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On the source and scope of priming effects of masked stimuli on endogenous shifts of spatial attention

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ABSTRACT

Unconscious stimuli can influence participants' motor behavior as well as more complex mental processes. Previous cue-priming experiments demonstrated that masked cues can modulate endogenous shifts of spatial attention as measured by choice reaction time tasks. Here, we applied a signal detection task with masked luminance targets to determine the source and the scope of effects of masked stimuli. Target-detection performance was modulated by prime-cue congruency, indicating that prime-cue congruency modulates signal enhancement at early levels of target processing. These effects, however, were only found when the prime was perceptually similar to the cue indicting that primes influence early target processing in an indirect way by facilitating cue processing. Together with previous research we conclude that masked stimuli can modulate perceptual and post-central levels of processing. Findings mark a new limit of the effects of unconscious stimuli which seem to have a smaller scope than conscious stimuli.

1. Introduction

Numerous priming studies have provided evidence for the view that humans can process unconscious visual stimuli to a degree that unconscious information influence motor behavior (e.g., Klotz & Neumann, 1999; Mattler, 2003; Mattler & Fendrich, 2007; Neumann & Klotz, 1994; Schmidt, 2000, 2002; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003, 2004; Wolff, 1989) and also more complex mental operations (e.g., Mattler, 2003, 2005). In these studies a visible imperative stimulus has been preceded by a masked prime stimulus that was either associated to the same (congruent) or to opposite operations (incongruent) as the visible stimulus. A performance difference between incongruent and congruent trials was taken as evidence for an effect of the masked prime stimuli (Wolff, 1989). These findings have been taken as evidence for effects of unconscious stimuli because priming effects have been dissociated from the performance in prime recognition tasks in respect to their time-course (e.g., Mattler, 2003; Vorberg et al., 2003) and individual differences in prime recognition tasks (e.g, Albrecht, Klapötke, & Mattler, 2010; Mattler, 2003). In addition, several studies reported priming effects in conditions where participants' prime recognition performance was at chance levels (e.g., Mattler, 2003; Mattler & Fendrich, 2007; Vorberg et al., 2003). However, the mechanisms underlying these priming effects are still not entirely clear. The present study contributes to this research by demarking the source and scope of the effects of unconscious stimuli on shifts of spatial attention. On the one hand, this relates to the issue of localizing where priming effects of masked stimuli arise (Klapötke, Krüger, & Mattler, 2011; Mattler, 2006). On the other hand, the signal detection task offers an opportunity to determine where the effects of unconscious stimuli end.

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1.1. Priming effects on executive control processes and spatial attention

Spatial attention, like eye movements, supports our ability to select relevant information from the wealth of stimuli in the environment. Psychological research has examined the mechanisms of spatial attention in distinction to eye movements with the spatial cueing paradigm (e.g. Posner, 1980). In these experiments participants have to shift their attention covertly without moving their gaze to detect or identify visual target stimuli which appear at one of several possible spatial locations on a computer monitor. Prior to this shift, participants are instructed to shift their attention according to a previously given cue which informs them about the likely location of the subsequent target stimulus (e.g. on the left or right side of the monitor). On most trials, the target appears at the cued spatial location (validly cued trials) and participants' performance is better than on those few trials were the target appears at the non-cued location (invalidly cued trials). This cueing effect indicates that participants used the cues to shift their attention and were influenced by the validity of the cues. Cueing effects have been observed with cues that appeared at a potential target location but also with centrally presented symbolic cues. However, an early distinction has been made between those processes that are involved in shifts of attention that were triggered by peripheral cues presented at the target location (exogenously triggered shifts) and shifts that follow on cues presented at the central location (endogenously triggered shifts; Jonides, 1981). It has been assumed that exogenously triggered shifts are based on rather automatically operating mechanisms whereas endogenous shifts require an interpretation of the cue and executive control processes which realize the instructed meaning of these stimuli (e.g., Jonides, 1981). More recent evidence suggests, however, that spatially corresponding central cues like arrows and eye gaze can affect spatial attention rather automatically as well (Friesen & Kingstone, 1998; Tipples, 2002). Here, we employed a paradigm with symmetrical central cues designed to induce endogenous shifts of attention which allows an examination of executive control processes.

Recently, several studies have provided evidence that masked stimuli can affect executive control processes (Krüger, Klapötke, Bode, & Mattler, 2013; van Gaal, de Lange, & Cohen, 2012; van Gaal & Lamme, 2012) which were previously considered processes that depend on consciousness (e.g. Dehaene & Naccache, 2001; Jack & Shallice, 2001). For instance, Van Gaal and Lamme (2012) proposed that high-level effects of unconscious stimuli can be explained as resulting from stimuli that are processed in a fast forward sweep which reaches even pre-frontal brain areas. Endogenous orienting of spatial attention, which is sometimes also called voluntary orienting, can be considered one example for executive control processes. Effects of unconscious stimuli on spatial attention have been demonstrated in previous research (see Mulckhuyse & Theeuwes, 2010 for a review). However, these effects were mostly found with peripheral or spatially compatible cues which might affect attention in an involuntary, exogenous manner. In a recent series of experiments we have shown that masked symmetrical primes that were presented in the center of the screen can nonetheless affect shifts of spatial attention (Palmer & Mattler, 2013). In two experiments, a visible cue (square or diamond in outer shape) prompted participants to shift attention to either the left or the right side of the screen. Afterwards, two letters (A and B, one on each side of the monitor) were presented and participants had to indicate in a speeded choice reaction time task whether the letter on the cued side was A or B. Each cue was preceded by a prime stimulus which shared the outer shape of the visible cues (square or diamond shaped). Thus, the outer shape of the prime was either the same as that of the cue (congruent trials) or the two stimuli differed in their outer shape (incongruent trials). On congruent trials, participants responded faster to the target stimuli than on incongruent trials. This finding indicated that masked primes can affect endogenous shifts of spatial attention. Moreover, the variation of the perceptual similarity between prime and cue stimuli revealed that cue-priming effects in this task arise from both, perceptual and post-perceptual levels of processing. However, the scope of the effects of primes remained unclear, because given the priming effects on choice reaction time we cannot distinguish between priming-effects on early or late levels of spatial selection.

1.2. Early and late selection by spatial attention

Validity effects in traditional spatial cueing experiments on signal detection and target discrimination performance have been explained by both early and late selection accounts. Early selection accounts propose that the early perceptual processing of unattended stimuli is halted or attenuated relative to the processing of attended stimuli at early perceptual levels (Kahneman & Treisman, 1984; Laberge & Brown, 1989). According to one view, stimulus processing at attended locations is more efficient because of amplification of neural signals and relatively increased signal-to-noise ratio (e.g., Hawkins et al., 1990; Hillyard, Vogel, & Luck, 1998). Late selection accounts, in contrast, assume that early perceptual processing of attended and unattended stimuli does not differ. Attended input is prioritized only at later stages of processing (e.g., Duncan, 1980; Shaw, 1984). According to one view of late selection accounts, attentional selection occurs at post-perceptual levels of target processing by relative weighting of input for decision or response processes (Shiu & Pashler, 1994).

Based on physiological measures, however, current theories assume that attentional selection can be located at various levels of processing depending on the task at hand (e.g. Desimone & Duncan, 1995; Duncan, 2006). One specific account is the perceptual load theory of attention (Lavie, 1995; Lavie & Tsal, 1994) which assumes that the locus of attentional selection depends on the amount of perceptual load in the given task. According to this view, attentional selection operates at early levels of processing when the perceptual load is high but selection operates on late levels of processing when perceptual load is low. A somewhat similar notion was put forward by Luck and Hillyard (2000) who proposed that attention operates at those stages of stimulus processing at which interference occurs.