (or may be slower to disengage) in tasks requiring stimulus identification, thereby prolonging the facilitatory effect, and, as a consequence, the SOA at which IOR occurs is also delayed. Thus, in line with Posner and Cohen (1984), IOR is assumed to reflect the tendency to attend to novel locations, which simply occurs later in tasks requiring stimulus identification. Behavioral support for the view that IOR is related to a tendency to attend to uncued locations comes from studies employing measures as d' and accuracy (see Klein & Dick, 2002; Handy, Jha, & Mangun, 1999). In addition, some studies employing event-related brain potentials (ERPs) confirmed that IOR is associated with a suppression of perceptual processing in extrastriate visual areas as a reduction of the P1 component for cued as compared to uncued trials was observed (Prime & Ward, 2004; McDonald, Ward, & Kiehl, 1999), although other studies failed to reveal this relationship (Hopfinger & Mangun, 1998, 2001; Eimer, 1994). The critical question remains, however, whether the different effects in detection and discrimination tasks are indeed due to changes in attentional effects on perceptual processing (see also Taylor & Donnelly, 2002).
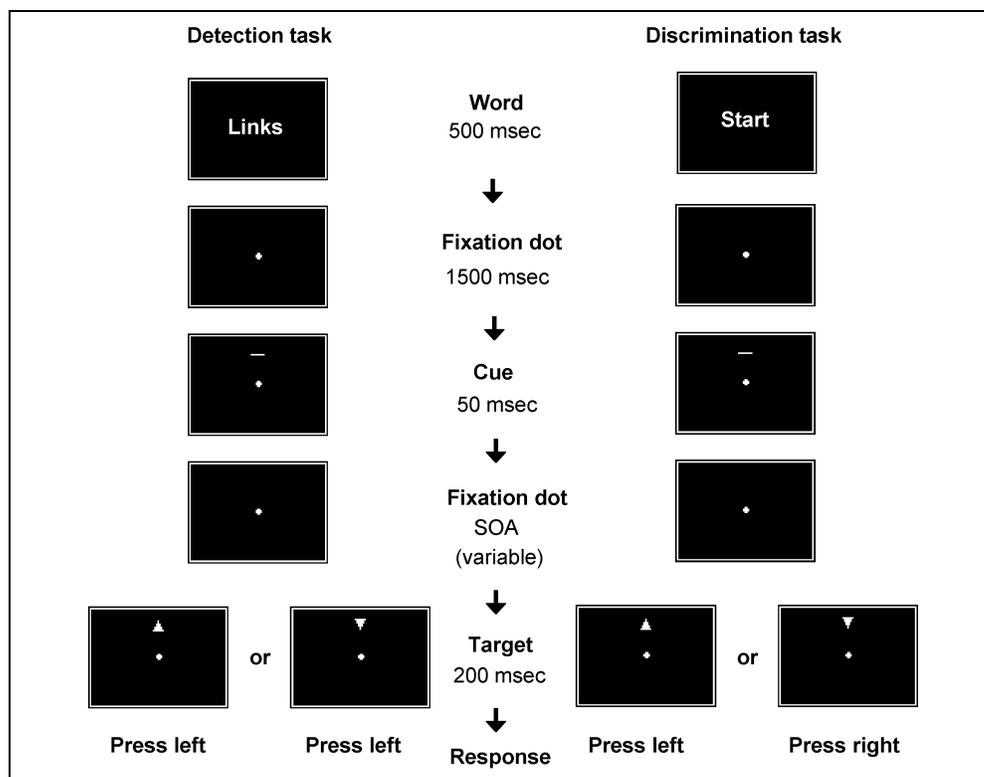
Klein and Taylor (1994) proposed that IOR may also arise from a reluctance to respond to events at the cued location, for example, inhibition may arise in a spatial motor map that directs action. Support for this motor inhibition hypothesis comes from studies in which it was shown that IOR was associated with a more conservative response criterion for cued than for uncued targets (Ivanoff & Klein, 2001; for related support, see Ivanoff, Klein, & Lupiáñez, 2002). In principle, motor inhibition might refer to a direct effect on motor processes themselves, thus, IOR might reflect a delay in the duration of motor processes. However, the proposal forwarded by Klein and Taylor seems to concern an influence on selection of responses towards specific locations in space rather than affecting the duration of motor processes per se. Importantly, detection and discrimination tasks are believed to differ in their initial state of motor preparation, as in detection tasks, motor preparation can already start before target presentation (e.g., see Van der Lubbe, Jaśkowski, Wauschkuhn, & Verleger, 2001; Ilan & Miller, 1999; Low & Miller, 1999; Henderson & Dittrich, 1998; see also Frith & Done, 1986). A possible consequence of these different preparatory

states is that motor inhibition induced by the cue also differs. Namely, due to increased motor preparation in the detection task, motor inhibition as triggered by the cue may rise much faster as compared to discrimination tasks, thereby providing an alternative explanation (i.e., speeded motor inhibition) for IOR at short SOAs in detection tasks.

The goal of the current study was to examine to what extent the delayed attention withdrawal hypothesis and/ or the speeded motor inhibition hypothesis can account for the different effects of exogenous cues in detection and discrimination tasks. We employed a wide range of SOAs for both tasks and focused not only on behavioral measures, but especially on measures derived from the EEG. Namely, posterior ERP components elicited by targets and the lateralized readiness potential (LRP) provide highly specific information about the influence on perceptual and motor processes. Dipole modeling techniques have localized the posterior P1 and N1 ERP components in the extrastriate cortex (Di Russo, Martínez, Sereno, Pitzalis, & Hillyard, 2001), and many studies revealed that spatial attention enhances the P1 component, which indicates that spatial attention modulates perceptual processing in extrastriate visual areas (see also Heinze et al., 1994). In addition, it has been argued that the amplitude of the N1 component may be related with the operation of a voluntary discrimination process taking place along the ventral pathway (e.g., see Hopf, Vogel, Woodman, Heinze, & Luck, 2002; Vogel & Luck, 2000; see also Mangun & Hillyard, 1991). Thus, task-dependent modulations of the P1 and N1 components may provide crucial information for the proposed hypotheses. Another informative measure is the LRP, which provides an index for task-related motor activation. The LRP can be determined by subtracting activity overlying at the site ipsilateral to the required response hand from activity at the site contralateral to the required response hand, for the sites overlying the primary motor areas (i.e., C3 and C4). Applying this procedure both for left- and right-hand responses, and averaging the obtained difference waves, results in the LRP, which subtracts out the activity unrelated to the required response hand (see De Jong, Wierda, Mulder & Mulder, 1988; Gratton, Coles, Sirevaag, Eriksen, & Donchin, 1988). An especially important measure that can be derived from the LRP concerns its onset, the moment at which the LRP deviates from the baseline, as it provides an index for the start of motor processes (e.g., see Osman, Moore, & Ulrich, 2003).

In our experiment (see Figure 1), detected or discriminated targets occurred above or below fixation, and were preceded by an exogenous cue (a stripe) above or below fixation, which provided unpredictable information about the forthcoming target position. Five different SOAs (144, 188, 236, 588, and 940 msec) between cue and target onset were employed. Every trial commenced with a start stimulus, which additionally indi-

Figure 1. An example of the sequence of stimuli from the start of a trial until target presentation. The duration of each stimulus frame is indicated along the time axis. The word ''Links'' (the Dutch word for ''left'') in the detection task indicates that the left button should be pressed when the triangle was presented. In the discrimination task, the word ''Start'' was presented instead of ''Links'' and the required button press was determined by the orientation of the target.

Detection task		Discrimination task	
Links	Word 500 msec	**Start**	
·	Fixation dot 1500 msec	·	
— ·	Cue 50 msec	— ·	
·	Fixation dot SOA (variable)	·	
▲· or ▼·	Target 200 msec	▲· or ▼·	
Press left · Press left	Response	Press left · Press right	

cated the required response hand in the detection task to enable an appropriate determination of baseline activity of the LRP.

According to the delayed attention withdrawal hypothesis, attention dwells much longer on the cued position in the discrimination task than in the detection task, which should be reflected in facilitation at longer SOAs in the discrimination task than in the detection task. Previous research (Lupiáñez, Miliken, et al., 2001; Lupiáñez, Milán, et al., 1997) suggests that the impact of this hypothesized delay of attention withdrawal should be most strongly evident in our experiment with an SOA of 588 msec. In the discrimination task, where attention may still dwell on the cued location at this SOA, an advantage for cued over uncued targets in the magnitude of the attention-related P1 (and possibly N1) component may be found. In the detection task, for which attention should be withdrawn from the cued location by 588 msec, this hypothesis would predict that the uncued P1 should be greater than the cued P1.[1] With regard to the onset of the LRP, facilitatory effects on RT, which are likely to be present for most SOAs in the discrimination task, should, according to this hypothesis, be accompanied by earlier LRP onsets for cued than for uncued targets, whereas IOR, likely to be present for several SOAs in the detection task, should be reflected in earlier LRP onsets for uncued than for cued targets (see Prime & Ward, 2004).

According to the speeded motor inhibition hypothesis, task differences in IOR are due to different states in motor preparation and are related to a delay in selecting responses for cued targets and not to changes in perceptual processing. As a consequence, cueing effects on the P1 component are predicted to be the same for both tasks. Task differences in IOR are likely to be observed for several SOAs, with predominantly IOR for detection tasks and facilitation for discrimination tasks. In case of such task differences, a clear delay of the LRP should be found for cued targets as compared to uncued targets in the detection task, whereas a smaller, or even reversed, effect may be observed in the discrimination task.[2] A possible reason why no reversal may be found in the latter task is that motor inhibition may be involved while attention is still allocated to the target location. Some support that motor inhibition and attentional orienting may be active at the same time comes from a study by Van der Lubbe, Keuss, and Stoffels (1996). They argued that exogenous cues in discrimination tasks, apart from an orienting and alerting effect, also induce motor inhibition, as the tendency to respond to the irrelevant stimulus side (i.e., the Simon effect) was weakened or reversed when cues occurred shortly before target onset, whereas at the same time responses were faster for cued targets as compared to targets preceded by warning cues. According to Ivanoff et al. (2002), however, this response tendency in discrimination tasks is only affected in case of IOR (at long SOAs), which nevertheless supports the view that IOR is localized at the level of response selection.

RESULTS

Behavioral Measures

During the cue–target interval, eye movements were detected in the electrooculogram (EOG) on 2.1% of the trials in the detection task and on 2.4% of the trials in the discrimination task. These trials were excluded from all further analyses.

Reaction Times

Mean correct RTs as a function of task (detection, discrimination), SOA (144, 188, 236, 588, 940 msec), cue (cued, uncued), and target position (above, below) are displayed in Figure 2. Cueing effects per SOA for both tasks, averaged across target position, are indicated in Table 1. Responses were much faster in the detection task (414 msec) than in the discrimination task (651 msec), $F(1,11) = 197.6$, $p < .001$. No cueing effect was observed, $F(1,11) = 1.6$, but we found a strong interaction between task and cue, $F(1,11) = 113.0$, $p < .001$, which reflects IOR (34 msec) in the detection task (see Figure 2), and facilitation (26 msec) in the discrimination task. Further analyses (see Table 1) confirmed that cueing effects differed between tasks for each SOA [Task × Cue, $Fs(1,11) > 40.6$, $p < .001$]. In addition, t tests revealed that facilitation was present for nearly all SOAs in the discrimination task, except for the SOA of 588 msec, whereas IOR was found for all SOAs in the detection task.

An interaction was found between target position and task, $F(1,11) = 12.8$, $p = .004$. In the discrimination task, responses were faster when the target occurred above than when it occurred below fixation (643 vs. 660 msec), but no such effect was present in the detection task (415 vs. 413 msec). Responses were faster when SOA increased, $F(4,44) = 8.4$, $\varepsilon = 0.30$, $p = .009$, but this effect differed between tasks (Task × SOA), $F(4,44) = 9.1$, $\varepsilon = 0.42$, $p = .003$, as a decrease of 62 msec from the shortest to the longest SOA was found in the detection task, whereas in the discrimination task, responses were slowest with an SOA of 144 msec, and fastest with an SOA of 236 msec. Furthermore, the effect of cue differed as a function of SOA, $F(4,44) = 8.0$, $\varepsilon = 0.67$, $p = .001$, which indicated that, averaged across task, costs were largest at an SOA of 588 msec (19 msec), and smallest at an SOA of 144 msec (4 msec).

Proportions Correct and Premature Responses

Proportions correct (PCs) were larger in the detection task (96.3%) than in the discrimination task (94.4%), $F(1,11) = 7.6$, $p = .019$. A main effect of SOA was found, $F(4,44) = 4.1$, $\varepsilon = 0.38$, $p = .045$, and an interaction was observed between task and SOA, $F(4,44) = 16.8$, $\varepsilon = 0.36$, $p < .001$, which reflected a decrease in accuracy as a function of SOA in the detection task (−4.7%), and a

slight increase in the discrimination task (1.2%). An interaction between cue and task, $F(4,44) = 15.7$, $p = .002$, reflected no cueing effect in the detection task (−0.1%), and improved accuracy for cued targets in the discrimination task (0.9%). Cueing effects per task for each SOA are indicated in Table 1. Interactions between task and cue were found for the SOAs of 236 and 588 msec, which on the basis of separate t tests per task (see Table 1), may be ascribed to improved accuracy for cued targets in the discrimination task.

Premature responses occurred seldom, but more often in the detection task (0.42%) than in the discrimination task (0.06%), $F(1,11) = 9.4$, $p = .011$, and also more often when SOA increased, $F(4,44) = 9.1$, $\varepsilon = 0.34$, $p = .005$. The latter effect differed between tasks (SOA × Task), $F(4,44) = 4.9$, $\varepsilon = 0.39$, $p = .028$, as the increase from the shortest to the longest SOA was more pronounced in the detection task (1.4%) than in the discrimination task (0.2%).

EEG Measures

The percentage of trials without artifacts, without detectable eye movements within the critical intervals, and with correct responses for the ERP and the LRP data, amounted to 89% and 90%, respectively.

ERPs

Target ERPs averaged across the PO7 and the PO8 sites and vEOG are displayed in Figure 3 as a function of task, SOA (588 and 940 msec), target position, and cue. Cueing effects for the P1 and N1 components per SOA (averaged across target position), and results of analyses per SOA are displayed in Table 1.

For the P1 component, analyses were performed on the mean amplitudes from 116 to 136 msec after target onset (i.e., a window of 20 msec around the peak), averaged across the PO7 and PO8 electrodes. A strong prediction of the attention withdrawal hypothesis concerned an interaction between task and cue for the SOA of 588 msec, which may be the result of a slight enhancement of the P1 component for cued targets in the discrimination but especially a reversed effect in the detection task. This pattern seems to be present in Figure 3, and the results of our analyses confirmed the predicted interaction, $F(1,11) = 5.8$, $p = .035$. Separate t tests per task (see Table 1) additionally revealed that IOR in the detection task was accompanied with a reduction of the P1 component, but no P1 cueing effect was found in the discrimination task. Control analyses on the vEOG (baselined against −100 to 0 msec before cue onset) for the SOA of 588 msec for the same time window (116–136 msec), revealed no significant interaction between task and cue, $F(1,11) = 0.04$, indicating that the effect on the P1 component is not caused by small differences in gaze direction.
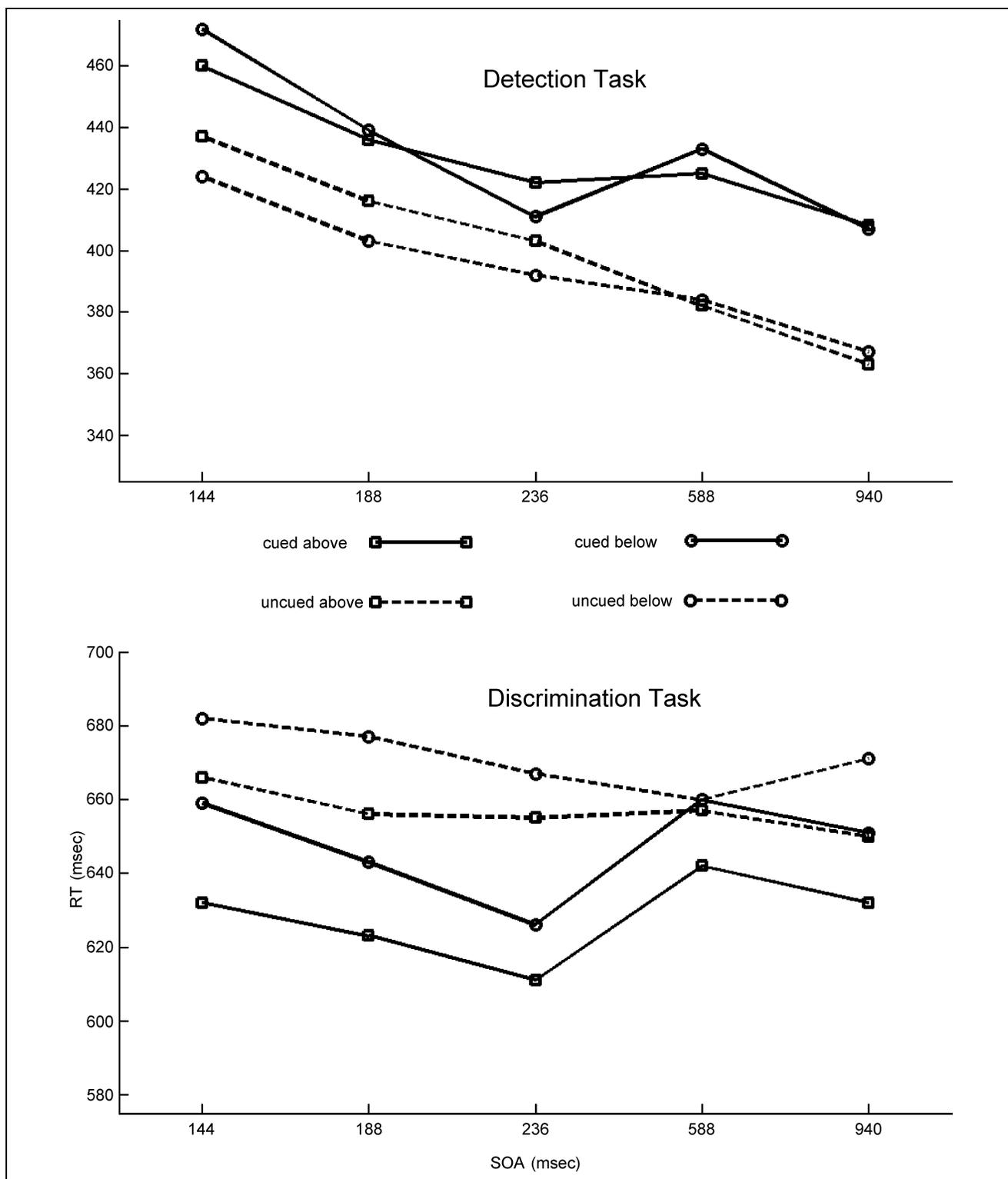
Figure 2. RTs (msec) as a function of SOA (144, 188, 236, 588, and 940 msec), cue (cued/uncued targets), and target position (above/below) for the detection task (top) and the discrimination task (bottom).

Overall analyses with the factors task, SOA (588 and 940 msec), target position, and cue revealed that the P1 component was larger for targets above (2.9 µV) than for targets below fixation (1.5 µV), $F(1,11) = 13.3, p = .004$, but this effect tended to be larger when SOA increased from 588 msec (0.8 µV) to 940 msec (1.6 µV), $F(1,11) = 4.7, p = .053$. The significant interaction between task and cue was nearly significant when both SOAs were

Table 1. Cueing Effects on RT, PCs, and Amplitudes of the P1 and N1 Component in the Detection and Discrimination Tasks for Each SOA

SOA		RT		PC		P1		N1	
		F(1,11)	*Cueing Effect*	*F(1,11)*	*Cueing Effect*	*F(1,11)*	*Cueing Effect*	*F(1,11)*	*Cueing Effect*
144	Task × Cue	**73.6**	**p <.001**	0.4	p = .53				
	Detection		**−35***		−.1				
	Discrimination		**28***		.4				
188	Task × Cue	**40.6**	**p <.001**	0.8	p = .38				
	Detection		**−28***		.0				
	Discrimination		**33***		.9				
236	Task × Cue	**66.7**	**p <.001**	8.4	**p = .01**				
	Detection		**−19***		.0				
	Discrimination		**42***		**2.0***				
588	Task × Cue	**55.1**	**p <.001**	10.4	**p = .008**	5.8	**p = .035**	0.6	p = .46
	Detection		**−46***		.0		**−.80***		−.08
	Discrimination		8		**1.5***		.33		.58
940	Task × Cue	**51.1**	**p <.001**	0.0	p = .85	1.7	p = .22	0.4	p = .53
	Detection		**−43***		−.4		−.19		−.84
	Discrimination		**19***		−.5		**.94***		−.41

For cued targets, facilitation on RT (msec) and improved accuracy on PC (%) are indicated as positive.

Enlargements of the P1 and N1 components (in μV) for cued targets are also indicated as positive. An asterisk (*) for a reported cueing effect indicates that a *t* test (one-tailed) revealed that the effect differed from zero ($p < .05$).

included in the analysis, $F(1,11) = 3.7$, $p = .08$. This seems due to the absence of an interaction between task and cue for the SOA of 940 msec (see Table 1). Nevertheless, separate *t* tests (see Table 1) revealed that the observed facilitation in the discrimination task for the SOA of 940 msec was accompanied with an enhancement of the P1 component for cued targets. Overall analyses also revealed an interaction between SOA and cue, $F(1,11) = 6.6$, $p = .026$, which suggests that the cueing pattern reversed from a reduced P1 for cued targets with the SOA of 588 msec (due to the effect in the detection task) to an increased P1 for cued targets with the longest SOA (due to the effect in the discrimination task). Control analyses on the vEOG including both SOAs for the same time window revealed no target position effect, no Target position × SOA interaction, no Task × Cue interaction, and no SOA × Cue interaction, Fs(1,11) < 0.2, indicating that observed effects cannot be ascribed to small differences in gaze direction.

For the N1 component, analyses were performed on the amplitudes within a window from 170 to 190 msec after target onset, averaged across the PO7 and PO8 sites. A significant increase of the N1 component was observed in the discrimination task as compared to the detection task ($−3.9$ vs. $−2.8$ μV), $F(1,11) = 9.7$, $p = .01$. However, the interaction between task and SOA, $F(1,11) = 5.1$, $p = .045$, indicates that this task effect was only present for the SOA of 588 msec, $F(1,11) = 20.3$, $p = .001$, and no longer for the SOA of 940 msec, $F(1,11) = 1.0$. An interaction between SOA and cue, $F(1,11) = 9.1$, $p = .012$, indicated that the N1 component was slightly more negative for uncued than for cued trials for the SOA of 940 msec ($−4.4$ vs. $−3.7$ μV), but not for the SOA of 588 msec ($−2.5$ vs. $−2.8$ μV). Neither a main effect of cue, $F(1,11) = 1.0$, nor an interaction between cue and task was found, $F(1,11) = 0.6$. Control analyses on the vEOG for the same time window (170–190 msec) revealed no task effect, no Task × SOA interaction, and no SOA × Cue interaction, Fs(1,11) < 1.2.

Lateralized Readiness Potential

Fitting of the LRP on the individual averages was quite successful, although for some participants no acceptable solution could be obtained in a few conditions, which resulted in some missing values. The mean LRPs as a function of SOA and cue per task are displayed in
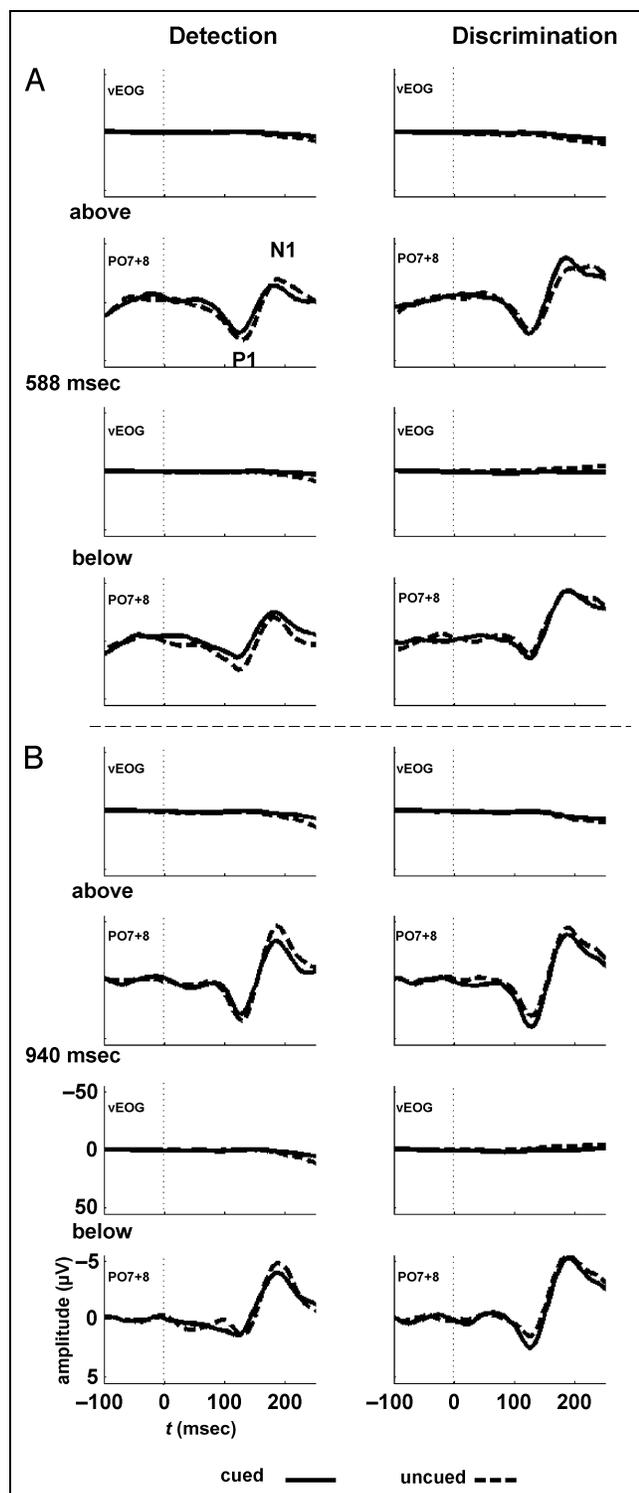
Figure 3. ERPs averaged across the PO7 and the PO8 electrodes (PO7 + 8), and the vEOG as function of cue (cued/uncued targets), target position (above/below), and SOA (588 msec in A and 940 msec in B) in the detection task (left panel) and the discrimination task (right panel), aligned to target onset. ERPs are baselined against −100 to 0 msec before target onset, but vEOG is baselined against −100 to 0 msec before cue onset, to examine whether systematic eye movements were made towards the cued location. The amplitudes of −10 to +10 μV for the vEOG in our experiment corresponds to eye movements of a size of approximately 0.45°.

Figure 4. An ANOVA on baseline activity, as a function of task, SOA (144, 188, 236, 588, and 940 msec), and cue, revealed no significant effects (mean 0.02 μV), $Fs < 1$. An ANOVA on estimated LRP onsets with the factors task, SOA, and cue revealed that the LRP started earlier in the detection task (33 msec) than in the discrimination task (221 msec), $F(1,6) = 95.2$, $p < .001$. In addition, a significant effect of SOA was found, $F(4,24) = 5.2$, $p = .036$, which seems due to the faster rise in motor activity in case of longer SOAs, as the onset decreased from 183 msec with an SOA of 144 to 28 msec with an SOA of 940 msec. A main effect of cue was found reflecting an earlier rise of the LRP for uncued than for cued targets (147 vs. 107 msec), $F(1,6) = 6.9$, $p = .039$, which did not interact with task, $F(1,6) = 1.3$, $p = .30$.

To examine more specifically whether IOR and facilitation are both localized before the start of motor activation, which could support the delayed attention withdrawal hypothesis (see Introduction), we conducted separate analyses per task. Analyses for the detection task revealed a main effect of cue, $F(1,10) = 7.5$, $p = .021$, reflecting the earlier rise of motor activity in case of uncued targets (14 msec) than in case of cued targets (87 msec), which points to a premotoric locus of IOR. A main effect of SOA, $F(4,40) = 6.9$, $p = .012$, indicates that motor activity started earlier when SOA increased (at 147 msec with an SOA of 144 msec, and at −84 msec with an SOA of 940 msec). Separate analyses for the discrimination task, however, revealed neither an effect of cue, $F(1,7) = 0.1$, nor an effect of SOA, $F(4,28) = 1.5$, nor an interaction between cue and SOA, $F(4,28) = 1.1$.

DISCUSSION

The goal of the current study was to provide an answer to the question whether different effects of exogenous cues in visual detection and discrimination tasks occur because of delayed attention withdrawal in discrimination tasks or because of speeded motor inhibition resulting from differences in motor preparation between these tasks. To enable an answer, we focused on indices derived from the EEG that are sensitive to the influence of variables on perceptual processes and the start of motor processes.

In line with earlier studies (Lupiáñez, Miliken, et al., 2001; Lupiáñez, Milán, et al., 1997), we observed a major difference on RT between the two tasks (see Figure 2). In the detection task, we observed IOR for all SOAs, being largest for the SOA of 588 msec (see Table 1). In the discrimination task, we observed facilitation for almost all SOAs, except for the SOA of 588 msec. Some other studies (e.g., Lupiáñez, Miliken, et al., 2000; Lupiáñez, Milán, et al., 1997; Pratt, Kingstone & Koe, 1997) observed IOR with SOAs longer than 500 msec in discrimination tasks, so the facilitation with the SOA of 940 msec in the current study seems remarkable.
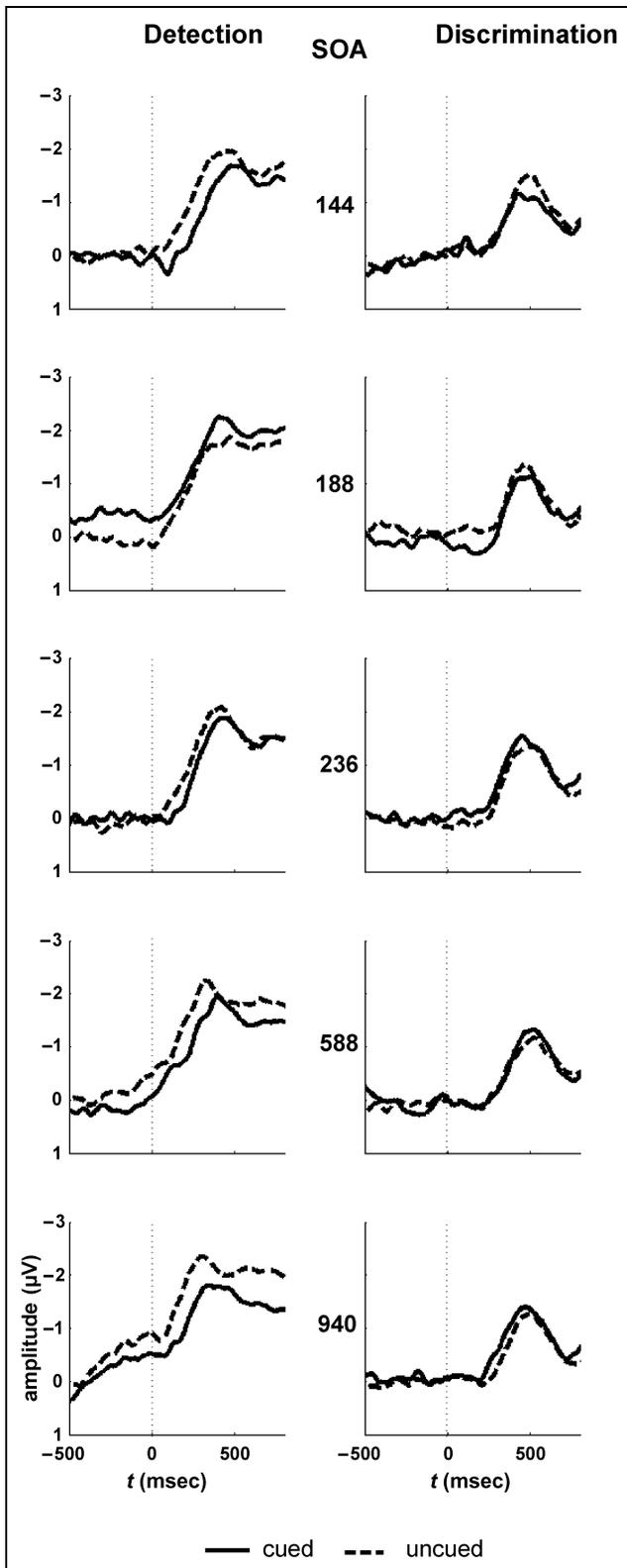
Figure 4. The LRP reflecting changes in motor activity from −500 msec before target onset (at 0 msec) until 800 msec after target onset for the detection task (left panel) and the discrimination task (right panel) as a function of SOA (144, 188, 236, 588, and 940 msec) and cue (cued/uncued targets).

Possibly, IOR is critically dependent on the use of boxes indicating possible target positions (e.g., see Lupiáñez, Milán, et al., 1997), but aspects such as the employment of intermediate fixation cues in other studies may also be crucial for obtaining IOR (see Pratt et al., 1997). Most importantly, the observed behavioral pattern clearly enables more specific tests regarding the proposed hypotheses. In our discrimination task, responses were faster for targets above than for targets below fixation, but not so in the detection task. This discrepancy may reflect better perception for targets above fixation, which is mainly relevant in the discrimination task. The reduced P1 component for targets below fixation seems in line with this interpretation, however, this amplitude reduction may also be due to overlap with the earlier C1 component (e.g., see Di Russo et al., 2001).

One important prediction of the delayed attention withdrawal hypothesis with regard to task-dependent cueing effects on the P1 component for the SOA of 588 msec was confirmed, which suggests that IOR in the detection task is indeed due to a withdrawal of attention, being reflected in a reduced P1 for cued targets. One could argue, however, that the facilitation in the discrimination task for the longest SOA is due to a redirection of attention towards the cued location, as a separate *t* test revealed a slightly enhanced P1 component for cued targets, which raises questions for the necessity of attention withdrawal. Not finding a reduced P1 component for cued targets in the detection task for the SOA of 940 msec seems also problematic for the proposed hypothesis, although one could argue that this is due to insufficient power. Another prediction concerning the premotoric locus of IOR in detection tasks and facilitation in discrimination tasks, was only partially confirmed, as no cueing effect was found on LRP onset in the discrimination task. This observation suggests that there is a stronger relation between stimulus onset and the start of motor processes in the detection task than in the discrimination task. Given the earlier start of motor processes with longer SOAs in the detection task (and also more premature responses), it appears that the build up of motor activation was not based on a full perceptual analysis of the target, which accords with studies mentioned in our introduction. On the basis of the aforementioned findings, also in combination with results from earlier ERP studies that found no relation between effects on the P1 component and IOR (Hopfinger & Mangun, 1998, 2001; Eimer, 1994), it appears that support for the delayed attention withdrawal hypothesis is rather weak. With regard to the speeded motor inhibition hypothesis, IOR should be reflected in a delay of LRP onset for cued as compared to uncued targets, whereas facilitation need not be accompanied by a reversed effect, which accords with our findings. However, the task-dependent cueing effects on the P1 component are evidently not in line

with this hypothesis. Thus, neither of the mentioned hypotheses can solely account for the observed findings.

Based on these findings, we want to advocate the view that effects of exogenous cues in detection and discrimination tasks in general are dependent on the interplay between two mechanisms, each having different temporal characteristics. The first mechanism concerns the modulation of perceptual processes taking place within the extrastriate visual cortex. In principle, the time course of activation is short, with maximal benefits after ±250 msec, although this time course may be modulated by the setting, in line with the delayed attention withdrawal hypothesis. According to Klein (2000) and Lupiáñez, Milán, et al. (1997), time courses may differ when the relevance of attention differs between tasks. Due to more intense allocation of attention in discrimination tasks, attention may dwell longer on the cued location in these tasks, which seems more probably due to an inability to disengage attention from the cued location rather than to a voluntary effort to attend to the cued position. The second mechanism concerns inhibition in a spatial motor map being triggered by the cue, which may occur by means of a modulation along a different route, possibly arising from subcortical areas projecting directly towards the spatial motor map. The latter option would allow for the possibility that motor processes are triggered before output from cortical perceptual processes becomes available. The time course of inhibition is rather slow but may be speeded up when motor preparation is already high, thereby accounting for the early costs in our detection task. Future studies should further disentangle the contribution of the two mechanisms, by focusing on the influence of exogenous cues on the P1 component for short SOAs in case of IOR. In addition, the question may be raised whether IOR critically depends on similarity between cues and targets. For example, can IOR with short SOAs be found in detection tasks with visual targets when auditory spatial cues are employed?

An issue of secondary interest concerns the presumed sensitivity of the visual N1 component for the operation of a voluntary discrimination process (Hopf et al., 2002; Vogel & Luck, 2000). Namely, the N1 component should be larger in discrimination tasks than in detection tasks, independent of variations in motor preparation or alertness. In our study, the N1 was larger in the discrimination task than in the detection task with an SOA of 588 msec, but not with an SOA of 940 msec. Vogel and Luck (2000) revealed that task differences on the N1 component remained in the absence of motor output, when speed stress was varied, and when perceptual load was varied. Speed stress was varied to examine whether the effect might be due to differences in arousal, nevertheless, this manipulation may load on other processes than our SOA manipulation. For example, other studies revealed that speed stress mainly affects motor-related pro-cesses (e.g., see Rinkenauer, Osman, Ulrich, Müller-Gethmann, & Mattes, 2004; Van der Lubbe, Jaśkowski, Wauschkuhn, et al., 2001), whereas effects due to differences in preparation over time as in the current study appear to have multiple sources (e.g., see Van der Lubbe, Los, Jaśkowski, & Verleger, 2004). Possibly, initial differences in preparation between detection and discrimination tasks may reduce when SOA increases, thereby canceling out the task-dependent effect on the N1 component. Thus, alternative hypotheses regarding the N1 task effect may need to be reconsidered.

In conclusion, on the basis of the current findings, we propose that the differential effects of exogenous cues in our detection and discrimination tasks are due to the involvement of two mechanisms with different temporal characteristics. One mechanism concerns the modulation of perceptual processes, being responsible for facilitation in our discrimination task, whereas a second mechanism, that links more directly towards a spatial motor map, may be held responsible for IOR in our detection task.

METHODS

Participants

The study was approved by a local ethics board of the University of Utrecht. Informed consent was obtained from 12 participants (aged 20 ± 2 years, 4 men, normal or corrected-to-normal vision, one left-handed) from the local student population who received € 91 for their voluntary participation.

Stimuli

A trial started with a light gray fixation dot (0.16° × 0.16°) presented in the center of a black screen in front of the participant at a distance of 145 cm. After 1500 msec, a short sound burst of 250 Hz was presented and the fixation dot was simultaneously exchanged for a duration of 500 msec by the Dutch equivalents of ''left'' or ''right'' in the detection task, or ''start'' in the discrimination task (see Figure 1). At 2000 msec after onset of the word, a precue (a light gray stripe of 0.24° × 0.04°, for 60 msec) was presented 0.43° below one of the two possible target positions (2.76° above or below the fixation dot). Next, the target (a triangle, with sides of 0.36°, pointing upwards or downwards) was presented for 200 msec after an SOA with the cue of 144, 188, 236, 588, or 940 msec. The next trial started 1500 msec after a correct response or after a maximum time interval after target offset of 3500 msec.

Tasks

Each task consisted of 1920 trials. In the detection task, participants had to press a button (indicated at the start

of each trial) as fast as possible when the target appeared. In the discrimination task, participants had to press a left or right button for a triangle pointing upwards or downwards, respectively. Responses had to be as fast and accurately as possible. In both tasks, it was emphasized that premature responses should be avoided and that no eye movements were allowed during a trial until a response was made.

Procedure and Design

The experiment was divided over two separate days. On each day, half of each task was performed. Each half of the task consisted of two parts, separated by a break of 15 min. Each part consisted of six blocks of 80 trials, which were separated by a break of 30 sec. The order of the tasks was counterbalanced.

The targets and precues within a block of 80 trials occurred randomly above and below fixation and the position of the precue was unrelated with the target position. Thus, on half of the trials, the target occurred on the cued position and on the other half the target occurred on the uncued position. A complete within-subjects design was used. In both tasks, response side (left or right), cue (cued or uncued), target position (above or below the fixation dot), and SOA (144, 188, 236, 588, or 940 msec) varied randomly from trial to trial. Each trial type was displayed 48 times. Before the start of the experiment participants performed a saccade task in which eyes had to be directed from fixation to one of the target positions to establish appropriate criteria for detecting eye movements. Forty practice trials were given before the experimental blocks started.

Apparatus and Recording

Participants were seated in a comfortable chiropodist armchair in a silenced and darkened chamber. Response buttons were placed on the left and right side of a hand-rest in front of the participant. EEG and EOG were recorded continuously from Ag/AgCl ring electrodes by a BrainAmp amplifier (Brain Products; München, Germany) at a rate of 250 Hz. EEG was measured from the following standard electrode positions (Pivik et al., 1993): FC3, FC4, C3, C1, Cz, C2, C4, P7, P3, Pz, P4, P8, PO7, PO3, POz, PO4, PO8, O1, Oz, and O2. EEG was off-line referenced to the averaged activity measured from electrodes attached to both mastoids. EOG was measured both vertically from above and below the left eye (vEOG) and horizontally from the outer canthi of both eyes (hEOG). Electrode resistance was kept below 5 kΩ. Measured activity was digitally filtered (TC = 5.0 sec, low-pass filter of 100 Hz) by Vision Recorder (1.0b) installed on a Pentium III computer operating under Windows 2000.

Presentation software (version 0.46), installed on a Pentium II computer operating under Windows 98,

controlled stimulus presentation on a 17-in. monitor and sent digital codes to Vision Recorder to indicate the moment and the type of the simultaneously presented stimulus. Button presses registered by Vision Recorder were used for the analysis of the behavioral measures.

Data Analysis

Trials with detectable eye movements (exceeding 60 μV on the hEOG and vEOG channels) from cue onset until target offset, determined by Vision Analyzer (1.03), were removed from all analyses. For the statistical analyses, SPSS (version 10.1.0) was used. Greenhouse–Geisser epsilon correction was performed to adjust the degrees of freedom whenever possible.

Behavioral Measures

Trials with premature responses (RT < 100 msec), too slow responses, or misses (RT > 1500 msec), and incorrect responses were excluded from the RT and EEG analyses. The mean RTs, proportions of correct responses (PCs), and premature responses, determined by using MATLAB 6.1, were evaluated by employing analysis of variance (ANOVAs) with the factors task, target position, cue, and SOA. In addition, separate ANOVAs per SOA were performed on RTs and PCs to establish at what SOA cueing effects differed between tasks, and separate t tests were performed to evaluate cueing effects per task.

EEG Measures

The EEG analysis was performed by using Vision Analyzer. Trials were selected that fulfilled the RT criteria and had no EEG artifacts within the critical intervals in the relevant channels. EEG was corrected for ocular artifacts due to eye movements outside the critical windows around cue and target presentation by employing the method of Gratton, Coles, and Donchin (1983).

In a first analysis, EEGs per task were aligned to target onset for the SOAs of 588 and 940 msec (see footnote 1), separately per target position (above/below) and cue (cued/uncued), and were averaged to construct target ERPs on trials with correct responses and without artifacts (amplitudes exceeding 100 μV, lowest allowed activity 0.1 μV per 50 msec, max allowed voltage step/sampling point 100 μV). ERPs were low-pass filtered (12 Hz, 12 dB/oct) and the baseline was determined from −100 to 0 msec before target onset. Mean amplitudes of the P1 and N1 components were determined from 116 to 136 msec and from 170 to 190 msec, averaged across the PO7 and PO8 electrodes.

To test the specific prediction of the delayed attention withdrawal hypothesis, we examined by means of an ANOVA whether a Cue × Task interaction was found for the P1 component for the SOA of 588 msec. In addition,

one-tailed t tests were performed to examine whether effects were in the predicted direction. ANOVAs were performed to examine the effect of task, SOA, cue, and target position for both the P1 and N1 components. Control analyses were performed on the vEOG for the 116–136 and the 170–190 msec time windows (relative to target onset), baselined against −100 to 0 msec before cue onset, to examine whether effects observed on our ERP components were possibly due to small eye movements in direction of the cue.

In a second analysis, we used EEGs for the C3 and C4 electrodes per response hand for each SOA, cue, averaged across target position on trials with correct responses without artifacts, separately per task. In the detection task, the baseline was determined from −100 to 0 msec before the left/right signal, and a correction was made for the artificial decrease over time because of the employed time constant. In the discrimination task, the baseline was determined from −100 to 0 msec before target onset. The LRP was determined by averaging the contra–ipsilateral difference wave for left-hand (i.e., C4–C3) and right-hand trials (C3–C4), thereby subtracting the activity unrelated to the required response side. A low-pass filter of 4 Hz, 12 dB/oct was applied to eliminate high-frequency artifacts (see Prime & Ward, 2004). Onset of the LRP was determined in MATLAB on the basis of individual averages by fitting two lines by using a least squares method (see Mordkoff & Gianaros, 2000; Schwarzenau, Falkenstein, Hoorman, & Hohnsbein, 1998). The first straight line estimates baseline activity (the first free parameter), which might differ between tasks, and the second line connects the onset of the LRP (the second free parameter) with the peak of the LRP. Time windows employed for the fitting procedure were from −500 to +500 msec after target onset in the detection task, and from −500 to +800 msec after target onset in the discrimination task. ANOVAs were performed on the individually estimated baseline activity and LRP onset to evaluate the influence of the factors task, cue, and SOA. Separate analyses on LRP onset were performed per task to test the prediction of the delayed attentional withdrawal hypothesis according to which IOR and facilitation, as found in detection and discrimination tasks, should be reflected in an effect on LRP onset.

Notes

1. The modulation of posterior components could not be accurately tested for the short SOAs (<250 msec) due to overlap of the cue- and the target-evoked ERPs; therefore, these data will not be detailed. Attempts to remove the overlap by employing a subtraction of the cue ERP as obtained in the long SOA condition, or the ADJAR technique (Woldorff, 1993), were not successful.

2. Note that the presence of a delayed LRP for uncued targets in the detection task with an opposite effect in the discrimination task accompanied with a task-dependent P1-cueing effect would support the delayed attention withdrawal hypothesis.

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