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Involuntary attention enhances identification accuracy for unmasked low contrast letters using non-predictive peripheral cues ☆

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ABSTRACT

There is controversy regarding whether or not involuntary attention improves response accuracy at a cued location when the cue is non-predictive and if these cueing effects are dependent on backward masking. Various perceptual and decisional mechanisms of performance enhancement have been proposed, such as signal enhancement, noise reduction, spatial uncertainty reduction, and decisional processes. Herein we review a recent report of mask-dependent accuracy improvements with low contrast stimuli and demonstrate that the experiments contained stimulus artifacts whereby the cue impaired perception of low contrast stimuli, leading to an absence of improved response accuracy with unmasked stimuli. Our experiments corrected these artifacts by implementing an isoluminant cue and increasing its distance relative to the targets. The results demonstrate that cueing effects are robust for unmasked stimuli presented in the periphery, resolving some of the controversy concerning cueing enhancement effects from involuntary attention and mask dependency. Unmasked low contrast and/or short duration stimuli as implemented in these experiments may have a short enough iconic decay that the visual system functions similarly as if a mask were present leading to improved accuracy with a valid cue.

1. Introduction

Cueing paradigms have been implemented as a means of measuring many aspects of visuo-spatial attention. A target stimulus is presented with some probability near to or away from a pre-cue which attracts attention to a spatial location or feature. The observer is required to maintain fixation in the center of the display while covertly attending to the peripheral visual field in search of the target stimulus (Posner, 1980). Attention can be directed voluntarily or involuntarily and there is controversy over the mechanisms by which each form of attention influences the perceptual and decisional processing of attended stimuli.

In a recent publication Kerzel, Gauch, and Buetti (2010) used non-predictive cues and target letters which were either unmasked and low contrast or masked and high contrast. Positive cueing effects were only observed for high contrast masked stimuli, arguing in favor of mask-dependent cueing effects. Interestingly, with unmasked low contrast targets observers performed worse with a valid cue than with an invalid cue. The authors hypothesized that crowding of the cue on the target contributed to the reversed cueing effects and to test this hypothesis they conducted an experiment where the stimuli were presented in the parafovea. They observed significant cueing effects with unmasked stimuli, but only when stimuli were presented in the parafovea where crowding effects are smaller. Since they only observed cueing effects in the periphery with backward masked stimuli but not unmasked stimuli, they concluded that cueing effects from involuntary attention were dependent on the presence of a post mask and were attributable to a mechanism of improved transfer of stimulus information into visual short term memory (VSTM) as proposed in the mask dependent cueing hypothesis (Liu, Wolfgang, & Smith, 2009).

There are some reports of improved accuracy judgment performance from involuntary attention with unmasked stimuli (Cameron, Tai, & Carrasco, 2002; Carrasco, Giordano, & McElree, 2006; Henderson, 1996; Lu & Dosher, 1998), with some studies reporting improved response accuracy with both masked and unmasked stimuli using the same task (Carrasco, Penpeci-Talgar, & Eckstein, 2000; Carrasco, Williams, & Yeshurun, 2002; Henderson, 1991; Yeshurun & Rashal, 2010). However, recent evidence indicates that cueing effects with unmasked stimuli that are not spatially localized can be confounded by spatial uncertainty (Gould, Wolfgang, & Smith, 2007), bringing into question the validity of some prior

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conclusions about cueing effects with unmasked stimuli. In Kerzel, Gauch, and Buetti (2010), it was reported that cueing effects were not due to spatial uncertainty reduction without spatially localizing the target stimuli. The cueing effects were only observed with backward masked stimuli. The present experiments were conducted to determine if target identification accuracy is improved with masked and unmasked stimuli similar to their experiments, but utilizing a luminance modulated cue to minimize masking or crowding of the target stimuli.

We hypothesized (similar to their hypothesis) that in their experiments, the high contrast cue stimulus presented in close proximity to the target stimuli interfered with perception of the low contrast target letters. As such, we predicted that a reduction in the cue contrast and an increase in the distance between the cue and target would produce significant positive cueing effects in the peripheral visual field where they previously did not obtain cueing effects for unmasked stimuli. To obtain support for our hypothesis that cueing effects occur in the periphery with unmasked stimuli, we lowered the contrast of the cue and kept the stimuli in the periphery. A cue with a lower contrast is better suited for low contrast targets, and may produce cueing effects with unmasked stimuli where cueing effects were previously absent. We also tested the effects of the high contrast cue on low contrast targets with masked stimuli, an important condition.

We tested this hypothesis in four experiments with low visibility letters and non-predictive cues. Robust cueing effects were observed with unmasked stimuli using a low contrast cue in two experiments with different temporal parameters. These cueing effects were obtained across a full range of contrast levels covering performance levels from chance guessing to near 100% accuracy. Two additional control experiments confirmed that the high contrast cue forward masking the low contrast targets, thereby lowering target discriminability. The results indicate improved accuracy judgment performance from involuntary attention capture at two different temporal durations without any dependence on backward masking.

2. Experiment 1: Low contrast letter identification with full contrast cue

The first experiment was conducted to verify that cueing effects were absent with the stimulus parameters utilized in their 5th experiment. We conducted the same task but used the method of constant stimuli rather than a staircase procedure to test for cueing effects across a range of target contrasts since some researchers have argued that cueing effects only occur near detection threshold (Kerzel, Gauch, & Buetti, 2010; Kerzel, Zarian, & Souto, 2009; Kerzel, Zarian, Gauch, & Buetti, 2010; Schneider, 2006). It was hypothesized that no cueing effects would be observed using a full contrast cue in close proximity to the low contrast targets since our experimental parameters are nearly identical to theirs.

2.1. Methods

2.1.1. Participants

In each of the experiments reported here, subjects were recruited from the local public community, consisting of students and non-students alike. Recruitment and experimental procedures were approved by the University of California affiliated Institutional Review Board ethics committee. Six subjects (3 male and 3 female; ages ranged from 19 to 32) participated in the experiments, five of which were naïve observers, and one was the primary author. All participants signed an informed consent and were financially compensated for their time.

2.1.2. Apparatus

In all experiments, stimuli were generated, presented, and responses recorded using the WinVis Psychophysical Testing platform, a toolbox for Matlab. Stimuli were presented on a 17 in. Sony Trinitron CRT monitor at a refresh rate of 100 Hz. The display resolution was 1024×768 pixels. The background was grey with an approximate luminance of 13 cd/m^2. Subjects were positioned in an Eyelink II eye tracker with a chin and forehead rest. Subject's eyes were positioned 50 cm from the display resulting in 2.1×2.1 min square pixels. Subjects were told that eye movements were being recorded during each trial and to avoid making eye movements during a trial. The experiment was conducted in moderate brightness indoor lighting conditions.

2.1.3. Stimuli

Monitor luminance linearity was achieved using an 8 bit gamma correcting look up table. A 25% contrast fixation circle 0.2° in size was presented at the center of the screen at the beginning of each trial (Fig. 1). The duration of the fixation circle was randomly selected from 1.5 to 3.0 s for each trial to prevent the subject from being able to predict the cue onset. The fixation target was removed during target presentation, whereas in Kerzel, Gauch, and Buetti (2010) the fixation stimulus was a plus sign and remained displayed throughout the entire experiment. The cue was a full contrast black horizontal line ($1.23° \times 0.27°$) presented 9.7° from fixation. In their experiment two cue sizes were tested, but the results were identical with significantly higher accuracy for invalid cue trials than valid cue trials. Similarly, we presented the same cue stimulus characterized as "large" in their experiments and the target stimulus was also presented at 9.7° eccentricity and

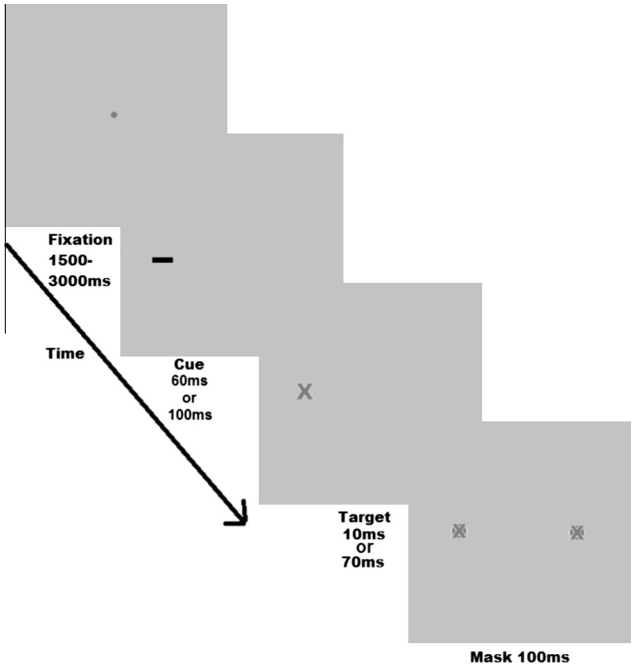

Fig. 1. The sequence of stimuli in a single trial. A valid cue trial is shown. In Experiments 1–3, after a fixation period the cue was presented for 100 ms and immediately followed by a 70 ms, low contrast letter target stimulus. In Experiment 4, the cue duration was 60 ms, followed by a 40 ms blank interval, after which a 10ms target was presented. The target stimulus was presented in isolation and unmasked in Experiments 1, 2, and 4. After the target offset, the subjects reported the target identity in response to a text prompt. The observer's task was to report the identity of the low contrast letter. The peripheral cue was non-predictive of the forthcoming target location, having 50% predictability. Observers reported their response by pressing either 1 or 2 (for O and X respectively). A mask was displayed only in the third experiment, but is shown here for illustrative purposes. The mask had the same contrast as the target stimulus in each trial.