Constraints on attentional orienting by symbolic and abrupt onset cues as revealed through masking

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Thesis Abstract

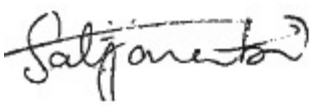
Previous research suggests that the exogenous orienting of spatial attention is an involuntary process; that is, it can occur without intent, effort or awareness. Recent studies, however, have shown that exogenous shifts of attention may, at least to some extent, be reliant on these three factors. On the basis of this finding, the purpose of the present thesis was to tease apart the relative contribution of intentions and conscious awareness, in particular, on the orienting of attention by abrupt onset cues in the periphery and symbolic (i.e., averted eye-gaze and arrow) cues at fixation. To investigate this issue, a visual masking paradigm was used and the task-relevance of cues was manipulated. It was found in Study 1 that both masked and unmasked abrupt onset cues produce a validity effect even when they are uninformative of target location. This pattern of results indicates that abrupt onset cues can exogenously shift attention regardless of intentions and conscious awareness. It was found in Studies 2 – 4 that masked symbolic cues also produce a validity effect when they are uninformative of target location. This effect, however, was restricted to experimental contexts that favoured cue utilization and tasks that allowed for the formation of stimulus-response mappings. Intriguingly, however, this pattern of results did not hold for unmasked symbolic cues. Those cues produced a validity effect regardless of task-relevance and task-type. The findings of Studies 2 – 4, therefore, suggest that the propensity to which symbolic cues shift attention relies on participants having a conscious appreciation of the orienting stimulus. Thus, the findings of the present thesis serve to further our understanding of the constraints imposed on the orienting of visual attention generated by masked abrupt onset and symbolic cues.

Statement of Candidate

I certify that the work in this thesis entitled “Constraints on attentional orienting by symbolic and abrupt onset cues as revealed through masking” has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree to any university or institution other than Macquarie University.

I also certify that the thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my research work and the preparation of the thesis itself have been appropriately acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

The research presented in this thesis was approved by Macquarie University Ethics Review Committee, reference number: HE22FEB2008-R05671.



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About this Thesis

This thesis has been prepared in accordance with the Macquarie University Journal article format thesis guidelines. Each chapter has been written in the format of a self-contained journal article. Where possible, all attempts have been made to minimize any referencing and stylistic inconsistencies between the chapters.

Study 1 has been submitted as:

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General Introduction

Human perception is capacity limited (Duncan, 1980). Observers are, nevertheless, exposed to a vast amount of information in the visual environment. Thus, given that observers cannot process all incoming information, a selection system that filters out the irrelevant input from the relevant input is used. This system is known as selective attention. Numerous studies have shown that selective attention can be directed endogenously to task-relevant objects in the environment or captured exogenously to salient, abrupt onset objects in the environment (e.g., Breitmeyer & Ganz, 1976; Luck, Hillyard, Mouloua & Hawkins, 1996; Posner & Cohen, 1984; Posner & Peterson, 1990; Posner, Rafal, Choate & Vaughan, 1985; Theeuwes & Van der Burg, 2007). Researchers typically differentiate between these two forms of selective attention by referring to the extent by which they depend on three factors; that is, intentions (i.e., search set and expectations), availability of cognitive resources and conscious awareness (for a review see Kiefer, Adams & Zovko, 2012). Classical theorists claim that processes which occur independently of all three factors are involuntary or reflexive (Posner & Snyder, 1975; Schneider & Shiffrin, 1977). Indeed researchers typically classify the exogenous orienting of attention, unlike the endogenous orienting of attention, as one such process (e.g., Jonides & Irwin, 1981; Jonides & Yantis, 1988; Posner & Cohen, 1984; Posner & Peterson, 1990; Schreij, Owens & Theeuwes, 2008; Theeuwes, 1991, 1992; Yantis & Johnson, 1990; Yantis & Jonides, 1984). Recently, however, this widely-held account of exogenous attention as being involuntary has become a topic of great contention. Several researchers, for example, now suggest that objects can exogenously capture attention *only* when they fit the search set of an observer (e.g., Ansorge, Horstmann & Scharlau, 2011; Ansorge & Neumann, 2005; Folk, Remington & Johnston, 1992; Held, Ansorge & Muller, 2010; Scharlau & Ansorge, 2003). This finding suggests that exogenous attentional orienting may not be exclusively involuntary or exclusively voluntary, but, perhaps, combines the features of each.

The aim of the present thesis was, therefore, to ascertain the role of intentions and conscious awareness on exogenous attentional orienting. I, in particular, focused on examining the orienting of attention brought about by abrupt onset and symbolic (i.e., eye-gaze and arrow) cues. Those cues were chosen because extant findings indicate that they exogenously shift attention (e.g., Breitmeyer & Ganz, 1976; Driver et al., 1999; Eimer, 1997; Friesen & Kingstone, 1998; Friesen, Ristic & Kingstone, 2004; Galfano et al., 2012; Jonides, 1981, 2010; Tipples, 2002). To pursue the aim of this thesis, I compared the propensity to which masked (i.e., subliminal) and unmasked (i.e., supraliminal) abrupt onset and symbolic cues orient attention. I was specifically interested in whether or not masked cues can shift attention when they are uninformative of target location; that is, when participants had no incentive to use the information that they provide. If we were to find that masked cues yield a cue validity effect under these conditions then such a result would imply a limited role of intentions and conscious awareness on exogenous attentional orienting. Below I will provide an overview of the debate about whether or not intentions and conscious awareness influence attentional orienting by abrupt onset and symbolic cues. I will also highlight the role of visual masking in informing this debate. As the main part of this thesis, I will present my own studies, and discuss the overall implications of my findings in clarifying the constraints imposed on attentional orienting brought about by abrupt onset and symbolic cues.

The divide between exogenous and endogenous orienting of attention

Selective attention is commonly investigated in the laboratory using the spatial cueing paradigm (Posner, 1980; Posner & Cohen, 1984; for reviews see Carrasco, 2011; Johnston & Dark, 1986). In this paradigm, a cue is presented then followed by a target. The cue can either be valid, such that it provides correct information about target location, or invalid, such that it provides incorrect information about target location. Studies typically show that participants respond faster to the target on valid trials as compared to invalid trials. This difference in response latencies between valid trials and invalid trials (known as the cue validity effect) reflects facilitated processing of the target stimulus due to a (prior) shift in attention to its location. One of the central issues in the study of visual attention is about the *control* of this location selection; that is, the manner in which the allocation of visual attention to a particular location, or shift of visual attention from one location to another location, is conducted.

The orienting of visual attention can, on the one hand, be exogenous. This exogenous capture of attention can be observed in the spatial cueing paradigm (Posner & Cohen, 1984). Typically, in this paradigm, two empty placeholder boxes are presented to the left and right of the screen. The outline of one placeholder box is then briefly brightened and a target is later presented in either box. Participants must respond to this target. Studies show that participants respond faster to validly cued targets relative to neutrally cued targets (e.g., both placeholder boxes brighten), and slower to invalidly cued targets relative to neutrally cued targets. This validity effect is thought to reflect a shift of attention to the peripheral cue that is, importantly, driven by the properties of that stimulus (e.g., abrupt onset, saliency, etc; Jonides & Yantis, 1988; Klein, Kingstone & Pontefract, 1992; Posner, 1980; Posner, Rafal, Choate & Vaughan, 1985). The classification of attentional shifts produced by peripheral cues as stimulus-driven is based on three sets of findings. First, the validity effect produced by peripheral cues emerges rapidly (100 – 120 ms), even when the cue is uninformative of target location (e.g., 50% valid; Muller & Rabbit, 1989). Second, the validity effect produced by peripheral cues emerges even when participants are told that the cue is counter-predictive of target location (e.g., 75% invalid; Tipples, 2008). Third, the validity effect produced by peripheral cues is unaffected by memory load (Jonides, 1981). These findings collectively indicate that the validity effects produced by peripheral cues reflect shifts of spatial attention that are stimulus-driven in so far as they are not reliant on intentions and cognitive resources, respectively; that is, such shifts of attention can occur independently of top-down factors.

In addition to the involuntary (exogenous) capture of attention, visual attention can also be voluntarily, or endogenously, oriented. Endogenous control of attention can also be investigated with the spatial cueing paradigm. In this paradigm, a centrally-presented cue (e.g., the letter "B", which participants are instructed denotes a 'left' location) precedes the appearance of a peripheral target to which participants must respond. The mapping between the cue and spatial location is arbitrary, thus participants need to interpret the stimulus before orienting attention to its conveyed direction. Studies that utilise this paradigm show that participants respond faster to validly cued targets compared to neutrally cued targets, but there is no cost to invalidly cued targets. This validity effect is thought to reflect a goal-driven shift of attention to the location denoted by the central and arbitrary cue (Posner, 1980; Posner, Snyder, & Davidson, 1980; Treisman & Gelade, 1980; Treisman, Sykes, & Gelade, 1977; Wolfe, 1994). The reasoning for this particular classification is three-fold. First, the validity effect produced by central and arbitrary cues emerges slowly (within 300 – 500 ms) and only when the cue is informative of target location (e.g., Müller & Findlay, 1988; Posner & Cohen, 1984). Second, the validity effect produced by central and arbitrary cues does not emerge when they are counter-predictive of target location (e.g., Shin, Marrett & Lambert, 2011). Third, the validity effect produced by central and arbitrary cues is affected by memory load (Jonides, 1981). Hence, when taken together, these findings indicate that the shifts of attention produced by arbitrary, centrally-presented cues are goal-driven in so far as they are reliant on the intentions of an observer and the availability of cognitive resources; that is, endogenous shifts, unlike exogenous shifts, of attention are dependent on top-down factors.

To briefly summarise, numerous studies indicate that selective attention can be exogenously or endogenously oriented. The two forms of attentional orienting can be differentiated by the type of cues that elicit them (central vs. peripheral), or the extent to which (if any) they rely on the top-down settings of an observer (i.e., involuntary vs. voluntary). This latter demarcation between exogenous and endogenous orienting of attention has, however, been recently put into question. Indeed some studies indicate that exogenously oriented attention, much like endogenously oriented attention, is not impervious to top-down factors, particularly the intentions of an observer (e.g., Eimer & Kiss, 2008; Folk, Remington, and Johnston, 1992; Hickey, McDonald & Theeuwes, 2006; Lupiáñez, Milliken, Solano, Weaver, and Tipper, 2001). This evidence indicates that, with a few possible exceptions, both the properties of a stimulus and the intentions of the observer determine a shift in attention.

A review of attentional capture by abrupt onset cues: on its reflexivity and sensitivity to intentions and awareness

Peripheral objects with an abrupt onset, which appear at or near a target location, are particularly effective in exogenously orienting attention to their location. Indeed some researchers assume that these exogenous shifts of attention carried out by abrupt onsets occur involuntarily so as to ensure that observers can quickly detect and react to potential danger in the environment (e.g., Egeth & Yantis, 1997; Schreij et al., 2008). Recently, however, this assumption that exogenous attentional orienting by abrupt onset cues is exclusively involuntary has been put into question (e.g., Bacon & Egeth, 1994; Folk, Remington & Johnston, 1992; Gibson & Kelsey, 1998). The results of those studies have become part of a discussion regarding the role of top-down factors, such as intentions, on attentional capture triggered by abrupt onset cues (for a review see Ruz & Lupianez, 2002). Moreover, given the classical assumption that top-down control by intentions is restricted to processes that are conscious, recent studies have also investigated the role of awareness on attentional shifts produced by abrupt onset cuess (for a review see Mulckhuyse & Theeuwes, 2010).

The role of intentions

According to the standard account of exogenous attentional orienting, the shifts of attention triggered by abrupt onset cues solely depend on the properties of the stimulus (e.g., saliency, eccentricity, etc; cf. Theeuwes, 1992, 1993, 2004), and cannot be overturned by top-down factors. Indeed several studies show that abrupt onset cues produce a validity effect even when they are uninformative (Jonides, 1981; Lambert, Spencer & Mohindra, 1987), or counter-predictive (Tipples, 2008), of target location. Importantly, the facilitation of response latencies at the cued location is transient, and at long cue-target intervals leads to inhibition of the cued location (known as inhibition of return; for a review see Klein, 2000). Hence, given these results, researchers commonly presume that abrupt onsets can exogenously capture attention regardless of an observer's intentions (e.g., Breitmeyer & Ganz, 1976; Franconeri, Simons & Junge, 2004; Theeuwes, 2010; Turatto & Galfano, 2000; Yantis & Jonides, 1984).

There are, however, reasons to think that the intentions of an observer are necessary for the emergence of an attentional shift produced by abrupt onset cues (Bacon & Egeth, 1994; Folk, Remington & Johnston, 1992; Folk, Remington & Wright, 1994; Gibson & Kelsey, 1998). In many studies, for instance, an abrupt onset cue that is similar to the target yields a stronger validity effect as compared to a cue that is dissimilar to the target (e.g., Ansorge & Heumann, 2003; Ansorge, Heumann & Scharlau, 2002; Folk & Remington, 1998, 1999; Folk et al., 1992; Gibson & Kelsey, 1998; Johnson, Hutchinson & Neill, 2001; Lambert, Spencer & Mohindra, 1987; Remington, Folk & McLean, 2001; Scharlau & Ansorge, 2003; Theeuwes, Atchley & Kramer, 1998; Theeuwes & Burger, 1998; Yantis &

Egeth, 1999). This observation indicates that an abrupt onset cue can more effectively capture attention when it matches a set of intentionally searched-for features of a target (for a review see Ruz & Lupianez, 2002). Thus, an abrupt onset cue that is dissimilar to the target is ignored and, consequently, yields a small (or no) validity effect. These findings indicate that the exogenous capture of attention triggered by abrupt onset cues may, in fact, be sensitive to the active intentions of an observer. On the basis of these findings, Folk et al. (1992) suggest that abrupt onsets have appeared to involuntarily capture attention in the spatial cueing paradigm because they have (typically) shared a defining attribute with the target (i.e., onset).

The role of conscious awareness

Classical theorists claim that processes, such as exogenous attentional orienting, can be classified as being truly involuntary only when they occur regardless of intentions, cognitive resources and conscious awareness (e.g., Bargh, 1989; Posner & Snyder, 1975; Scheider & Shiffrin, 1977). The aforementioned studies indicate that intentions may be a necessary component for the effect of abrupt onset cues on attention to emerge in a spatial cueing paradigm. Recent studies have, therefore, attempted to assess the relative contribution of other factors, such as conscious awareness, on attentional capture by abrupt onset cues using visual masking (e.g., Ansorge & Heumann, 2006; Ansorge & Neumann, 2005; Fuchs & Ansorge, 2012; Fuchs, Theeuwes & Ansorge, 2013; Ivanoff & Klein, 2003; McCormick, 1997; Mulckhuyse, Talsma & Theeuwes, 2007; Scharlau & Neumann, 2003). The advantage of this paradigm is that it allows researchers to control both the task relevance and visibility of the abrupt onset cue within the experiment, thus ensuring that any observed validity effects cannot be attributed to intentions and conscious awareness. Mulckhuyse, Talsma and Theeuwes (2007), for example, asked participants to detect a peripheral target (small, black circle) that was preceded by three discs (large, grey circles) at either short or long stimulus onset asynchronies (SOAs). One of those discs appeared earlier and served as the peripheral cue by virtue of its abrupt onset. Participants had difficulty determining which of the three placeholders were first presented; hence, the abrupt onset cue was deemed subliminal. The researchers also ensured that the cue was uninformative of target location and perceptually dissimilar to the target. This design minimised the likelihood of participants developing an incentive to use the cue. Despite these stringent conditions, Mulckhuyse, Talsma and Theeuwes (2007) found that response latencies to detect the target were faster for validly cued than invalidly cued trials in the short SOA condition, and slower for validly cued than invalidly cued trials in the long SOA condition. The emergence of this biphasic effect (facilitation followed by inhibition) suggests that abrupt onset cues do not necessarily rely on intent or awareness to orient attention (for similar conclusions see Fuchs & Ansorge, 2012; Fuchs, Theeuwes & Ansorge, 2013). It is important to note, however, that both the cue and target in this experiment were defined by an onset. Hence, the cue validity effect observed in the experiment of Mulckhuyse, Talsma and Theeuwes (2007) may be attributed to the formation of a search set for 'abrupt onsets' throughout the task by the participants.

In fact, there are reasons to think that the emergence of attentional capture by masked abrupt onset cues is reliant on an observer's intentions (Ansorge & Heumann, 2006; Ansorge, Horstmann & Worschech, 2010; Ansorge & Neumann, 2005). In Experiment 1 of Ansorge and Neumann (2005), for instance, participants were asked to indicate the location of a peripheral target that was preceded by a (metacontrast) masked peripheral cue. Both the target and cue were black in colour. The researchers found that the masked peripheral cue yielded a validity effect even though it was uninformative of target location. However, in Experiment 2, participants were asked to indicate the orientation of a peripheral target that again was preceded by a masked peripheral cue. The target was this time red in colour, though the cue remained black in colour. Interestingly, the results of Experiment 2 showed that the uninformative cue did not produce a validity effect under masked conditions. Based on this finding, the researchers suggested that the masked cue was ignored in Experiment 2 relative to Experiment 1 because it did not contain information about the appropriate response (orientation vs. location) and did not match the expected set of searched for target colours (red vs. black). Hence, the results of Ansorge and Neumann (2005) demonstrated that abrupt onset cues can indeed shift attention when they are masked, but, much like unmasked cues, such orienting occurs only when the cue matches the active task set of a participant. The cue-target SOA in this task (68 ms) was, however, longer than that used by Mulckhuyse et al. (16 ms; 2007); hence, it is possible that Ansorge and Neumann (2005) did not find a validity effect when the abrupt onset cue was task irrelevant because attention at the cued location was rapidly disengaged (Theeuwes, Atchley & Kramer, 2000). Given this SOA difference in experimental design between the studies, the question of whether or not abrupt onset cues can capture attention regardless of intentions and conscious awareness is still outstanding.

SUMMARY

Several studies have shown that peripheral objects with an abrupt onset can trigger exogenous shifts of attention (e.g., Jonides, 1981; Yantis & Jonides, 1984). The role of intentions and conscious awareness in producing these shifts of attention has, however, not yet been ascertained. On the one hand, some studies indicate that masked abrupt onset cues can orient attention regardless of a participant's search set. This pattern of results implies a limited role of intentions and conscious awareness on the capture of attention generated by abrupt onset cues. On the other hand, some studies indicate that the orienting of attention generated by masked abrupt onset cues is conditional (or contingent) on a match between stimulus features and the search set of an observer. This pattern of results implies that intentions, but not conscious awareness, play a role in the capture of attention generated by abrupt onset cues.

Given the existing conflict in the literature, the aim of Study 1 in the present thesis was to ascertain the relative contribution of both intentions and awareness on attentional shifts triggered by abrupt onset cues. This question was investigated using a spatial cueing paradigm in which participants were asked to detect a peripheral target. The target was preceded by a peripheral abrupt onset cue that was masked. Indeed the purpose of masking the cues was to examine whether or not the capacity of abrupt onset cues to shift attention relies on conscious awareness. The task utilised in Study 1 was also designed to guard against the possibility of intentions driving any validity effects by ensuring that the cues were uninformative of target location or response and did not resemble the target in colour or form. If abrupt onset cues capture attention in a truly involuntary manner then the cues utilised in Study 1 should produce rapid facilitation at the short SOA (i.e., 20 ms) and inhibition of return at the long SOA (i.e., 1000 ms). Unlike Ansorge and Neumann (2005), the SOAs we used in our study closely resemble those used by Mulckhuyse, Talsma and Theeuwes (2007). We should, therefore, be able to clarify whether or not masked abrupt onset cues can shift attention when they are irrelevant to the task. Given the stringent task conditions, the emergence of a biphasic effect (facilitation followed by inhibition of return) would serve to demonstrate that abrupt onset cues can orient attention independent of intent and awareness. This finding would imply a limited contribution of those two factors on exogenous attentional capture.

A review of gaze-triggered shifts of attention: on its reflexivity and sensitivity to intentions and awareness

The eye-gaze of another individual is a crucial social stimulus. Eye-gaze provides information about an individual's attentional, mental and emotional states (e.g., Baron-Cohen, 1995; Baron-Cohen et al., 2001). Indeed it has been proposed that humans have so much experience with interpreting the spatial meaning of gaze stimuli such that they can, like abrupt onsets, trigger involuntary shifts of attention awareness (Hommel et al., 2001). The question of whether or not this orienting of attention by averted gaze cues is, as assumed, a truly involuntary process has been recently investigated (for a review see Frischen, 2007). This investigation, like the one for abrupt onset cues, has been carried out by ascertaining the contribution of intentions and conscious awareness on gaze-triggered exogenous orienting.

The role of intentions

Evidence for the proposal that averted eye-gaze cues involuntarily orient attention comes from the spatial cueing paradigm. In this paradigm, a centrally-presented face cue with averted left/right eye-gaze can either validly or invalidly cue the location of a subsequently presented, peripheral target. Researchers typically find that these gaze cues produce a rapid validity effect (i.e., as early as 105 ms; Friesen & Kingstone, 1998). This early validity effect emerges even when the gaze cues are uninformative (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Kunde, Skirde & Weigelt, 2011; Langton & Bruce, 1999), or counter-predictive (e.g., Friesen, Ristic & Kingstone, 2004), of target location. The fact that averted gaze cues can produce rapid validity effects under these conditions has led to the suggestion that they, like abrupt onset cues, trigger exogenous shifts of attention that are impervious to active intentions (e.g., Friesen & Kingstone, 1998; Friesen, Ristic & Kingstone, 2004).

There is some evidence, however, that indicates the shift of attention produced by averted eye-gaze cues does not occur independently of participants' intentions. Vecera and Rizzo (2004), for example, investigated whether or not a patient (EVR) with orbitofrontal damage (a brain region implicated in voluntary control) can orient attention. EVR was asked to complete a spatial cueing task in which he detected a peripherally presented target. The target was preceded by either a peripheral and abrupt onset cue, a central and arbitrary cue (e.g., the words 'left' and 'right'), or an averted eye-gaze cue. The researchers found that EVR was able to orient attention in response to the abrupt onset cues, even though those cues were uninformative of target location. Interestingly, however, EVR was unable to orient attention in response to either the arbitrary or eye-gaze cues, even though they were informative of target location (75% valid). A control group was able to orient attention in response to all three cues. This observed difference in EVR between the cue types was not due to the use of brief SOAs, which would have made it difficult to observe potentially 'sluggish' attentional orienting in the task (Vecera & Rizzo, 2006). Thus, given that the only difference between EVR and the control group was damage to the orbitofrontal cortex, Vecera and Rizzo (2004) concluded that averted eye-gaze cues require top-down control to shift attention. Another indication that the orienting of attention in response to averted eye-gaze cues can be goal-driven is the result of a study in which validity effects emerged only when participants were instructed that the cue reflected a face stimulus (Ristic & Kingstone, 2005). This study showed that no validity effect emerged when participants were instructed that the identical cue was a car as opposed to a face stimulus with averted eye-gaze. The findings of both Vecera and Rizzo (2004, 2006) and Ristic and Kingstone (2005), therefore, indicate that the orienting of attention in response to averted eye-gaze does not always take place by 'default', unlike what was previously assumed. In fact, these findings suggest that gaze-triggered orienting is sensitive to an observer's active intentions (for similar conclusions also see Bentin et al., 2002; Hietanen, Nummenmaa, Nyman, Parkkola & Hamalainen, 2006).

The role of conscious awareness

To further ascertain which other factors of reflexivity are represented by gaze-triggered orienting, Sato, Okada and Toichi (2007) used visual masking. The advantage of visual masking is that it allows researchers to control both the task-relevance and visibility of a cue. This control enables researchers to draw conclusions about which variable combinations of the two factors of reflexivity (intentions and awareness) are required for gaze-triggered orienting to emerge in a spatial cueing task. In their experiment, Sato, Okada and Toichi (2007) asked participants to localise a peripheral target that was preceded by a face cue with an averted eye-gaze. The cue was centrally-presented, uninformative of target location, and either (backward) masked or unmasked. It was expected that if averted eye-gaze cues can involuntarily shift attention then they should be able to produce a validity effect under these conditions. Sato, Okada and Toichi (2007) indeed found that response latencies to localise the target were faster in the valid condition compared to the invalid condition for both the masked and unmasked cues. This pattern of results indicated that averted eye-gaze cues can trigger shifts of attention independent of both intent and awareness. It is important to note, however, that Sato, Okada and Toichi (2007) established the thresholds for subliminal presentation prior to the experiment proper by requiring participants to respond directly to the averted eye-gaze cues. This design may have encouraged participants to incorporate 'eye-gaze' into their search set prior to the experiment. Hence, the cue validity effects observed in the experiment of Sato, Okada and Toichi (2007) may have been driven by active intentions. Due to this possible issue in experimental design, the question of whether or not averted eye-gaze cues can shift attention regardless of intentions and conscious awareness still remains.

SUMMARY

Eye-gaze information is important for inferring the mental states of other individuals. Several researchers have, therefore, predicted that eye-gaze cues would be particularly potent in shifting attention to the gazed-at location. However, although several studies have shown that the shift of attention produced by gaze cues is involuntary (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999), there are several neurophysiological and behavioural findings that indicate the shift of attention produced by these cues may depend on top-down factors, namely the intentions of an observer (e.g., Bentin et al., 2002; Burra, Kerzel, de Gelder & Pegna, *in press*; Ristic & Kingstone, 2005; Vecera & Rizzo, 2006).

As a result of the conflicting findings, the purpose of Studies 2 and 3 were to examine whether or not masked eye-gaze cues can produce a validity effect in an experimental context that does *not* provide participants with an incentive to incorporate the cues into their search set. This question was investigated by using a spatial cueing paradigm in which participants were asked to localise, detect or discriminate a target. In this paradigm, the averted eye-gaze cues were either masked or unmasked. The validity of the unmasked cues was manipulated between experiments, whereas the masked cues remained uninformative of target location. To further guard against the possibility of top-down factors driving any observed validity effects, the averted eye-gaze cues did not resemble the target and, importantly, the cue visibility task was conducted following the experiment. Participants were asked to complete the cue visibility task after the experiment proper to ensure that they were not initially prompted to formulate a task set that included gaze direction, as may have occurred in the Sato and colleagues (2007) study. It was expected that both the masked and unmasked eye-gaze cues would produce a rapid validity effect, even when they are uninformative of target location. If this pattern of results is found in all three tasks then it would indicate that eye-gaze cues can orient attention regardless of intentions and conscious awareness. The results of this investigation would, therefore, serve to clarify the contribution of those two factors on the exogenous orienting of attention triggered by averted eye-gaze cues.

A review of arrow-triggered shifts of attention: on its reflexivity and sensitivity to intentions and awareness

Attending to a spatial location can facilitate responses to objects that appear at that location relative to objects that appear at an unattended location (e.g., Posner & Cohen, 1984; Posner, Snyder & Davidson, 1980). Numerous studies have shown that this attentional benefit can be triggered exogenously by a centrally-presented arrow cue (Eimer, 1997; Hommel, Pratt, Colzato & Godijn, 2001; Ristic, Friesen & Kingstone, 2002; Tipples, 2002). It is assumed that these cues can reflexively direct the attention of an observer to the location of a relevant event in the environment because they are highly learned (Hommel, Pratt, Colzato & Godijn, 2001; Kuhn & Benson, 2007; Tipples, 2002, 2008). Indeed recent studies have sought to investigate the validity of the assumption that arrow-triggered orienting is involuntary by ascertaining the role of an observer's intentions and conscious awareness on these shifts.

The role of intentions

Arrow-triggered attentional orienting has been commonly investigated using the spatial cueing paradigm. In this paradigm, a centrally-presented arrow cue can either validly or invalidly cue the location of a subsequently presented, peripheral target. Interestingly, results observed in the spatial cueing paradigm indicate that participants respond faster to a target that is presented in a validly cued location as opposed to an invalidly cued location when the arrow cue is uninformative of target location (e.g., Tipples, 2002). This validity effect can be produced by arrow cues even when the target appears immediately after the cue onset (e.g., Gibson & Bryant, 2005), as found with averted eye-gaze cues (e.g., Hietanen & Leppanen, 2003), and even when the cues are counter-predictive of target location (e.g., Tipples, 2008). Thus, these findings indicate that arrow cues, like averted eye-gaze cues and abrupt onset cues, can trigger exogenous shifts of attention regardless of an observer's active intentions.

There are several behavioural findings, however, that suggest the effect of arrow cues on attention is relatively amenable to top-down control (e.g., Friesen, Ristic & Kingstone, 2004; Pratt & Hommel, 2003; Ristic, Wright & Kingstone, 2007). In a study conducted by Pratt and Hommel (2003), for example, participants were instructed to respond to a target only if it matched the colour of a precue. The target was preceded by four centrally-presented arrows, each coloured differently and each pointing in a different direction (left, right, up and down). Interestingly, Pratt and Hommel (2003) found that only arrow cues that are of the same colour as the target to which participants must respond triggered a shift in attention. This effect occurred even when the precue was not a coloured square, but, rather, a colour word (e.g., BLUE). Pratt and Hommel (2003) took these results to mean that arrows are *more likely* to shift attention when they possess the task-relevant feature of an expected target. Thus, based on this finding, the researchers suggest that arrow-triggered attentional orienting occurs by default, but the process can be modulated by the active intentions of a participant.

The role of conscious awareness

Based on these prior findings, an obvious follow-up question concerns the role of other factors on the orienting of attention generated by arrow cues. To answer this question, researchers have turned to using visual masking (Gayet et al., 2013; Reuss, Pohl, Kiesel & Kunde, 2011). The advantage of masking is that it allows researchers to examine the relative contribution of both intentions and awareness, which are markers of reflexivity, on attentional orienting. Reuss, Pohl, Kiesel and Kunde (2011), for example, asked participants to identify a peripheral target that was preceded by central unmasked and (metacontrast) masked arrow cues. The cues were uninformative of target location. Intriguingly, Reuss et al. (2011) found that unmasked, but not masked, cues can produce a validity effect. The lack of a validity effect by masked arrow cues was taken to mean that such stimuli do not shift attention when they do not fit the participant's search set. Gayet, Van der Stigchel and Paffen (2013) set out to investigate this interpretation by manipulating the predictive value of arrow cues in a target localisation task. In this task, the (flash-suppressed) masked arrow cues were always uninformative of target location, but the predictive value of the unmasked arrow cues was varied between blocks. This manipulation served to create a context for participants that favours cue utilization. The researchers observed that masked cues produced a validity effect only when they appeared in the context of informative unmasked cues. The researchers concluded on the basis of these findings that masked arrow cues can indeed orient attention, but that those shifts depend on the intentions of a participant. It is important to note, however, that Gayet and colleagues (2013) cannot ascertain whether the influence of the masked arrow cues on behaviour was due to a shift in attention or the preparation of a motor response to the arrow because, in their task, an arrow cue that was informative of target location was also informative of a response; that is, their task conflated spatial attention with response priming.

SUMMARY

Numerous studies suggest that arrow cues can elicit exogenous shifts of attention that are impervious to intentions and conscious awareness because they have an over-learned spatial meaning (e.g., Friesen, Ristic & Kingstone, 2004; Langton & Bruce, 1999). The studies that have sought to clarify the exact contribution (if any) of these two factors on arrow-triggered orienting of attention are, however, unclear in their findings.

The aim of Study 4 was, therefore, to determine whether or not arrow cues can shift attention when masked and uninformative of target location. This question was examined by using a spatial cueing paradigm in which participants were asked to localise or discriminate a target. The discrimination task was used because it can isolate cue validity effects due to spatial attention from cue validity effects due to response formulation. In the task used in Study 4, the arrow cues were either masked or unmasked. The validity of the unmasked cues was manipulated between experiments, whereas the masked cues remained uninformative of target location. To further prevent participants from intending to use the arrow cues, the stimuli did not resemble the target and the cue visibility check was conducted after the experiment proper. It was expected that both the masked and unmasked arrows would produce a rapid validity effect, even when they are uninformative of target location. If this pattern of results emerges in both tasks then it would indicate that arrows can orient attention regardless of intentions and awareness. Indeed such a finding would indicate a limited role of these two factors in arrow-triggered orienting.

Overview of the present thesis

There is considerable debate in the visual attention literature concerning the extent to which selection is controlled by an observer (e.g., for reviews see Burnham, 2007; Corbetta & Schulman, 2002; Ruz & Lupianez, 2002; Theeuwes, 2005). A widely-held assumption is that exogenous attentional orienting, unlike endogenous attentional orienting, is one manner in which information can be selected without the control of an observer; that is, involuntarily (for reviews see Ruz & Lupianez, 2002; Theeuwes, 1991, 1992, 1994, 1995, 2004). The purpose of the present thesis was, therefore, to test this fundamental assumption that exogenous attentional orienting, unlike endogenous attentional orienting, is an involuntary process. This test was carried out by an investigation of the role that intentions and conscious awareness play in the orienting of exogenous attention. These two factors are part of “the four horsemen of automaticity” (Bargh, 1989, 1992); hence, processes that occur independently of intentions and conscious awareness are considered involuntary (Posner & Snyder, 1975).

The studies presented below focus, in particular, on exogenous shifts of attention triggered by two different classes of cues: abrupt onset cues (Study 1) and symbolic cues; that is, averted eye-gaze (Studies 2 and 3) and arrows (Study 4). It is important to note that, in the following studies, the cues were either unmasked or masked. The visibility of the cues was manipulated to investigate the role of conscious awareness on driving cue validity effects. It is also important to note that the masked cues were *always* uninformative of target location or response, and did not resemble the target in colour or form. The cue visibility task was, furthermore, always conducted at the end of the experiment proper. These design choices were made so as to prevent participants from intending to use the masked cues. Though we expected response latencies to the target to be faster on valid trials than invalid trials in the unmasked cue condition, it was not apparent how participants would respond in the masked cue condition. If these masked cues can produce a cueing effect in an experimental context that did not encourage participants to utilize the cues then this result would suggest that exogenous attentional orienting triggered by abrupt onset and symbolic cues is involuntary in so far as it is not contingent or conditional on the intentions and awareness of an observer.

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Study 1

Evidence of exogenous orienting by masked abrupt onset cues

Abstract

Recent studies have shown that subliminal abrupt onset cues can produce exogenous attentional capture. The results of those studies are in conflict, however, when it comes to determining whether or not this exogenous attentional capture effect is defined by early facilitation that is necessarily followed by late inhibition of return. The purpose of the present study was to investigate this controversy. In Experiment 1, we show that a subliminal abrupt onset cue can facilitate target detection at a short cue-target interval. This subliminal, abrupt onset cue, however, did not lead to inhibition of return at intermediate and long cue-target intervals. In Experiment 2 we demonstrated that the emergence of inhibition of return is dependent on the formation of a search set, which is possible only when the abrupt onset cue is supraliminal. Specifically, we showed that supraliminal, but not subliminal, abrupt onset cues facilitated target detection at a short cue-target interval and produced inhibition of return at long cue-target intervals. Our findings, therefore, indicate that subliminal abrupt onset cues produce an attentional capture effect that is not necessarily followed by inhibition of return. These results suggest that the widely held notion that exogenous orienting follows a biphasic pattern, where facilitation is necessarily followed by inhibition of return, should be revised.

Evidence of exogenous orienting by masked abrupt onset cues

As we move through our environment, our sensory systems are bombarded with a tremendous amount of information. Thus, due to the limited capacity of our visual system, we use selective attention to filter out irrelevant from relevant inputs. Selective attention can be directed voluntarily (endogenously) to task-relevant objects in our environment or it can be captured involuntarily (exogenously) by salient objects in our environment. This latter form of attention is commonly investigated in the laboratory using the spatial cueing paradigm. In this paradigm, participants fixate at the centre of the screen while an uninformative, abrupt onset cue appears in the periphery. Studies show that when there is a short delay between cue offset and target onset observers are faster to respond to validly cued targets (i.e., cue and target appear in similar locations) than invalidly cued targets (i.e., cue and target appear in opposite locations). This phenomenon, known as the *facilitation effect*, is thought to reflect a shift of attention to the cued location that occurred prior to target presentation (Posner, 1980). Intriguingly, studies also show that when there is a long delay between cue offset and target onset observers are slower to respond to validly cued targets than invalidly cued targets. This phenomenon, known as *inhibition of return*, is thought to reflect inhibition of a previously attended location (Posner, Rafal, Choate & Vaughan, 1985). The biphasic pattern (i.e., facilitation followed by inhibition of return) is commonly considered an indicator of exogenous attentional capture (e.g., Maylor, 1985; Taylor & Klein, 1998a), even though there is some evidence to suggest that the pattern does not necessarily emerge when attention is oriented exogenously (e.g., Danziger, Kingstone & Snyder, 1998; Enns & Richards, 1997).

Of particular importance for the present study is the recent debate about whether or not an abrupt onset cue can exogenously capture attention without awareness, and the diagnostic role that the inhibition of return phenomenon has played in this debate. McCormick (1997) was the first to examine this issue. In the McCormick (1997) task, participants were asked to discriminate between two target letters ('X' or 'O'). These target letters were preceded by a peripheral cue that was presented either above or below participants' threshold of awareness. The cue was counter-predictive of target location in that it appeared more often at the location opposite to where the target was later presented. Participants were asked to indicate whether or not they had perceived the cue at the end of each trial as a measure of cue awareness. At short SOAs (80 and 500 ms; Experiments 1 – 3), it was expected that the subliminal cue would produce an exogenous shift of attention to the cued location, which would be marked by faster response latencies to discriminate the target on valid than on invalid trials. Indeed this pattern of results is what was found, thus indicating that subliminal cues can produce a facilitation effect. McCormick (1997) also hypothesised that if subliminal cues can exogenously capture attention then the facilitation effect found at the short SOAs should reverse when the cue target SOA was extended (1000 ms; Experiment 3). Interestingly, however, McCormick (1997) found no inhibition of return effect at this long SOA. It was reasoned that the subliminal cues did not produce inhibition of return at this long SOA because participants set up a particular strategy to search for the informative cue. Nevertheless, McCormick (1997) interpreted the emergence of early facilitation, on its own, as evidence that abrupt onset cues can exogenously capture attention without awareness.

An important limitation of the McCormick (1997) study, however, is that it did not fulfil the requirement for exogenous attentional capture as set out by Yantis and Egeth (1999, p. 663), "one can only speak of attentional capture in a purely stimulus-driven fashion when the stimulus feature in question is completely task-irrelevant". McCormick's (1997) study did not meet this criterion because the cue was informative of target location, and cue awareness was measured after each trial. This experimental design may have led participants to think that the cue is task-relevant, and, as a result, incorporate the cues into their search set. Indeed this suggestion is not novel to the masked priming literature where it is known that masked priming effects are strongly modulated by top-down strategies (Ansorge & Neumann, 2005; Dehaene et al., 1998; Kiesel et al., 2006). Thus, the facilitation effect observed in the subliminal condition of the McCormick (1997) study may have been driven by top-down, rather than bottom-up, factors (i.e., intentions). Ivanoff and Klein (2003) set out to resolve this issue in their study by manipulating the time at which cue report was conducted within a go/no-go task. In this task, participants were presented with either a peripheral go target (black circle), to which participants had to respond, or a peripheral no-go target (grey circle), to which participants were not required to respond. The targets were preceded by an uninformative, peripheral cue that was either supraliminal or subliminal. Participants were required to complete two experiments: one in which cue awareness was assessed at the end of each trial, as in McCormick (1997), and one in which cue awareness was assessed at the end of the experiment. Ivanoff and Klein (2003) found that supraliminal cues produced the typical biphasic effect (facilitation followed by inhibition of return) in both the cue report and no cue report conditions. For subliminal cues, however, the researchers found evidence of target facilitation at the short SOA (105 ms), but no inhibition of return at the long SOA (1005 ms), when cue report was part of the task. This result is in-line with that of McCormick (1997). Ivanoff and Klein (2003) suggested that inhibition of return is absent in this condition because, given that that the cue is task-relevant, participants fail to disengage from the cued location. Interestingly, when cue report was not part of the task, the researchers found evidence of inhibition of return at the long SOA, but no facilitation at the short SOA. Ivanoff and Klein (2003) argued that the abrupt onset cue was task-irrelevant in the no cue report condition, thus disengagement from the cued location occurred rapidly, which caused facilitation to combine with inhibition of return. The researchers concluded that the absence of facilitation along with the subsequent emergence of inhibition of return in this no cue report condition nevertheless indicates that abrupt onset cues can exogenously capture attention (hence leading to inhibition) without awareness.

Although Ivanoff and Klein (2003) showed evidence of attentional capture without awareness in a task that did not encourage participants to utilise the cues, it is important to note that the researchers informed participants of the cues prior to the experiment. This task design is open to the same criticism levied at the McCormick (1997) study; that is, given participants knew a cue will appear in the task, they may have intentionally included the cue as part of their task set. Indeed Van den Bussche, Van den Noortgate and Reynvoet (2009) suggest that the exact task instructions participants receive prior to a task may affect observed priming effects, and Al-Janabi and Finkbeiner (2012) show that knowledge of a cue prior to the experiment proper affects subsequent masked cueing effects. Hence, in order to verify that exogenous attentional capture is triggered entirely by the stimulus itself, the task must be devoid of such strategic factors. Given the presence of these methodological issues in the masked cueing literature, Mulckhuyse, Talsma and Theeuwes (2007) sought to convincingly demonstrate exogenous attentional capture by subliminal abrupt onset cues. In their study, Mulckhuyse et al. (2007) used a paradigm that was carefully designed so as to limit the possibility of top-down effects; that is, the cue did not resemble the target, the cue was uninformative of the response and target location, cue report was not part of the main experiment, and participants were not informed of the cue prior to the experiment. In their task, participants were asked to detect a target (small black circle) that was preceded by three discs (large grey circles) at either short (16 ms) or long (1000 ms) SOAs. Critically, one of those discs appeared earlier than the other two and served as the spatial cue by virtue of its sudden onset. It was expected that this cue would not be consciously perceived because the other two discs followed immediately after its presentation, thus giving the impression that all three discs were simultaneously presented. Mulckhuyse et al. (2007) found that response latencies to detect the target were faster for valid than invalid cues in the short SOA condition and slower for valid than invalid cues in the long SOA condition. Given that the researchers had attempted to control for top-down factors, they took the emergence of this biphasic pattern as indication that abrupt onset cues can capture attention without awareness.

Unfortunately, the finding reported by Mulckhuyse, Talsma and Theeuwes (2007) has not been easy to reproduce. Specifically, Fuchs and Ansorge (2012) used the same paradigm as Mulckhuyse, Talsma and Theeuwes (2007), but, interestingly, did not replicate the biphasic pattern of results under subliminal conditions. These researchers showed in Experiment 1 of their study that subliminal, abrupt onset cues lead to facilitation in the short SOA condition, but this effect was not followed by inhibition of return in the long SOA condition. Given that this initial result was at odds with that of Mulckhuyse, Talsma and Theeuwes (2007), Fuchs and Ansorge (2012) included 5 intermediate SOAs in Experiment 2 of their study to address the possibility that an observable inhibition of return effect was present at other SOAs. Again, consistent with their Experiment 1, the results of Experiment 2 revealed no inhibition of return effect in the intermediate SOA conditions (50, 100, 200, 300 and 700 ms). These findings of Fuchs and Ansorge (2012) are important because they are indicative of a disassociation between the emergence of facilitation and the emergence of inhibition under subliminal conditions. Specifically, the researchers took the emergence of early facilitation (on its own) as indication that their subliminal cues had exogenously captured attention. Moreover, the researchers took the absence of inhibition of return in their study as indication that perhaps this effect is not a necessary consequence of exogenous attentional capture (for a similar conclusion also see Fuchs, Theeuwes & Ansorge, 2013).

Together, the prior studies show that, while a facilitation effect can be found with subliminal cues, the emergence of inhibition of return by such cues is inconsistent. Although the aforementioned researchers all concluded that exogenous capture of attention can occur without awareness, the fact that inhibition of return was inconsistently observed is important. Specifically, the conflicting findings suggest that the (biphasic) assumption of facilitation necessarily leading to inhibition of return is misleading. This issue is relevant given that there is a tendency in the literature to use inhibition of return as a litmus test in establishing whether or not a particular object exogenously captures attention (for examples of such studies see Theeuwes & Godijn, 2002; Theeuwes & Van der Stigchel, 2006). Indeed if it is the case that facilitation and inhibition of return are not tightly coupled then one could not rely on the emergence of one effect, for example inhibition of return, to infer that the other effect, for example, facilitation, has also emerged. This precise rationale, however, is used given the prevailing assumption that facilitation and inhibition of return are two parts of a single biphasic process (Lambert & Hockey, 1991; Rafal et al., 1989; Rafal & Henik, 1994).

Hence, given the amount of weight placed on observing a biphasic pattern when investigating exogenous capture of attention, in addition to the fact that the effect is inconsistently observed under subliminal conditions, the aim of the present study was to reproduce the Mulckhuyse et al. (2007) finding of facilitation followed by inhibition of return under subliminal conditions. To pursue our aim, we asked participants to detect a peripheral target (a circle) that was preceded by a peripheral, abrupt onset cue (a triangle) at either a short (30 ms), intermediate (500 ms) or long (1000 ms) SOA. Unlike Mulckhuyse et al. (2007), we used a variant of sandwich masking instead of flicker fusion to mask the cue. The purpose of using a different masking procedure was to better control for cue visibility given that participants were able to objectively discriminate between the cues in the Fuchs and Ansorge (2012) study. This limitation observed in the Fuchs and Ansorge (2012) study indicates that the Mulckhuyse et al. (2007) task, which depends on the timing of the placeholder array to 'mask' cue onset, is perhaps not ideal for controlling cue visibility. Hence, in our task, the cue was forward and backward masked by an array of randomly generated and positioned shapes (e.g., Finkbeiner, 2011). Indeed initial pilot testing confirmed that our sandwich masking procedure was effective in preventing cue awareness. Furthermore, to guard against the possibility of top-down factors driving our cueing effects, we, like the previous researchers, ensured that our cues did not resemble the target and that they were uninformative of the upcoming target location and response. It is important to note, however, that it may have been possible for participants to set up a search set for ‘onsets’ throughout the task given that the target, like the cue, is marked by an onset in the intermediate and long SOAs. This possibility was also present in the very study that the present research aims to replicate and extend (i.e., Mulckhuyse, Talsma & Theeuwes, 2007).

If we were to find evidence of facilitation at the short SOA that is followed by inhibition of return at the longer SOAs then this pattern of results would replicate the results of Mulckhuyse et al. (2007) and, in turn, provide support for the standard account, which holds that inhibition of return is a necessary consequence of exogenous attentional capture. In contrast, if we were to observe facilitation at the short SOA, but no inhibition of return at longer SOAs, then this pattern of results would replicate the findings reported by Fuchs and Ansorge (2012) and, in turn, further reinforce their repudiation of using inhibition of return as a diagnostic of exogenous capture. To anticipate our results, we observed, in Experiment 1, evidence of facilitation at the short SOA, but no inhibition of return at the intermediate and long SOAs. In Experiment 2 we modified the task previously used by including a supraliminal abrupt onset cue. Under these conditions, we observed that both subliminal and supraliminal cues produced facilitation, but that only the supraliminal cue produced inhibition of return. Thus, following Fuchs and Ansorge (2012), we too interpret our findings to indicate that subliminal abrupt onset cues can exogenously capture attention and that inhibition of return is not a necessary consequence of this capture. We also suggest that inhibition of return may be limited to contexts in which knowledge of the cue can be attained.

Experiment 1

The purpose of Experiment 1 was to confirm that subliminal, abrupt onset cues produce facilitation at a short SOA then inhibition of return at longer SOAs. This biphasic effect has only been previously observed under subliminal conditions by Mulckhuyse et al. (2007).

Method

Participants. Twenty participants (9 males and 11 females; mean + SD age, 24 + 6 years) at Macquarie University participated in the study for course credit. Informed consent was obtained from all participants.

Stimuli. The forward and backward mask arrays consisted of overlapping regular polygon outlines constrained within 4.9° x 3.9° rectangles of which 70% were grey (RGB 185, 185, 185) and 30% were white (RGB 255, 255, 255). The outlines had between 3 to 8 sides. A single grey circle was used as the cue and a single white triangle was used as the target. The cue and target were 2.3° in height. A white fixation point (0.5°) was used. All stimuli were presented on a grey background.

Procedure. The factors manipulated in this task were SOA (30 ms, 500 ms, 1000 ms) and Cue Validity (valid, invalid). There were 50 test trials in each of the six conditions. Participants were required to complete 120 practice trials and 300 experimental trials. The trial structure was as follows: a white fixation cross appeared at the centre of the screen for 950 ms along with a forward mask array (7.3° to the left and right of fixation). At the offset of both the fixation cross and forward mask array, the cue appeared. The cue was presented for 30 ms in either the left or right screen location. This peripheral cue was uninformative of target location (50% valid). At the shortest SOA (30 ms), the cue was immediately followed by the backward mask array and target. At the intermediate SOA (500 ms), the cue was immediately followed by the backward mask array, which persisted for 470 ms before the target appeared. At the longest SOA (1000 ms), the cue was immediately followed by the backward mask array, which persisted for 970 ms before the target appeared. At this SOA, the fixation cross re-appeared 870 ms after cue offset. The fixation cross was presented for 50 ms and served as a reorienting cue. This reorienting cue was used to orient attention away from the cued location at the long SOA to ensure that the facilitative effects of the cue do not obscure inhibition of return. The target then appeared after 50 ms for 100 ms on either the left or right screen locations. Participants were required to detect the target by pressing a button. Trials ended as soon as a response was made, or 1000 ms after the offset of the target if no response was made. Twenty percent of all trials were catch trials in which the target did not appear and no response was required. All trials were randomised. See Fig. 1.

Participants completed 60 trials that tested for cue visibility after the experiment. These trials were the same as the detection task, except that, in addition to responding to the target, participants were asked to identify the side in which the cue appeared by clicking on a circle positioned to the left or a circle positioned to the right. The same trial structure as the experiment proper was used so that participants' perception of the cues under those exact task conditions can be ascertained. There were no catch trials in this task. Feedback was not given.

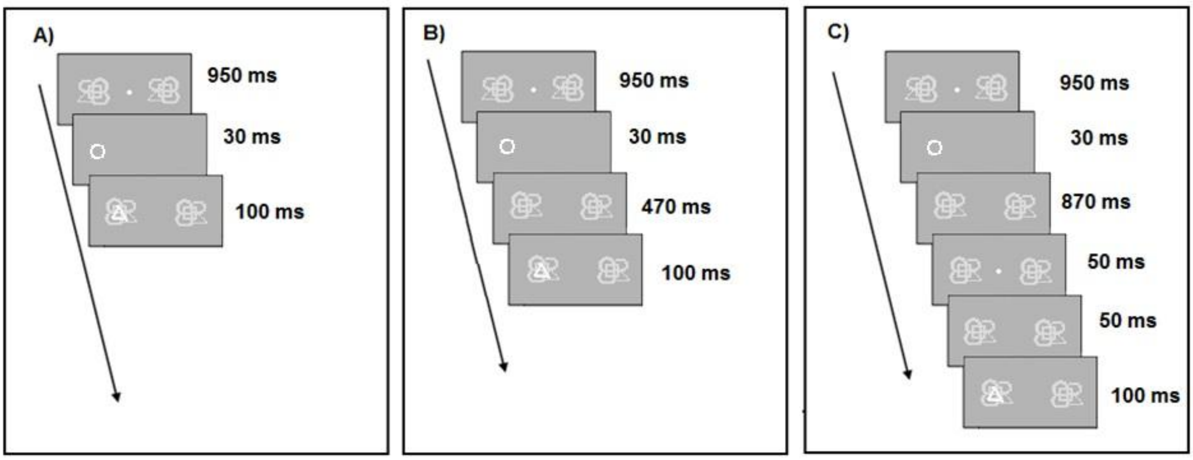

Figure 1. This figure depicts the sequence of displays for Experiment 1: **a)** short SOA **b)** intermediate SOA and **c)** long SOA. The figure represents a valid trial in which the location of the cue predicts target location.

Results

Response latencies. Mean accuracy on the catch trials for the 30 ms, 500 ms and 1000 ms SOAs was 98% (*SD* = 3%), 96% (*SD* = 5%), and 81.25% (*SD* = 13%), respectively. Catch trials were discarded from data analysis. Responses that were below 100 ms (0.75%) and greater than 1, 000 ms (0.88%) were discarded. These trials were categorised as anticipations and misses, respectively. The dependent variable was mean reaction time for correct responses. A 3 x 2 ANOVA was conducted on response latencies to detect the target with SOA (30 ms, 500 ms, 1000 ms) and Cue Validity (valid, invalid) as repeated-measures factors. We found a main effect of SOA, $F(1, 19) = 136.74$, $p < 0.0001$, $\eta^2p = 0.89$, with longer response latencies to detect the target in the 30 ms condition (*M* = 597 ms, *SD* = 47 ms) than in the 500 ms (*M* = 499 ms, *SD* = 48 ms) and 1000 ms (*M* = 478 ms, *SD* = 59 ms) conditions. There also was a significant main effect of Cue Validity, $F(1, 19) = 7.58$ $p < 0.05$, $\eta^2p = 0.29$, with shorter response latencies to detect the target on valid trials (*M* = 522 ms, *SD* = 49 ms) compared to invalid trials (*M* = 527 ms, *SD* = 47 ms). There was, more importantly, a significant interaction between SOA and Cue Validity, $F(1, 19) = 6.13$, $p < 0.01$, $\eta^2p = 0.24$. As can be seen in Figure 2, at the short SOA of 30 ms, participants' response latencies to detect the target were faster when the target followed a valid cue (*M* = 589 ms, *SD* = 47 ms) than an invalid cue (*M* = 605 ms, *SD* = 49 ms), $t(19) = 3.74$, $p < 0.001$. However, at the intermediate SOA of 500 ms, validly cued targets (*M* = 503, *SD* = 48) were not responded to differently than invalidly cued targets (*M* = 496 ms, *SD* = 49 ms), $t(19) = 1.95$, $p = 0.07$. Similarly, at the long SOA of 1000 ms, there was no difference in responses to validly cued targets (*M* = 475 ms, *SD* = 62 ms) and invalidly cued targets (*M* = 481 ms, *SD* = 59 ms), $t(19) = 1.14$, $p = 0.27$. These results demonstrate that subliminal abrupt onset cues produce a facilitation effect, which, importantly, is not necessarily followed by inhibition of return.

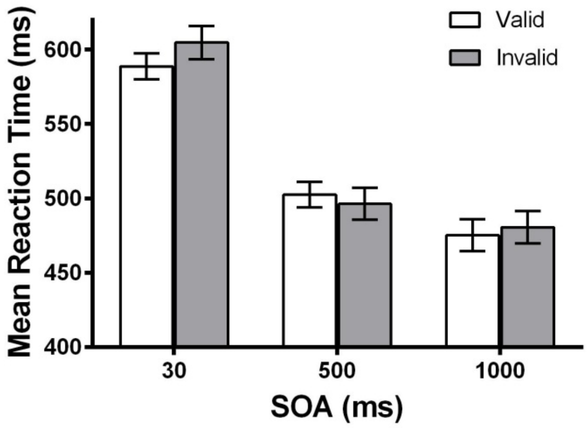

Figure 2. Mean response latencies to detecting the target at each SOA (with CI bars) in Experiment 1.

Cue Visibility. Percent accurate localisation of the subliminal peripheral cue was 50% (*d'* = - 0.009, *SD* = 0.48), which was not significantly different from chance, t (19) = 0.08, *p* = 0.94. The *d'* value was calculated using the following equation: z(hit rate) – z(false alarm rate), where z is the inverse cumulative of the normal distribution (Green & Swets, 1966).

Discussion

The purpose of Experiment 1 was to replicate the findings of Mulckhuyse et al. (2007). We observed evidence of facilitation at the short SOA that was not followed by inhibition of return (or any other effect) at the intermediate and long SOAs. This result is consistent with Experiment 2 of Fuchs and Ansorge (2012), which indicates that subliminal cues produce a facilitation effect that dissipates very rapidly (within < 50 ms) and is not followed by another effect at longer SOAs (100, 200, 300, 700 or 1000 ms). Our finding is, however, inconsistent with Mulckhuyse et al. (2007) who found a facilitation effect at the short SOA that was followed by a 5 ms inhibition of return effect at the long SOA. The relatively small magnitude of the inhibition of return effect observed by Mulckhuyse et al. (2007), along with the fact that neither we nor Fuchs and Ansorge (2012) were able to replicate the finding, causes us to question whether or not it was due to Type 1 error. Nevertheless, our finding is also inconsistent with that of Ivanoff and Klein (2003), who found an inhibition of return effect at both short and long SOAs by subliminal cues. The discrepancy in findings between us and Ivanoff and Klein (2003) could be due to the fact that we, unlike them, did not inform participants of the cue prior to the experiment proper. Hence, given this discrepancy, it is possible that inhibition of return emerges under subliminal conditions only when participants are encouraged to utilise the cue prior to the experiment. With the exception of the aforementioned studies, the only other studies that find an inhibition of return effect at long SOAs are those that utilise supraliminal (that is, visible) abrupt onset cues (e.g., Danziger & Kingstone, 1999 Kingstone & Pratt, 1999; Posner & Cohen, 1984; Taylor & Klein, 1998b). Cue masking is the obvious difference between our Experiment 1 and the other studies that find inhibition of return. This difference prompts the question of whether or not the emergence of inhibition of return following exogenous attentional capture, in a task that does not encourage cue utilisation, depends on cue visibility. The purpose of Experiment 2 was, therefore, to investigate this question by including supraliminal cues in the same task.

Experiment 2

In the experiment reported above, we found evidence of facilitation at the short SOA that was not followed by inhibition of return at the intermediate and long SOAs. This pattern of results is consistent with Fuchs and Ansorge (2012), but not with Mulckhuyse et al. (2007). Our findings, therefore, suggest that inhibition of return is not a necessary outcome of exogenous attentional capture by subliminal abrupt onset cues. This conclusion is obviously at odds with the numerous studies that suggest exogenous capture is characterised by a biphasic pattern of facilitation that is followed by inhibition of return (for a review see Klein, 2000). With the exception of Mulckhuyse, Talsma and Theeuwes (2007), however, those studies that found a biphasic pattern of results used supraliminal abrupt onset cues. Hence, given that masking of the abrupt onset cue is the obvious property that differentiates our study from that of others who find a biphasic pattern of results, it is possible that the emergence of this effect is dependent on visibility of the abrupt onset cue. Hence, we set out to investigate this question in Experiment 2 by adding supraliminal abrupt onset cues to our task. If we were to find that supraliminal abrupt onset cues, but not subliminal abrupt onset cues, produce facilitation at the short SOA that is followed by inhibition of return at the intermediate and long SOAs then this result would suggest that the emergence of inhibition of return depends on feedback mechanisms (e.g., Lamme, Super, & Spekreijse, 1998; Van Gaal & Lamme, 2011).

Method

Participants. Twenty participants (8 males and 12 females; mean + SD age, 19 + 2 years) at Macquarie University participated in the study for course credit. Informed consent was obtained from all participants.

Stimuli. The stimuli in Experiment 2 were the same as in Experiment 1 with the addition of two 4.9° x 3.9° grey rectangles that served as placeholders for the supraliminal cues.

Procedure. The factors manipulated in this task were Cue Type (subliminal, supraliminal), SOA (30 ms, 500 ms, 1000 ms) and Cue Validity (valid, invalid). There were 50 test trials in each of the twelve conditions. Participants were required to complete 60 practice trials and 600 experimental trials. The trial structure for the subliminal cue condition was the same as in Experiment 1. This trial structure was also used in the supraliminal cue condition except that the forward and backward mask arrays were replaced with rectangular placeholders (placed 7.3° to the left and right of fixation). Those cues were, thus, visible. All trials were randomised. See Fig. 3. Participants completed 120 trials of the cue visibility task after the experiment.

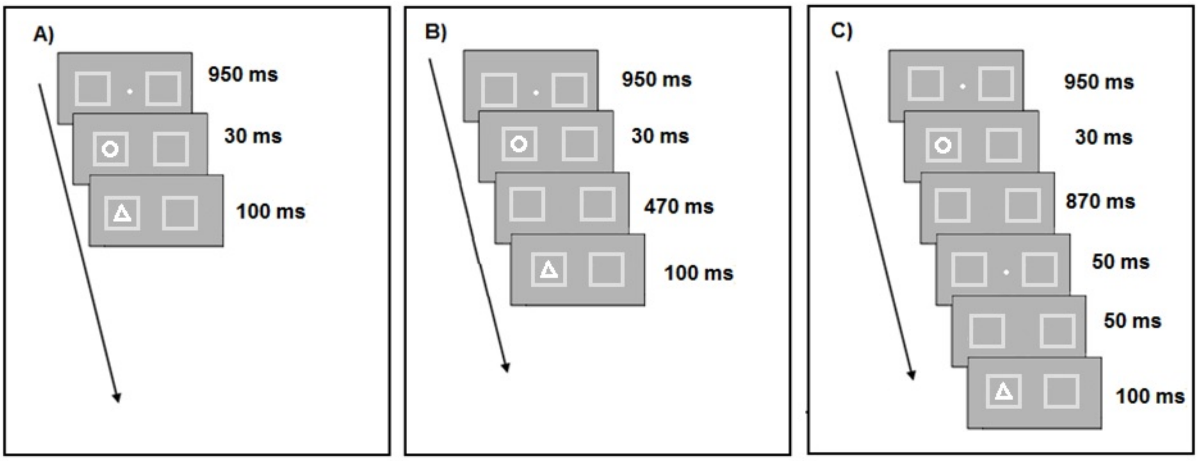

Figure 3. This figure represents the sequence of displays for the supraliminal cue condition in Experiment 2: **a)** short SOA **b)** intermediate SOA and **c)** long SOA. The figure represents a valid trial in which the location of the supraliminal cue predicts the location of the target.

Results

Response latencies. Mean accuracy on the catch trials for the 30 ms, 500 ms and 1000 ms SOAs was 93% (*SD* = 5%), 93% (*SD* = 6%) and 85% (*SD* = 13%), respectively. Catch trials were discarded from data analysis. Responses that were below 100 ms (0.23%) and greater than 1,000 ms (0.63%) were discarded. These trials were categorised as anticipations and misses, respectively. The dependent variable was mean reaction time for correct responses. A 2 x 3 x 2 ANOVA was conducted on response latencies to detect the target with Cue Type (subliminal, supraliminal), SOA (30 ms, 500 ms, 1000 ms) and Cue Validity (valid, invalid) as repeated-measures factors. We found a main effect of Cue Type, F (1, 19) 18.16, $p < 0.0001$, $\eta^2p = 0.49$, SOA, F (1, 19) = 80.45, $p < 0.0001$, $\eta^2p = 0.81$, and Cue Validity, F (1, 19) = 13.61, $p < 0.01$, $\eta^2p = 0.42$. We also found significant interaction effects between Cue Type and SOA, F (1, 19) = 77.03, $p < 0.0001$, $\eta^2p = 0.80$, Cue Type and Cue Validity, F (1, 19) = 23.85, $p < 0.0001$, $\eta^2p = 0.56$, and SOA and Cue Validity, F (1, 19) = 26.69, $p < 0.0001$, $\eta^2p = 0.58$. There was, more importantly, also a significant three-way interaction with Cue

Type, SOA and Cue Validity, F (1, 19) = 13.41, $p < 0.0001$, $\eta^2p = 0.41$. To explore the nature of this three-way interaction, we conducted further analyses to compare the validity effect for the supraliminal and subliminal abrupt onset cues separately in each SOA.

Short SOA. A 2 x 2 ANOVA was conducted on response latencies to detect the target in the short SOA condition, with Cue Type (subliminal, supraliminal) and Cue Validity (valid, invalid) as repeated-measures factors. The ANOVA revealed a main effect of Cue Type, F (1, 19) = 71.51, $p < 0.0001$, $\eta^2p = 0.79$, indicating that participants detected the target slower when it followed a subliminal abrupt onset cue (*M* = 580 ms, *SD* = 57 ms) as compared to a supraliminal abrupt onset cue (*M* = 484 ms, *SD* = 52 ms). We also found a main effect of Cue Validity, F (1, 19) = 7.34, $p < 0.05$, $\eta^2p = 0.28$, which, as is indicated by Fig. 4, reveals that participants are faster to detect the target when it follows a valid abrupt onset cue (*M* = 527 ms, *SD* = 46 ms) than an invalid abrupt onset cue (*M* = 537 ms, *SD* = 51 ms). There was no significant interaction between Cue Type and Cue Validity, F (1, 19) = 0.17, $p = 0.69$, η^2p = 0.009, hence indicating that the subliminal and supraliminal abrupt onset cues were no different in their propensity to exogenously capture attention at the short SOA.

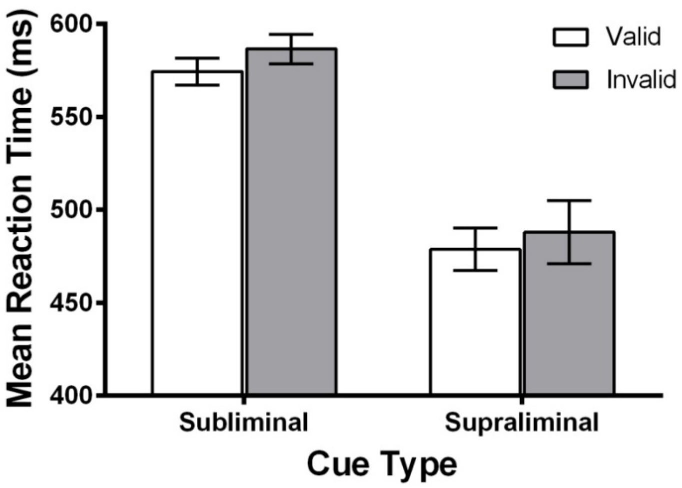

Figure 4. Mean response latencies to detecting the target following a subliminal abrupt onset cue and a supraliminal abrupt onset cue at the short SOA (with CI bars) in Experiment 2.

Intermediate SOA. The same 2 x 2 ANOVA as above was conducted on response latencies to detect the target in the intermediate SOA condition. We found no significant main effect of Cue Type, F (1, 19) = 2.69, $p = 0.12$, $\eta^2p = 0.12$, though we did find a significant main effect of Cue Validity, F (1, 19) = 24.93, $p < 0.0001$, $\eta^2p = 0.57$. There was, furthermore, a significant interaction effect between Cue Type and Cue Validity, F (1, 19) = 25.29, $p < 0.0001$, $\eta^2p = 0.57$. As is suggested by Fig. 5, when the abrupt onset cue was subliminal, response latencies to detect the target were no different on cue valid trials (*M* = 487 ms, *SD* = 52 ms) as compared to cue invalid trials (*M* = 489 ms, *SD* = 55 ms), t (19) = 0.39, $p = 0.70$. In contrast, when the abrupt onset cue was supraliminal, response latencies to detect the target were slower on cue valid trials (*M* = 502 ms, *SD* = 48 ms) than on cue invalid trials (*M* = 451 ms, *SD* = 47 ms), t (19) = 5.62, $p < 0.0001$. This result suggests that supraliminal, unlike subliminal, cues can produce inhibition of return at intermediate SOAs of 500 ms.

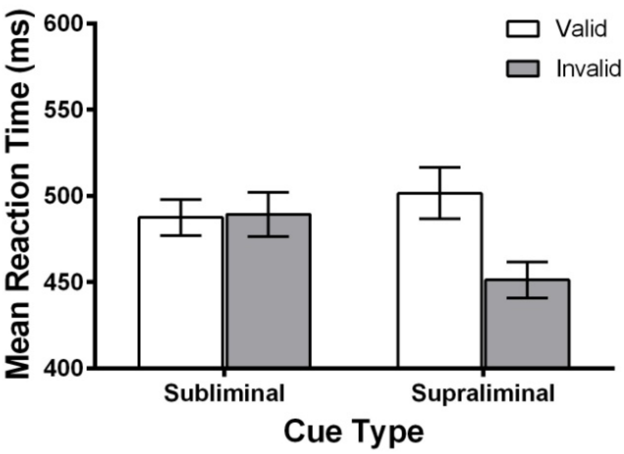

Figure 5. Mean response latencies to detecting the target following subliminal and supraliminal abrupt onset cues at the intermediate SOA (with CI bars) in Experiment 2.

Long SOA. We conducted the same 2 x 2 ANOVA on response latencies to detect the target in the long SOA condition. Here we found no significant main effect of Cue Type, F (1, 19) = 0.006, $p = 0.94$, $\eta^2p = 0.0001$, though we did find a significant main effect of Cue Validity, F (1, 19) = 25.91, $p < 0.0001$, $\eta^2p = 0.58$. We also found a significant interaction effect between Cue Type and Cue Validity, F (1, 19) = 24.25, $p < 0.0001$, $\eta^2p = 0.56$. As is revealed by Fig. 6, when the abrupt onset cue was subliminal, response latencies to detect the target were no different on cue valid trials (*M* = 453 ms, *SD* = 63 ms) as compared to cue invalid trials (*M* = 448 ms, *SD* = 68 ms), t (19) = 1.003, $p = 0.33$. In contrast, when the abrupt onset cue was supraliminal, response latencies to detect the target were slower on cue valid trials (*M* = 467 ms, *SD* = 55 ms) than on cue invalid trials (*M* = 432 ms, *SD* = 50 ms), t (19) = 7.10, $p < 0.0001$. This pattern of results indicates that subliminal abrupt onset cues, unlike supraliminal abrupt onset cues, do not produce inhibition of return at long SOAs of 1000 ms[1].

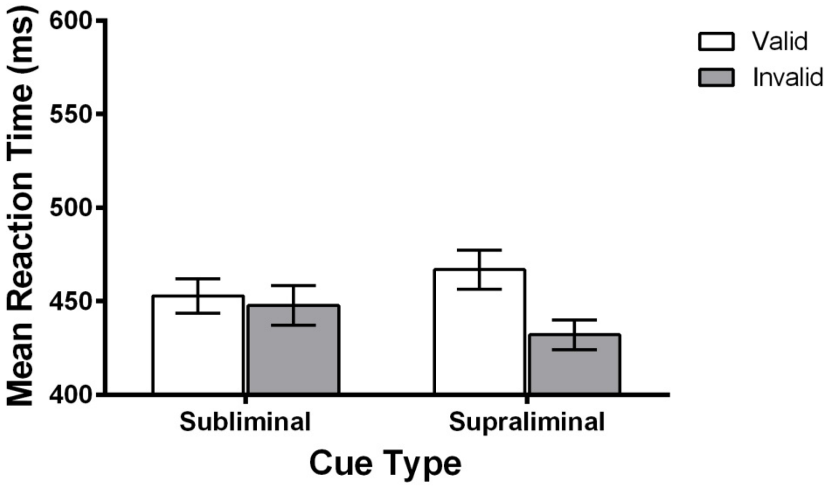

Figure 6. Mean response latencies to detecting the target following a subliminal abrupt onset cue and a supraliminal abrupt onset cue at the long SOA (with CI bars) in Experiment 2.

[1] We collapsed across the subliminal conditions of Experiment 1 and Experiment 2 for a more powerful test of inhibition of return in the intermediate and long SOA. Here we found an interaction between SOA (30 ms, 500 ms and 1000 ms) and Cue Validity (valid, invalid), F (1, 39) = 7.54, $p < 0.001$. Results from a paired t-test showed a significant difference in participants' response latencies to detect the target in the valid than in the invalid condition of the 30 ms SOA, t (39) = 5.32, $p < 0.0001$. In contrast, the results from the paired t-test did not reveal a significant difference in participants' response latencies to detect the target in the 500 ms, t (39) = 0.79, $p = 0.44$, and 1000 ms, t (39) = 0.04, $p = 0.97$, SOA conditions. This result indicates that inhibition of return does not emerge for subliminal cues even with a greater number of participants. Indeed a power analysis conducted using the 'pwr' package on R (Champley, 2012) indicated that the sample size for 80% power should be 110 and 138 in the intermediate and long SOAs, respectively. In contrast, the analysis revealed that a sample size for 80% power should be 13 in the short SOA (we had 20 in each experiment). Thus, we conclude that, as compared to a facilitation effect, it is unlikely to find inhibition of return for subliminal, abrupt onset cues.

Cue Visibility. Percent accurate localisation of the subliminal peripheral cue was 53% (*d'* = 0.11, *SD* = 0.44), which was not significantly different from chance, t (19) = 1.14, p = 0.27. In contrast, the hit rate for the supraliminal peripheral cue was 94% (*d'* = 2.98, *SD* = 0.86), which was significantly different from chance, t (19) = 26.16, $p < 0.0001$.

Discussion

The results of Experiment 2 reveal a clear disassociation between supraliminal and subliminal abrupt onset cues. The supraliminal cues produced facilitation at the short SOA followed by large inhibition of return effects at the intermediate and long SOAs. This result nicely replicates previous findings in the literature (cf. Taylor & Klein, 1998b). In contrast, the subliminal cues produced facilitation at the short SOA that was not followed by inhibition of return at the intermediate or long SOAs. The absence of an inhibition of return effect by subliminal cues is consistent with the results of Fuchs and Ansorge (2012). The pattern of findings observed here suggests that inhibition of return is limited to contexts in which the cue is visible, or cue knowledge was attained prior to the experiment (e.g., Ivanoff and Klein, 2003).

General Discussion

The purpose of the present study was to confirm the existence of subliminal exogenous cueing effects and to clarify the role of inhibition of return in diagnosing the presence of these effects. Recently, Mulckhuyse et al. (2007) observed that facilitation by subliminal abrupt onset cues is followed by inhibition of return. Given that inhibition of return effects are typically restricted to cases in which attention is involuntarily captured, the researchers took the classic biphasic pattern of results in their study as indication that subliminal cues can produce exogenous capture of attention. Fuchs and Ansorge (2012), on the other hand, observed that early facilitation by subliminal cues is not followed by late inhibition of return.

Fuchs and Ansorge (2012) modelled their experimental paradigm after Mulckhuyse et al. (2007) in an effort to prevent their cueing effects from being driven by top-down factors. Thus, the researchers also took their pattern of results (facilitation at the short SOA and no inhibition of return at the long SOAs) to mean that subliminal cues can produce exogenous capture of attention. However, Fuchs and Ansorge (2012) also suggested that inhibition of return is clearly not a necessary consequence of such exogenous capture of attention. The present study was designed to replicate and extend the findings of Mulckhuyse et al. (2007) in an effort to clarify whether or not inhibition of return is a necessary consequence of facilitation produced by subliminal abrupt onset cues.

We have observed several important findings in the present study. First, we found evidence of exogenous attentional capture by subliminal abrupt onset cues. We observed this attentional capture effect with cues that were not informative of target location (50% valid), were not available for conscious report (cue visibility was at chance) and did not match participants' top-down search template for task-relevant features (e.g., circle cues vs. triangle targets; although our targets were marked by an onset). Second, and in sharp contrast, we found no evidence of inhibition of return by these subliminal abrupt onset cues. The absence of inhibition of return cannot be due to an absence of exogenous attentional capture, given that we found large facilitation effects with the same abrupt onset cues in the short SOA condition of Experiments 1 and 2. Indeed our results from Experiment 2 demonstrate that inhibition of return following exogenous attentional capture emerges only when the abrupt onset cue is completely visible. The fact that we observed exogenous attentional capture without inhibition of return lends support to the account that the effect is not a necessary consequence of exogenous capture of attention. This finding further adds merit to the Fuchs and Ansorge (2012) warning that researchers cannot and should not use the presence of inhibition of return as a test of whether or not attention has been exogenously oriented.

Importantly, we are not the first to conclude that inhibition of return is not a necessary consequence of exogenous attentional capture. In other paradigms, with supraliminal cues, there are several studies that have similarly concluded that exogenous capture of attention and inhibition of return are brought about by independent processes (e.g., Berlucchi, 2006; Dukewich, 2009; Lambert, Spencer & Hockey, 1991; Posner & Cohen, 1984) and different cortical structures (e.g., Toffanin et al., 2011; Zhaoping, 2008). Although the present study cannot speak to the precise neural processes or cortical structures that give rise to exogenous attentional capture or inhibition of return, our results suggest that the latter may be dependent on the those processes that give rise to visual awareness, such as recurrent processing within early vision (e.g., Lamme, Super, & Spekreijse, 1998; Van Gaal & Lamme, 2011). That is, it appears that conscious awareness of the cue may be required for the emergence of inhibition of return following exogenous capture of attention. This suggestion is consistent with findings that implicate conscious awareness in the inhibition of responses (e.g., Dehaene & Naccache, 2001; Jack & Shallice, 2001; for a review see Kunde, Reuss & Kiesel, 2012).

Consciousness may be important in the emergence of inhibition of return because it alters the relation between search sets and the cues. In our task, although we went to great lengths to minimise top-down strategies, it is possible that participants may have nevertheless set up a search set for ‘onsets’. This search set may have been formulated because the target, like the cue, was marked by an onset in the intermediate and long SOAs. We are not unique in having this issue. Indeed the same criticism has been levied at Mulckhuyse et al. (2007) by Ansorge, Horstmann and Scharlau (2011). However, this limitation of our task may be important for the interpretation of our finding that subliminal, unlike supraliminal, cues do not produce inhibition of return. Specifically, Gibson and Amelio (2000) have argued that the biphasic effect emerges for (supraliminal) abrupt onset cues only when the target is also marked by an onset. In fact, when the target is marked by a colour, Gibson and Amelio (2000) find only a facilitation effect. Hence, in our Experiment 2, it is possible that, when the cues were subliminal, participants had set up a search set for ‘shape’, in accordance to the task instructions, which is the reason for which we find facilitation at the short SOA that is not followed by inhibition of return at the long SOA. In contrast, it is likely that, when the cues were supraliminal, participants revised their search set for ‘shape’ to ‘onsets’, which is the reason for which we find facilitation at the short SOA followed by inhibition of return at the long SOA. Our suggestion that participants were able to form a search set for ‘onsets’ only in the supraliminal, but not subliminal, condition is consistent with Kiefer, Adams and Zovko’s (2012) conclusion that top-down influences can only be initiated in advance of subliminal stimulus presentation (i.e., preemptive control), whereas such influences can be initiated in response to ongoing or completed supraliminal stimulus processing (i.e., reactive control). Thus, the results of this study indicate that a search set for ‘onset’, which can be implemented only when the cues are supraliminal, may be necessary for the emergence of inhibition of return. This conclusion does not, however, imply that subliminal cues cannot produce inhibition of return. Indeed the findings of Ivanoff and Klein (2003) indicate that subliminal cues produce inhibition of return when participants are informed of those cues.

CONCLUSION

Facilitation and inhibition of return are considered classic indicators of exogenous attentional orienting by peripheral, abrupt onset cues. We show here that this biphasic effect does not necessarily emerge for subliminal abrupt onset cues. The present study establishes that exogenous capture of attention by subliminal cues is not followed by inhibition of return. This pattern of results has three consequences. Firstly, the emergence of exogenous capture without inhibition of return suggests that the two phases may be driven by independent processes or structures. Secondly, our findings indicate that inhibition of return may depend on a search set of ‘onset’, which is available when the cue is visible. Lastly, the de-coupling of exogenous attentional capture from inhibition of return implies that inhibition of return should not be used as a test of whether or not a visual stimulus has exogenously captured attention as its occurrence following facilitation may be largely dependent on task demands.

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Study 2

Effective processing of masked eye gaze requires volitional control

Abstract

The purpose of the present study was to establish whether the validity effect produced by masked eye gaze cues should be attributed to strictly reflexive mechanisms or to volitional top-down mechanisms. While we find that masked eye gaze cues are effective in producing a validity effect in a spatial cueing paradigm, we also find that the efficacy of masked gaze cues is sharply constrained by the experimental context. Specifically, masked gaze cues only produced a validity effect when they appeared in the context of unmasked and predictive gaze cues. Unmasked gaze cues, in contrast, produced reliable validity effects across a range of experimental contexts, including Experiment 4 where 80% of the cues were invalid (counter-predictive). Taken together, these results suggest that the effective processing of masked gaze cues requires volitional control, whereas the processing of unmasked (clearly visible) gaze cues appears to benefit from both reflexive and top-down mechanisms.

Effective processing of masked eye gaze requires volitional control

The eye gaze of another person is an informative, and perhaps even vital, social signal (George & Conty, 2008). For instance, the direction of another person's gaze may indicate her locus of attention, reflect her underlying intention or communicate danger in the surrounding space (Adams & Kleck, 2005; Farroni et al., 2002). Human children seem predisposed to consider the gaze direction of another person by virtue of their ability to follow another person's gaze as early as 4 months of age (Farroni et al., 2000; Hood et al., 1998). Despite the ease with which gaze-induced shifts of attention are obtained, even in infants, important questions about the so-called automaticity of one's response to another person's gaze remain.

On the one hand, there are several neurophysiological findings suggesting that the shifts of attention produced in response to gaze are driven in a "reflexive", bottom-up manner (resistant to top-down influence) by cells in the inferior temporal cortex (Langton et al., 2000). These findings are corroborated by behavioural studies that also indicate gaze-induced orienting is reflexive. For example, Friesen and Kingstone (1998) found that shifts of attention can be triggered by uninformative gaze stimuli. In a Posner-like cueing task, participants were asked to detect, localise or identify a target that appeared to the left or right of fixation. This target was preceded by centrally presented face cues with averted (left, right) or direct gaze. Importantly, even though these cues did not reliably predict the target's location, participants' response latencies were faster when the gaze was directed to the target location rather than away from the target location. This result suggests that gaze-triggered attentional shifts are reflexive in the sense that they manifest rapidly (within 100 ms) and regardless of the observer's goals (Langton & Bruce, 1999; Ristic et al., 2002; Tipples, 2002). In addition, it has been observed that participants respond faster to gazed-at targets even when a large majority of the gaze cues are counter-predictive; that is, during the course of the experiment, the eye gaze is directed to the location opposite to the target's location (i.e., invalid) on, say, 80% of the trials (Driver et al., 1999; Friesen et al., 2004). Such a finding indicates that the orienting of attention in response to eye gaze is resistant to cognitive control (i.e., unavoidable), further strengthening the claim that gaze-induced shifts of attention occur reflexively.

There are, however, reasons to think that gaze-induced shifts of spatial attention are strongly modulated by top-down cognitive processes (Logan & David, 2011). For instance, while Bentin et al. (2002) found that non-face components (e.g., ovals) triggered face-specific activity (enhanced N170) when presented in isolation, this was only true after those shapes had been presented within schematic faces in a previous block. These results indicate that the observed face-specific activation depended upon face context to prime participants to interpret the ovals as eyes. Similarly, Ristic and Kingstone (2005) suggest that orienting to a gaze may be partly dependent on top-down factors. In their task, Ristic and Kingstone (2005) asked participants to detect a peripheral target, which was preceded by a centrally presented stimulus that could be perceived as either eyes with an averted gaze or as wheels of a car. The results of Ristic and Kingstone (2005) indicated that participants' response latencies to detect the target were shorter when it was preceded by a valid gaze cue than by an invalid cue, but only when participants knew that the cues were eyes, not wheels. Interestingly, when participants were first prompted that the stimulus represented eyes and then later told to treat the stimulus as a car, attentional shifts to the gaze location were found with both sets of task instructions. These effects suggest that top-down factors are required initially to produce gaze-induced shifts of spatial attention.

Despite the considerable amount of research investigating the mechanisms that underlie gaze-triggered shifts of attention, relatively little work has been done on the role of conscious awareness in this phenomenon. Do participants need to be aware of the gaze cue for it to induce a shift of attention? In the one published study designed to address this question, Sato et al. (2007) found that gaze cues were effective in producing shifts of attention even when presented without conscious awareness. In their experiment, participants were asked to localise a disc presented to the left or right of fixation. Before target presentation, a face with averted gaze was presented either subliminally (using a backward masking procedure) or supraliminally. Sato et al. (2007) found that response latencies to localise the disc were faster for valid gaze cues than invalid cues in both the subliminal and supraliminal conditions, suggesting that shifts of attention can occur without awareness. An important aspect of the Sato et al. (2007) study, though, had to do with how the participants were introduced to the masked cue. Sato et al. (2007) established the thresholds for subliminal presentation prior to the experiment proper by requiring participants to respond directly to the masked gaze cues. We will argue below that this design may have led participants to incorporate the cues into their task set and, hence, that the cue-induced effects observed in the experiment proper may have been driven by top-down, rather than bottom-up, factors.

In the threshold assessment task used by Sato et al. (2007), participants were asked to detect and verbally report the direction of eye gaze cues presented at short durations. Importantly, this threshold assessment task was conducted prior to the experiment proper. This pre-exposure to the gaze cues might have caused participants to notice the task-relevance of these stimuli, leading them to include the cues in their response set. Indeed, this suggestion follows directly from the well-known phenomenon that masked priming effects are strongly modulated by top-down strategies and learning effects (Ansorge & Neumann, 2005; Dehaene et al., 1998; Kiesel et al., 2006). For example, in a magnitude-judgment task (e.g., “Is it bigger than 5?”), Kunde et al. (2003) found that primes (e.g., 1 or 9) produced priming when they were included in the target set, but not when they were outside of that set. Similarly, it has recently been shown that, while both novel primes (i.e., those that are never presented consciously) and repeated primes (i.e., those that have been practiced) produce reliable priming effects, the effects for novel primes are reduced compared with those for repeated primes (Finkbeiner & Friedman, 2011). Findings such as these are ubiquitous in the masked priming literature, and taken together, they suggest that the processing of masked stimuli is strongly modulated by the task set that the participant establishes early on in the experimental context.

Given that the processing of masked stimuli is strongly modulated by top-down factors, the demonstration of a gaze-cueing effect by masked cues does not speak to whether this effect can be attributed to top-down or strictly bottom-up processes. With this idea in mind, the purpose of the present study was to investigate whether or not masked eye gaze cues can produce a validity effect in an experimental context that does not provide participants with an incentive to incorporate the cues into their task set. To pursue this question, we used a modified version of the task used by Sato et al. (2007). In Experiment 1, we presented masked cues on half of the trials and unmasked cues on the other half. All cues were uninformative of target location (50% valid). To anticipate our results, we found reliable cueing for the unmasked cues, but not for the masked cues. In Experiment 2, we modified the design so that the unmasked cues were informative of target location (80% valid). The masked cues remained 50% valid. Under these conditions, we expected that participants would notice the advantage conferred by the unmasked cues and begin to incorporate them into their response formulation process - a strategy that is known to carry over to the processing of masked stimuli (Dehaene et al., 1998). This is what we found. Experiment 3 was designed to replicate the findings from Experiments 1 and 2 in a within-subjects design. Finally, in Experiment 4, the unmasked cues were counter-predictive of target location (80% invalid). The masked cues were once again 50% valid. Under these conditions, we reasoned that participants would not incorporate the gaze cues into their response formulation process and, thus, that we would not observe a cueing effect for masked cues. To anticipate our results once again, this is what we observed.

Experiment 1

The purpose of Experiment 1 was to investigate whether or not, without any prior exposure, masked gaze cues can orient spatial attention. Participants were asked to localise a disc that was preceded by an averted gaze cue that was either backward masked or not. The masked and unmasked eye gaze cues were uninformative of target location.

Method

Participants. Twelve students (10 females and 2 males; mean + SD age, 31 + 15 years) at Macquarie University participated in the study for course credit. Informed consent was obtained from all participants.

Stimuli. Two images of the same individual were used in the task: one with left gaze and one with a right gaze (see Fig. 1). The averted gaze directions were created by shifting the pupils 2 mm to the left or right of the eye's centre. Photographs were frontal head-shots of a female with a neutral facial expression attained from the Psychological Image Collection at Stirling (PICS) database (http://pics.psych.stir.ac.uk/). The photographs were standardised, such that each face was cropped to remove the background, converted to grey-scale and equated for contrast. The experiment also utilised 10 scrambled faces as backward masks; two photographs were divided into squares that are 30 pixels horizontal and 30 pixels vertical and re-ordered randomly. Each image measured 2 cm wide × 2.65 cm high, subtending a visual angle of 4.58° × 4.91° with a viewing distance of approximately 55 cm. The target was a small, dark grey disc that measured approximately 0.98° × 0.74°. A 1.37° × 1.03° white fixation cross was used. Stimuli were presented on a black background.

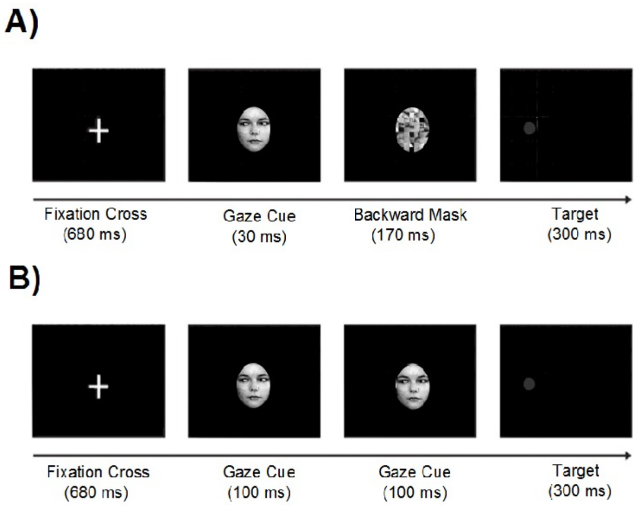

Figure 1. This figure reflects the sequence of displays for Experiment 1: masked presentation (**a**) and unmasked presentation (**b**). In particular, the figure represents a valid trial in which the direction of the gaze cue predicts the location of the target disc.

Procedure. Participants pressed two keys to initiate each of the 20 practice trials and 400 experimental trials. The trial structure was as follows: a white cross appeared for 680 ms in the centre of the screen, followed by a gaze cue in the same locus. This cue was valid or invalid with equal probability. In the unmasked condition, the cue was presented for 200 ms. In the masked condition, the cue was presented for 30 ms and followed by the mask, which was presented for 170 ms in the same locus. Following the offset of the gaze cue (in the unmasked condition) or mask (in the masked condition), a grey disc was displayed in either the left or right side of the screen (5° from the centre) with equal probability. Participants were required to localise this disc by pressing one of two response buttons. The target remained on screen for 300 ms or until a response was detected. All trials were randomised. The factors manipulated in this task were Cue Masking (masked, unmasked) and Cue Validity (valid, invalid); thus, there were 100 trials in each of the four conditions.

Results

Response latencies. The dependent variable was mean reaction time for correct responses. Responses that were below 100 ms (1.46%) and greater than 1,000 ms (0.33%) were discarded. Such trials were categorised as anticipations and misses, respectively. A 2 × 2 ANOVA was conducted on response latencies to localise the disc, with Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated-measures factors. There was a significant main effect of validity, $F(1, 11) = 29.43$, $p < 0.0001$, $\eta^2p = 0.73$, with longer response latencies in the invalid ($M = 278$ ms, $SD = 40$ ms) than in the valid ($M = 271$ ms, $SD = 41$ ms) condition. There was no effect of Cue Masking ($F < 1$), but, importantly, there was a significant interaction between Cue Masking and Cue Validity, $F(1, 11) = 21.91$, $p < 0.001$, $\eta^2p = 0.67$. As can be seen in Fig.2, when the gaze cue was unmasked, response latencies were shorter when the disc followed a valid cue ($M = 267$ ms, $SD = 41$ ms) than when it followed an invalid cue ($M = 283$ ms, $SD = 39$ ms), $t(11) = 5.85$, $p < 0.0001$. In contrast, when the gaze cue was masked, there was no significant difference in disc localisation responses when the target followed a valid cue ($M = 275$ ms, $SD = 43$ ms) than when it followed an invalid cue ($M = 274$ ms, $SD = 41$ ms), $t(11) = 0.36$, $p = 0.73$. Thus, this interaction suggests that, without prior training, masked gaze cues do not modulate response latencies in this task.

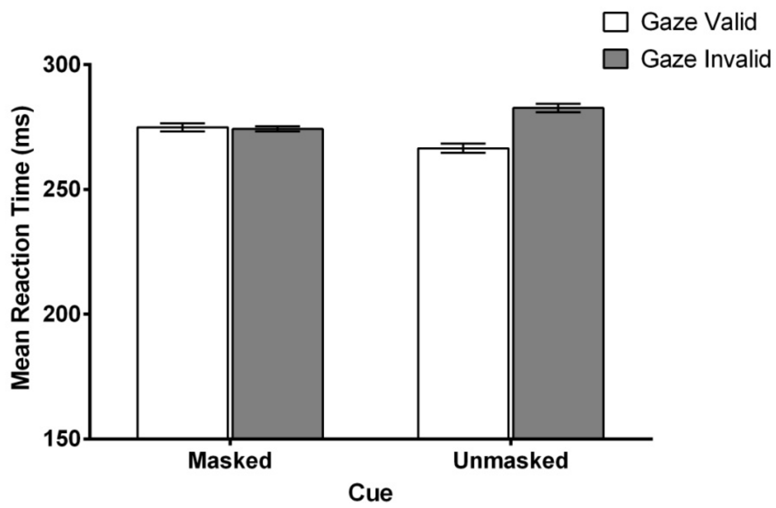

Figure 2. Mean response latencies to localising the disc, when the target is presented following masked and unmasked gaze cues (with SE bars) in Experiment 1.

Accuracy rates. We analysed the accuracy rates using the same repeated-measures ANOVA as above. The mean accuracy rates for the masked valid and invalid conditions were 97.50% (*SD* = 4.48%) and 97.17% (*SD* = 5.04%), respectively. Similarly, the mean accuracy rates for the unmasked valid and invalid conditions were 97.67% (*SD* = 4.64%) and 96.65% (*SD* = 4.44%), respectively. For these accuracy scores, the ANOVA revealed no significant main effect of Cue Masking, F (1, 11) = 0.25, p = 0.63, $\eta^2 p$ = 0.02, or Cue Validity, F (1, 11) = 2.82, p = 0.12, $\eta^2 p$ = 0.20. Importantly, the interaction between Cue Masking and Cue Validity was not significant, F (1, 11) = 0.67, p = 0.43, $\eta^2 p$ = 0.06.

Experiment 2

The results of Experiment 1 revealed that masked gaze cues do not produce a reflexive shift of spatial attention. Of course, it could be that the masked cues in Experiment 1 did not produce an effect because they were presented too briefly to be processed (but see Sato et al., 2007). In Experiment 2, we tested the possibility that the masked cues would produce an effect when they were presented in the context of predictive unmasked cues. This reasoning follows from the findings reported by Ristic and Kingstone (2006). In their study, which also used a Posner-like cueing task, they showed that number cues could facilitate responses, but only when they were informative of target location. Ristic and Kingstone (2006) took this finding to mean that the effects by number cues were under the volitional control of the participants. If the same is true for masked gaze cues, then using predictive unmasked cues should cause participants to include gaze direction in their task set. Further, if this strategy carries over to the processing of masked cues, then we should observe a validity effect for masked cues in this Experiment even though the masked cues are still uninformative of target location (50% valid).

Method

Participants. Twelve students (6 females and 6 males; mean + SD age, 21 + 4 years) at Macquarie University participated in the study for course credit. These participants had not participated in Experiment 1. Informed consent was obtained from all participants.

Stimuli. The stimuli were the same as those used in Experiment 1.

Procedure. The procedure was identical to that adopted in Experiment 1, except that the unmasked cue was now valid on 80% of trials, whilst the masked cue remained 50% valid.

Results

Response latencies. The dependent variable was mean reaction time for correct responses. Responses that were below 100 ms (3.54%) and greater than 1,000 ms (0.17%) were discarded. Such trials were categorised as anticipations and misses, respectively. Given the unbalanced design in this experiment (only 20% of data were invalidly cued in the unmasked condition), it was more appropriate to analyse the data using linear mixed modelling (LMM; c.f. Bates, 2005; Baayen et al., 2008). The LMM returns the grand mean dependent variable (RT) as the intercept and the fixed-effect parameters as deviations from the intercept. Fixed-effect parameters can be interpreted in the same way as the main effects and interactions in an ANOVA. For each analysis below, we report the regression coefficients (b), the standard errors (SEs), the t values and P, the Markov chain Monte Carlo P-value. The LMM was conducted with Cue Masking and Cue Validity as within-subject factors and Subject as a random factor. The two-way interaction with Cue Masking and Cue Validity was reliable, b = 17.7, SE = 5.0, t (11) = 3.5, $p < 0.001$, indicating that the effectiveness of the gaze cues was modulated by the masking procedure. Further, this interaction (see Fig. 3) suggests that, while masked uninformative gaze cues can cue attention effectively in a central cueing paradigm, they, not surprisingly, produce a smaller effect than unmasked, predictive cues. The follow-up analyses revealed a significant effect of Cue Validity for unmasked gaze cues, b = 32.9, SE = 3.3, t (11) = 10.1, $p < 0.0001$, such that response latencies were shorter when the disc followed a valid cue (*M* = 238 ms, *SD* = 23 ms) than when it followed an invalid cue (*M* = 272 ms, *SD* = 27 ms). There also was a significant effect of Cue Validity for the masked gaze cues, b = 15.7, SE = 3.5, t (11) = 4.4, $p < 0.0001$, wherein response latencies were shorter when the target followed a valid cue (*M* = 250 ms, *SD* = 21 ms) than when it followed an invalid cue (*M* = 262 ms, *SD* = 19 ms). The presence of an effect for masked gaze cues in Experiment 2 juxtaposed with the absence of an effect in Experiment 1 suggests that the efficacy of masked gaze cues is under volitional control. Before drawing any conclusions from the pattern of findings across Experiments 1 and 2, though, it is important to replicate the pattern within participants. This was the purpose of Experiment 3.

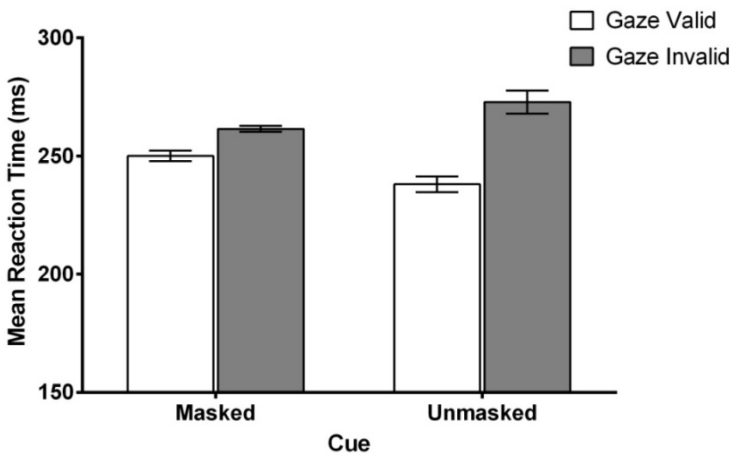

Figure 3. Mean response latencies to localising the disc, when the target is presented following masked and unmasked gaze cues (with SE bars) in Experiment 2.

Accuracy rates. We analysed the accuracy rates using the same repeated-measures ANOVA as Experiment 1. The mean accuracy rates for the masked valid and invalid conditions were 97.50% (SD = 2.54%) and 95.90% (SD = 3.34%), respectively. Similarly, the mean accuracy rates for the unmasked valid and invalid conditions were 97.59% (SD = 2.42%) and 89.77% (SD = 1.29%), respectively. For these accuracy scores, the ANOVA revealed no significant main effect of Cue Masking, $F\ (1,\ 11) = 3.96$, $p = 0.07$, $\eta^2p = 0.27$, or Cue Validity, $F\ (1,\ 11) = 4.68$, $p = 0.053$, $\eta^2p = 0.30$. Importantly, the interaction between Cue Masking and Cue Validity was not significant, $F\ (1,\ 11) = 3.22$, $p = 0.10$, $\eta^2p = 0.23$.

Experiment 3

The purpose of Experiment 3 was to replicate the findings from Experiments 1 and 2 in a within-subjects design. To do this, we manipulated the predictiveness of the unmasked gaze cue within participants across blocks. In the first block, the unmasked gaze cues were uninformative (50% valid), whereas in Block 2, they were informative (80% valid). Based on the findings from Experiments 1 and 2, we expected to observe a cue validity effect for the unmasked gaze cues in both blocks, but only in the second block for the masked cues. To ensure that the validity effect that emerged in Block 2 was due to our manipulation of (unmasked) cue predictiveness, as opposed to increased experience with the task, we included a group of control participants. The unmasked gaze cues were uninformative in both blocks for the control group. The masked gaze cue was always uninformative (50% valid) throughout the experiment for both groups of participants. Finally, we included a cue detection task to be completed after the experiment proper in order to ensure that any differences found between the experimental and control groups were not due to differences in cue visibility.

Method

Participants. Twenty-four students (21 women and 3 men; mean + SD age, 23 + 6 years) at Macquarie University participated in the study for course credit. These participants had not participated in Experiment 1 or Experiment 2. Informed consent was obtained from all participants.

Stimuli. The stimuli were the same as those used in Experiment 1.

Procedure. The within-subjects factors manipulated in this task were Experimental Block (block 1, block 2), Cue Masking (masked, unmasked) and Cue Validity (valid, invalid). There were 50 trials in each of the 8 conditions for the Control Group. For the Experimental Group, however, there were 50 trials in each of the 4 conditions in Block 1, and in Block 2, there were 80 valid and 20 invalid trials in the unmasked condition, and 50 valid and 50 invalid trials in the masked condition. The trial structure of Experiment 3 was the same as in Experiment 1, except that the validity of the unmasked cue was manipulated between participants. For participants allocated to the control group, the unmasked cue was valid or invalid with equal probability in both Blocks 1 and 2. For the experimental group, the unmasked cue was uninformative of target location in Block 1, but 80% valid in Block 2. The masked cue was always 50% valid for all participants.

Following the experiment proper, participants completed 200 trials that tested for cue visibility, using the same cues from the experiment proper. Trials were identical to the localisation task except that the participants were presented with two alternative cue stimuli (the true gaze cue and its counterpart) following target localisation and asked to indicate which stimulus they thought was the cue. The masked and unmasked cues in this task were uninformative so as to prevent participants from using the target location to identify which gaze cue may have been shown.

Results

Response latencies. The dependent variable was mean reaction time for correct responses. As before, responses that were below 100 ms (1.73%) and greater than 1,000 ms (0.41%) were discarded as anticipations and misses, respectively. We first ran an LMM with the factors Experimental Block (block 1, block 2), Cue Masking (masked, unmasked), Cue Validity (valid, invalid) as within-subject factors and Group as a between-subjects factor. We also included Subject as a random factor. The four-way interaction with Block, Cue Masking, Cue Validity and Group was marginally significant, $b = 20.47$, $SE = 10.83$, $t(11) = 1.89$, $p = 0.059$. Hence, given our motivation to compare the performance of the Experimental Group to the Control Group within each block of the cueing task, we conducted the additional analyses separately for each block.

Block 1. A 2 × 2 × 2 ANOVA was conducted on response latencies to localise the disc, with Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated-measures factors and Group (control, experimental) as a between-groups factor. Recall that in the first block, the unmasked cues were uninformative for both groups of participants. This analysis yielded a significant interaction between Cue Masking and Cue Validity, $F(1, 22) = 22.71$, $p < 0.0001$, $\eta^2p = 0.51$, and a significant main effect of Cue Validity, $F(1, 22) = 34.03$, $p < 0.0001$, $\eta^2p = 0.61$, but no other effects (all *F*s < 1.61). The nature of the two-way interaction can be seen in Fig. 4a. When the gaze cue was unmasked, response latencies were shorter when the disc followed a valid cue (*M* = 252 ms, *SD* = 33 ms) than when it followed an invalid cue (*M* = 275 ms, *SD* = 30 ms), $t(23) = 6.86$, $p < 0.0001$. However, when the gaze cue was masked, there was no significant difference in responses to the target when it followed a valid cue (*M* = 259 ms, *SD* = 28 ms) than when it followed an invalid cue (*M* = 262 ms, *SD* = 27 ms), $t(23) = 1.35$, $p = 0.19$. This interaction between Cue Masking and Cue Validity replicates our finding in Experiment 1.

Block 2. Due to the unbalanced design in Block 2 (only 20% of data were invalidly cued in the unmasked condition for the experimental group), we used linear mixed models to analyse the data. The first LMM included Cue Masking and Cue Validity as within-subject factors and Group as a between-subjects factor. We also included Subject as a random factor. The three-way interaction with Cue Masking, Cue Validity and Group was reliable, $b = 24.1$, $SE = 6.4$, $t(23) = 3.8$, $p = 0.0002$, suggesting that the effectiveness of the gaze cues was modulated by the masking procedure differently for the two groups. To pursue this three-way interaction further, we analysed each group separately. Looking first at the results for the Experimental Group, the two-way interaction between Cue Masking and Cue Validity was significant, $b = 33.8$, $SE = 4.7$, $t(23) = 7.1$, $p < 0.0001$. The nature of this interaction is clear in Fig. 4b. The follow-up analyses revealed a reliable effect of Cue Validity for the unmasked gaze cues, b = 42.6, SE = 3.9, t (23) = 10.9, $p < 0.0001$, such that response latencies were shorter when the disc followed a valid cue (*M* = 239 ms, *SD* = 30 ms) than when it followed an invalid cue (*M* = 281 ms, *SD* = 42 ms). The follow-up analyses also revealed a reliable effect of Cue Validity for the masked gaze cues, b = 9.2, SE = 2.7, t (23) = 3.4, $p < 0.001$, wherein response latencies to localise the disc were shorter when the target followed a valid cue (*M* = 253 ms, *SD* = 27 ms) than when it followed an invalid cue (*M* = 264 ms, *SD* = 27 ms). Looking now at the Control Group, the two-way interaction between Cue Masking and Cue Validity was significant, b = 8.7, SE = 4.2, t (23) = 2.1, $p = 0.04$. The nature of this interaction is apparent in Fig. 4b The follow-up analyses revealed a reliable effect of Cue Validity for the unmasked gaze cues, b = 12.9, SE = 3.1, t (23) = 4.1, $p < 0.0001$, such that response latencies were shorter when the disc followed a valid cue (*M* = 255 ms, *SD* = 30 ms) than when it followed an invalid cue (*M* = 268 ms, *SD* = 31 ms). The analyses revealed no reliable effect of Cue Validity for the masked gaze cues, b = 4.3, SE = 2.8, t (23) = 1.5, $p = 0.13$, indicating that there was no difference in disc localisation responses when the target followed a valid cue (*M* = 256 ms, *SD* = 28 ms) than when it followed an invalid cue (*M* = 262 ms, *SD* = 33 ms).

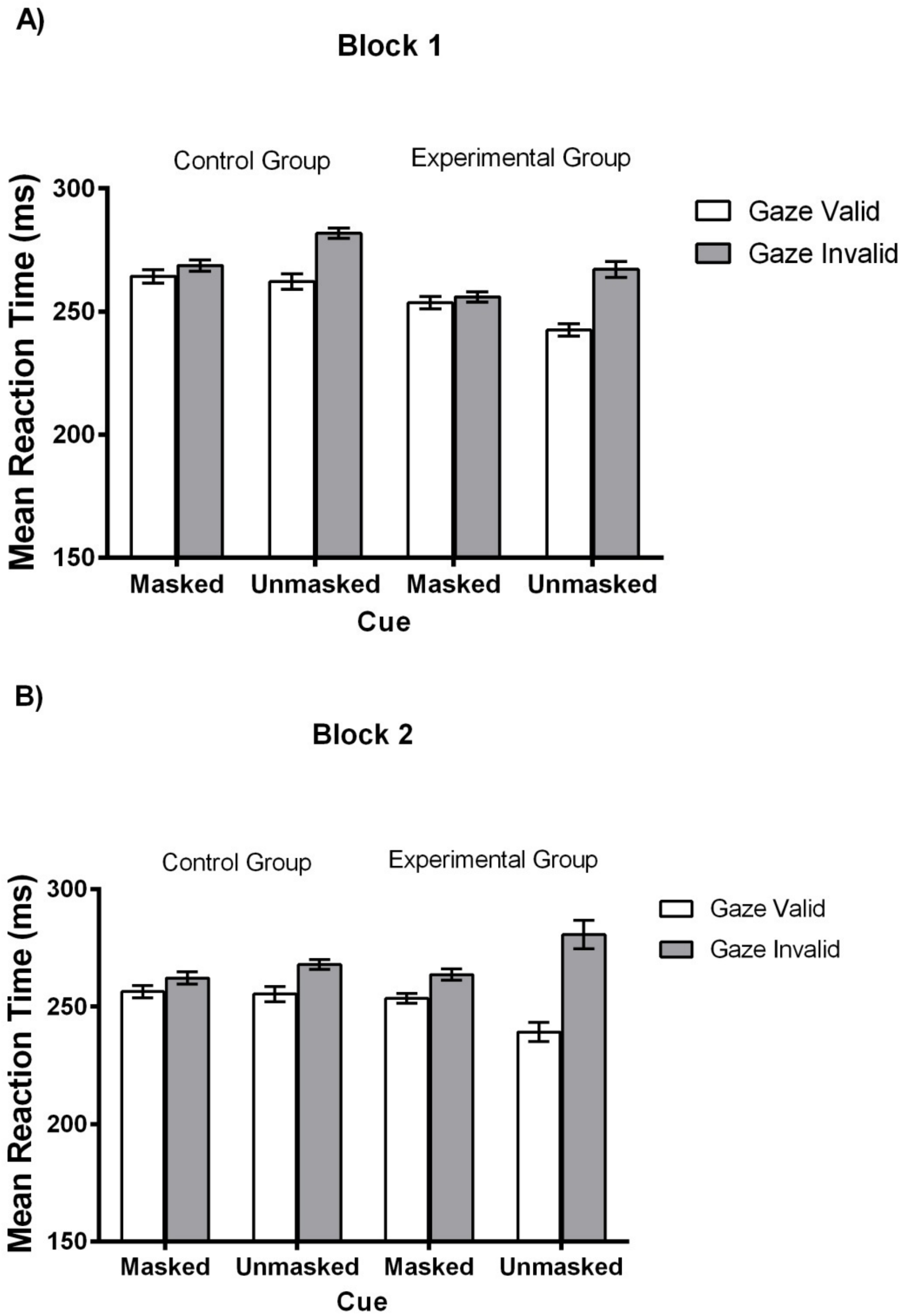

Figure 4. Mean response latencies to localising the disc, when the target is presented following masked and unmasked gaze cues (with SE bars) in Experiment 3 where **a)** represents Block 1, whilst, **b)** represents Block 2 of the experiment.

Accuracy rates

Block 1. We analysed the accuracy rates using the same ANOVA as above. The mean accuracy rates for the masked valid and invalid conditions were 97.58% (*SD* = 2.43%) and 97.67% (*SD* = 2.62%), respectively. Similarly, the mean accuracy rates for the unmasked valid and invalid conditions were 98.50% (*SD* = 1.98%) and 93.90% (*SD* = 6.10%), respectively. For these accuracy scores, the ANOVA revealed a significant main effect of Cue Masking, $F(1, 22) = 4.54$, $p < 0.05$, $\eta^2p = 0.17$, and Cue Validity, $F(1, 22) = 10.50$, $p < 0.01$, $\eta^2p = 0.32$. There also was a significant interaction between Cue Masking and Cue Validity, $F(1, 22) = 9.96$, $p < 0.01$, $\eta^2p = 0.31$. The follow-up analyses revealed a reliable effect of Cue Validity for the unmasked gaze cues, $t(22) = 3.68$, $p < 0.001$, which indicated that accuracy was higher for valid cues than for invalid cues. In contrast, no reliable effect of Cue Validity for the masked gaze cues was found, $t(22) = -0.13$, $p = 0.90$. No other effects were significant (all *F*s < 0.54).

Block 2. We analysed the accuracy rates using the same ANOVA as Block 1. The mean accuracy rates for the masked valid and invalid conditions were 95.42% (*SD* = 5.36%) and 94.25% (*SD* = 4.87%), respectively. Similarly, the mean accuracy rates for the unmasked valid and invalid conditions were 96.58% (*SD* = 3.03%) and 91.08% (*SD* = 9.25%), respectively. For these accuracy scores, the ANOVA revealed a significant main effect of Cue Validity, $F(1, 22) = 17.66$, $p < 0.0001$, $\eta^2p = 0.45$, wherein participants' accuracy was higher for valid cues (*M* = 96.0%, *SD* = 3.84%) than for invalid cues (*M* = 92.67%, *SD* = 5.95%). The analysis also revealed a significant interaction between Cue Masking and Group, $F(1, 22) = 6.53$, $p < 0.05$, $\eta^2p = 0.23$. Follow-up analyses showed no significant effect of Cue Masking for participants in the Control Group, $t(22) = -1.18$, $p = 0.26$. There was, however, a reliable effect of Cue Masking for participants in the Experimental Group, t

(22) = 2.28, $p < 0.04$, where participants were more accurate in the masked condition ($M = 95.92\%$, $SD = 3.20\%$) than in the unmasked condition ($M = 92.91\%$, $SD = 6.40\%$). No other effects were significant (all Fs < 3.85).

Cue Visibility. The hit rate for the unmasked gaze cues was 91% for participants in the control group ($d' = 2.38$, $SD = 1.29$) and 94% for participants in the experimental group ($d' = 2.53$, $SD = 1.03$).The mean hit rate for the masked gaze cues was 63.95% ($d' = 0.65$, $SD = 0.60$) for the control group and 62.32% ($d' = 0.61$, $SD = 0.79$) for the experimental group. Importantly, though the d' scores for the two groups were different from zero, they did not differ from one another, t (23) = 2.09, $p = 0.89$. This lack of a difference in the d' scores suggests that the differences in the gaze cueing effects for the two groups were not due to differences in the visibility of the masked eye gaze cue.

Experiment 4

In the experiments reported above, we have shown that the effectiveness of masked gaze cues is limited to contexts in which the unmasked gaze stimuli are informative. This pattern of findings is similar to the one observed for number cues by Ristic and Kingstone (2006). In their study, Ristic and Kingstone (2006) found that number cues produced reliable cueing effects, but only when they were predictive. Ristic and Kingstone (2006) took these findings to suggest that the efficacy of the cues was under the participant's volitional control. Similarly, in our experiments, it may be that the predictiveness of the unmasked gaze stimuli prompted participants to incorporate the cues into their task set. If, indeed, presenting predictive unmasked cues is a pre-requisite for participants to process masked gaze cues effectively, then it is interesting to ask how participants would respond to masked gaze stimuli that are presented in the context of unmasked, counter-predictive gaze cues. Given that counter-predictive gaze cues are just as informative as predictive cues, participants may similarly be prompted to incorporate these cues into their task set; but it is less clear what that might entail in this context. Below we briefly consider two different possible outcomes.

If the effective processing of masked gaze cues is limited to those contexts in which participants must first notice the task relevance of the (unmasked) gaze cues, then we would expect masked gaze cues to produce an effect whenever the unmasked cues are informative. In the context of counter-predictive cues, this may lead to a normal cue validity effect, replicating the findings that have been observed previously with unmasked counter-predictive cues (e.g., Driver et al., 1999; Friesen et al., 2004). In contrast, upon noticing that the unmasked cues are counter-predictive and, thus, detrimental, it may be that participants try to suppress or block the gaze cues. Note that in the measure to which the attempt to block the processing of gaze cues is effective, it would reduce the validity effect for both masked and unmasked cues. Such a strategy may eliminate the cue validity effect for masked, but not unmasked, cues because cue suppression is robust to short (but not long) stimulus presentation durations. As we see below, the results of Experiment 4 are consistent with this second possible outcome.

Method

Participants. Twelve students (10 females and 2 males; mean + SD age, 21 + 2 years) at Macquarie University participated in the study for course credit, none of which had participated in the previous experiments. Informed consent was obtained from all participants.

Stimuli. The stimuli were the same as those used in Experiment 1.

Procedure. The experiment was identical to Experiment 1, except that on 80% of trials, the target disc appeared in the location opposite from the side that the unmasked face gazed towards; that is, the unmasked cues were counter-predictive. The masked cue remained 50% valid. Following the experiment proper was the same cue identification task used in Experiment 3.

Results

Response latencies. As before, responses that were below 100 ms (1.04%) and greater than 1,000 ms (0.13%) were discarded as anticipations and misses, respectively. Given that the design of this experiment was also unbalanced (only 20% of data were validly cued in the unmasked condition), we used linear mixed models to analyse the data. The first LMM included Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated-measures factors and Subject as a random factor. This analysis yielded a significant interaction between Cue Masking and Cue Validity, b = 11.6, SE = 4.8, t (11) = 2.4, $p = 0.02$, but no other effects (all *p*s > 0.3). The interaction is depicted in Fig. 5. The follow-up analyses revealed a reliable effect of Cue Validity for the unmasked gaze cues, b = 12.9, SE = 4.0, t (11) = 3.3, $p < 0.001$, such that response latencies were shorter when the target disc followed a valid cue (*M* = 263 ms, *SD* = 33 ms) than when it followed an invalid cue (*M* = 274 ms, *SD* = 38 ms). There was no significant effect of Cue Validity for the masked gaze cues, b = 1.3, SE = 2.8, t (11) = 0.5, $p = 0.6$, indicating that there was no difference in disc localisation responses when the target followed a valid cue (*M* = 267 ms, *SD* = 41 ms) than when it followed an invalid cue (*M* = 267 ms, *SD* = 39 ms).

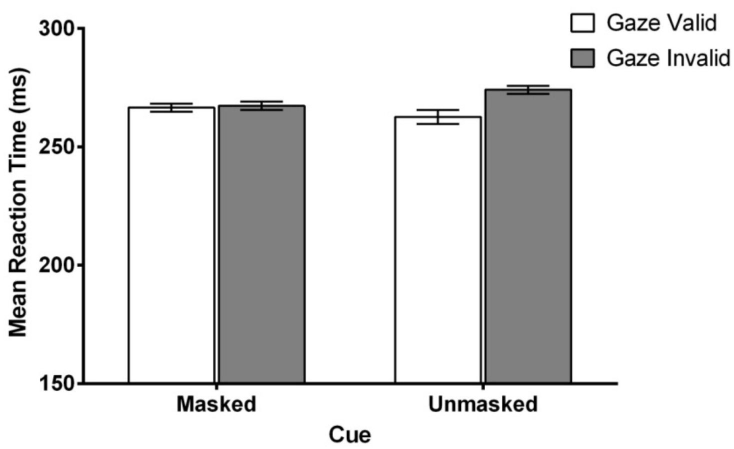

Figure 5. Mean response latencies to localising the disc, when the target is presented following masked and unmasked gaze cues (with SE bars) in Experiment 4.

Accuracy rates. We analysed the accuracy rates using the same repeated-measures ANOVA as Experiment 1. The mean accuracy rates for the masked valid and invalid conditions were 97.33% (*SD* = 2.31%) and 97.25% (*SD* = 2.09%), respectively. Similarly, the mean accuracy rates for the unmasked valid and invalid conditions were 97.71% (*SD* = 2.71%) and 97.40% (*SD* = 2.34%), respectively. For these accuracy scores, the ANOVA revealed no significant main effect of Cue Masking, F (1, 11) = 0.30, p = 0.60, η^2p = 0.03, or Cue Visibility, F (1, 11) = 0.13, p = 0.72, η^2p = 0.01. Importantly, the interaction between Cue Masking and Cue Validity was not significant, F (1, 11) = 0.07, p = 0.80, η^2p = 0.01.

Cue visibility. The hit rate for the unmasked gaze cues was 94% (d' = 2.67, *SD* = 1.26), indicating that those cues were clearly visible. The mean hit rate for masked cues was 60% (d' = 0.48, *SD* = 0.54), which was comparable to the d' scores in Experiment 3.

General Discussion

The present study establishes several important findings on the automaticity of gaze cue processing. First, we have shown that masked eye gaze cues can reliably modulate responses in a central cueing paradigm. This aspect of our findings replicates the first published study to use masked eye gaze cues in a Posner-like cueing paradigm (Sato et al., 2007). Second, we have shown that the effectiveness of these masked eye gaze cues is sharply constrained by the experimental context. In our study, masked eye gaze cues were only effective in modulating response latencies when they appeared in the context of predictive (80% valid), gaze unmasked cues. Third, we found that masked eye gaze cues were not effective in the context of counter-predictive (80% invalid), unmasked gaze cues.

In short, this study investigated whether masked gaze cues produce a validity effect in an experimental context that does not provide any incentive for participants to incorporate the cues into their task set. In one respect, the findings of the present study are consistent with those recently reported by Sato et al. (2007). In their study, they, like us, found that masked gaze cues produced a validity effect in a central cueing task. Left unanswered in the study by Sato et al. (2007), though, was whether the validity effects produced by masked gaze cues should be attributed to reflexive mechanisms or to top-down mechanisms. The findings of the present study are conclusive in this regard. While we found strong validity effects for masked eye gaze cues (Experiments 2 and 3), these effects were limited to contexts in which the unmasked gaze cues were predictive. Thus, it appears that in order for participants to process masked gaze cues effectively, they must first incorporate eye gaze into their task set, which is something that they readily do when the eye gaze cues are predictive.

The finding that top-down factors modulate the processing of masked stimuli is not surprising in the masked priming literature (for recent reviews, see: Finkbeiner &

Friedman, 2011; van Gaal & Lamme, 2011). Nevertheless, it is remarkable that masked eye gaze stimuli are not processed independently of these top-down influences. One might expect, given the social relevance and early age with which humans are sensitive to eye gaze (~ 4 months), eye gaze stimuli would be processed regardless of task set. And yet, our findings suggest that participants do not process masked gaze cues effectively unless those cues appear in an experimental context that encourages participants to incorporate gaze direction into their task set. Though this pattern of results cannot adjudicate between models of gaze-triggered orienting, which attempt to ascertain the link between gaze perception mechanisms and attention, the findings do constrain such models of social attention (see Bayliss et al., 2010). Specifically, the findings of our study indicate that accounts of gaze-triggered orienting must allow for task sets.

Our findings, moreover, reveal an important distinction between the processing of masked and unmasked gaze cues. While our masking procedure did not completely prevent visual awareness, the validity effect produced by masked gaze cues was, nevertheless, sharply constrained by the experimental context. The validity effect for unmasked cues, on the other hand, was robust to the wide range of experimental contexts that we employed in the present study. The distinction between masked and unmasked gaze cues is most apparent in Experiment 4. In this case, the unmasked cues were counter-predictive of target location (80% invalid), and yet, they still produced a validity effect. The presence of a cue validity effect in the context of largely counter-predictive gaze cues has been taken as evidence for reflexive shifts of attention by such stimuli (Driver et al., 1999; Friesen et al., 2004). If, however, unmasked gaze cues can be processed reflexively, which is how results like those obtained in Experiment 4 are generally interpreted, then why were the masked gaze cues not also processed reflexively in Experiment 4? This question is especially of interest since the masked cues in Experiment 4 appeared in the context of informative unmasked cues. One tentative possibility, which we introduced above as a possible outcome for Experiment 4, is that individuals tried to suppress the gaze cues upon noticing that they were counter-predictive. This account can also be used to explain the findings of Experiment 1, wherein individuals attempted to suppress processing of the gaze cues because they had no actual value in helping them localise the target. Attempts to suppress or block the processing of symbolic stimuli like gaze and arrow cues, which are not helpful to the task at hand, presumably fail when they are clearly visible due to the meaning of these stimuli having been over-learned (c.f. Reuss et al., in press). In the masked case, the gaze information is fleeting and, hence, may not be processed sufficiently to overcome the participant's strategy to suppress this information. It is important to note that we offer this tentative account as a way of motivating further work in this important area of research.

CONCLUSION

The purpose of the present study was to establish whether the validity effect produced by masked eye gaze cues should be attributed to strictly reflexive bottom-up factors or to volitional top-down factors. While we observed strong validity effects for masked gaze cues, thereby replicating the previous study by Sato et al. (2007), we found that the efficacy of masked gaze cues was sharply constrained by the experimental context. Specifically, masked gaze cues only produced a validity effect when they appeared in the context of unmasked and predictive gaze cues. These results imply that the processing of masked gaze cues is under the volitional control of the participants. We suggest that the presence of predictive unmasked cues led participants to incorporate eye gaze information into their task set which, in turn, led to the effective processing of masked gaze cues.

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Study 3

Responding to the direction of the eyes: In search of the masked gaze-cueing effect

Abstract

Recent studies have demonstrated that masked gaze cues can produce a cueing effect. Those studies, however, all utilised a localisation task and, hence, are ambiguous with respect to whether the previously observed masked gaze-cueing effect reflects the orienting of attention or the preparation of a motor response. The aim of the present study was to investigate this issue by determining whether masked gaze cues can modulate responses in a detection and discrimination task, both of which isolate spatial attention from response priming. First, we found a gaze-cueing effect for unmasked cues in a detection, discrimination and localisation task, which suggests that the gaze-cueing effect for visible cues is not task dependent. Second, and in contrast, we found a gaze-cueing effect for masked cues in a localization task, but not a detection or discrimination task, which suggests that the gaze-cueing effect for masked cues is task dependent. Therefore, the present study shows that the masked gaze-cueing effect is attributed to response priming as opposed to the orienting of spatial attention.

Responding to the direction of the eyes: In search of the masked gaze-cueing effect

The ability to follow a person's gaze is necessary for seamless social interactions as it enables one to understand the underlying attitudes of others in the surrounding space, collaborate with others in the community, and assess potential threat in the environment (Jones et al., 2010). This capacity for gaze following is most commonly investigated in the laboratory using variants of the Posner cueing task (Posner & Cohen, 1984). In this paradigm, a centrally presented, uninformative face cue with averted left/right gaze can either validly or invalidly cue the location of a subsequently presented, peripheral target. Studies typically show that observers are faster to respond to validly cued targets than invalidly cued targets, a phenomenon that is known as the gaze-cueing effect (Friesen & Kingstone, 1998). Researchers have emphasized that this effect reflects the spatial orienting of attention in response to the averted gaze since it can be observed in the context of various experimental tasks, such as detection, localisation and discrimination (Driver et al., 1999; Friesen & Kingstone, 1998; Friesen, Ristic, & Kingstone, 2004). Recently, the question of whether the gaze-cueing effect can be obtained for cues presented subliminally has been investigated (Al-Janabi & Finkbeiner, 2012; Sato, Okada, & Toichi, 2007). The results of these studies have become part of a discussion regarding the role of visual awareness in orienting attention.

In the first study to look at how participants' awareness of the gaze cue affects the gaze-cueing effect, Sato, Tokada and Toichi (2007) used the spatial cueing task with unmasked and masked gaze cues. It was expected that a gaze-cueing effect would emerge for both unmasked (supraliminal) and masked (subliminal) gaze cues on the assumption that individuals follow the gaze of others reflexively (Friesen & Kingstone, 1998; Langton & Bruce, 1999). To test this assumption, Sato and colleagues (2007) asked participants to localise a disc shown to the left or right of fixation. A centrally presented, averted gaze cue was presented either supraliminally or subliminally (using backward masking) prior to the target. This averted gaze cue was uninformative of target location (50% valid). Results showed that response latencies to localise the disc were faster for valid than invalid gaze cues in both unmasked and masked conditions, thereby suggesting that masked cues can produce a gaze-cueing effect. A potential problem of Sato et al's (2007) study, however, was that participants had viewed and practiced responding to the gaze cues in a prior 'cue detection' task. Therefore, the masked cues may have yielded a gaze-cueing effect by virtue of being incorporated into a task set. Al-Janabi and Finkbeiner (2012) specifically addressed this issue in their replication of Sato et al's (2007) original study. Critically, in their study, participants did not view or respond overtly to the gaze cues before the experiment proper and, hence, were not given the opportunity to incorporate the cues into a task set. These researchers replicated the gaze-cueing effect with unmasked cues. More importantly, Al-Janabi and Finkbeiner (2012) also found a gaze-cueing effect for masked cues, but, specifically, only when they appeared in the context of visible and informative (80% valid) unmasked cues. Collectively, these findings indicate that, while masked cues can indeed produce a gaze-cueing effect, the efficacy of such cues is sharply constrained by experimental context.

Al-Janabi and Finkbeiner (2012) took their findings to suggest that the masked gaze-cueing effect is subject to experimental contexts that allow for top-down influences. Nevertheless, they agreed with Sato and colleagues (2007) that the effect should be attributed to a spatial orienting of attention. This attentional orienting account is the standard interpretation of the gaze-cueing effect, wherein participants shift their attention to the gaze direction, which, consequently, facilitates target localization on gaze valid, but not invalid, trials. There is, however, an alternative account for these effects; that is, the gaze-cueing effects reported by Sato et al. (2007) and Al-Janabi and Finkbeiner (2012) may be due to response priming. In contrast to the attentional orienting account of the masked gaze-cueing effect, the response priming account stipulates that the averted gaze cue activates a covert left/right localisation response that is appropriate for gaze valid trials, but not invalid trials (Spence & Driver, 1996). We note that this response priming account is well established in the masked priming literature, where there is compelling evidence demonstrating that participants are able to establish stimulus-response mappings (or ’action triggers’) during the course of the experiment, which, in turn, drive the observed priming effects (Abrams & Greenwald, 2000; Eimer & Schlaghecken, 2002; Kunde, Kiesel, & Hoffmann, 2003; Leuthold & Kopp, 1998; Neumann & Klotz, 1994). Indeed, the previous two studies (Al-Janabi & Finkbeiner, 2012; Sato et al., 2007) that investigated whether the gaze-cueing effect can be obtained for cues presented subliminally are inconclusive with respect to which interpretation (attentional orienting versus response priming) best accounts for the observed masked gaze-cueing effect. It is unclear which interpretation is correct because both Sato et al. (2007) and Al-Janabi and Finkbeiner (2012) used a localisation task (i.e. press left button for ‘left’ targets and right button for ‘right’ targets), which conflates the effects of spatial attention with those of response priming (Zehetleitner & Muller, 2010).

The purpose of the present study was, therefore, to establish which account (the standard attentional orienting account or the alternative response priming account) is best able to explain the gaze-cueing effect with masked cues. Hence, we modified the task used by Al-Janabi and Finkbeiner (2012) by having participants detect, rather than localise, the target. In a detection task, participants are asked to press a single button (e.g., the space bar) as soon as they detect the target stimulus. The advantage of this task is that both valid and invalid gaze cues map onto the same motor response. Importantly, if the masked gaze-cueing effect is attributed to gaze-triggered shifts of attention, then it should be robust to this change in experimental tasks. If, however, the masked gaze-cueing effect is attributed to response formulation processes, then it should be limited to the localization task and fail to generalize to the detection task. Thus, to adjudicate between the attentional orienting account and the response priming account, we compared the masked gaze-cueing effects obtained in a localization task with those obtained in a detection task. In Experiment 1, participants were asked to detect the target, which was preceded by unmasked and masked gaze cues. All cues were uninformative (50% valid). To anticipate our results, we found reliable gaze-cueing effects for the unmasked gaze cues, but not for the masked gaze cues. In Experiment 2, participants were again asked to detect the target, but, in this case, the unmasked gaze cues were informative (80% valid), while the masked gaze cues remained 50% valid. Under these conditions, we once again found a gaze-cueing effect for unmasked, but not masked, cues. Having established that the masked gaze-cueing effect does not emerge in the detection task, even when the unmasked gaze cues are informative, we then used a within-subjects design to pursue the possibility that this gaze-cueing effect was limited to the localization task. To investigate this possibility, we manipulated task type (localisation versus detection) over two days in Experiment 3. We observed an unmasked gaze-cueing effect in both the localization and detection tasks and a masked gaze-cueing effect only in the localization task. It is possible that the detection task is less robust than the localization task in revealing masked gaze-cueing effects. Therefore, in Experiment 4, we doubled the number of detection task trials to improve our chances of observing a masked gaze-cueing effect. To anticipate our results once more, we observed a gaze-cueing effect with unmasked, but not masked, cues. The results, thus far, indicate that the emergence of the masked gaze-cueing effect is limited to tasks that allow response priming effects to masquerade as gaze-cueing cueing effects. We pursued this possibility in Experiment 5 by using a discrimination task. The discrimination task required two response buttons, thereby allowing us to equate the number of response effectors across the discrimination task (which did not allow for response priming effects) and the localization task (which allowed for response priming effects). Just as in the detection task, the discrimination task yielded an unmasked gaze-cueing effect, but no masked gaze-cueing effect. Hence, given our observation that the masked gaze-cueing effect is limited to the localization task, which is consistent with the response priming account and inconsistent with the attentional orienting account, we suggest that the masked gaze-cueing effect should be attributed to response formulation processes not shifts in spatial attention.

Experiment 1

The purpose of Experiment 1 was to determine whether or not masked eye-gaze cues produce a gaze-cueing effect in a detection task. Participants were asked to detect a peripherally presented target that was preceded by a centrally presented averted gaze cue. The gaze cue was backward masked on half of the trials and unmasked on the other half. Both masked and unmasked eye-gaze cues were uninformative of target location (50% valid) in Experiment 1.

Method

Participants. Thirteen participants (5 males and 8 females; mean + SD age, 21 + 4 years) at Macquarie University participated in the study for AUD $15. Informed consent was obtained from all participants.

Stimuli. A photograph of a female with a neutral facial expression was attained from the Psychological Image Collection at Stirling (http://pics.psych.stir.ac.uk/) and used in this task as the cue. The photograph was then manipulated to have an averted gaze direction by shifting the pupils 2 mm to the left or right of the eye's centre. Each image of the two images was then cropped to remove the background, converted to grey-scale and equated for contrast. Ten scrambled faces were used as backward masks by randomly dividing two photographs of a female face (different from the cue) into squares that were 30 pixels horizontal and 30 pixels vertical. Each image was 2 cm wide x 2.65 cm high, subtending a visual angle of 4.58° x 4.91° with a viewing distance of approximately 55 cm. A small, dark grey circle that measured approximately 0.98° x 0.74° served as the target. The fixation cross was white and measured 1.37° x 1.03°. All stimuli were presented on a black background using a 17-inch CRT monitor with a 1024 x 768 screen resolution and a 100 Hz refresh rate.

Procedure. The factors manipulated in this task were Cue Masking (masked, unmasked) and Cue Validity (valid, invalid). Participants were required to press a response button to begin each of the 40 practice trials and 440 experimental trials. The experiment included 40 catch trials in which the target did not appear and no response was required, thus, there were 100 test trials in each of the four conditions. The trial structure of Al-Janabi and Finkbeiner (2012) was adopted (see Fig. 1): a centrally-presented white fixation cross appeared for 680 ms, followed by an averted eye gaze cue in the same locus. This cue was uninformative of target location (50% valid). The cue was presented for 200 ms in the unmasked condition. In contrast, in the masked condition, the cue was presented for 30 ms and followed by the backward mask, which appeared in the same locus for 170 ms. A grey disc was presented with equal probability in either the left or right side of the screen (5° from the centre) following the offset of the cue (in the unmasked condition) or mask (in the masked condition). Participants were required to detect this target disc by pressing a single response button with their preferred index finger. The disc remained on screen for 300 ms or until a response was made. All trials were randomised.

After the experiment proper, participants completed 220 trials that tested for cue visibility. These trials were the same as the detection task, except that participants were presented two alternative cue stimuli (the true gaze cue and its counterpart) following target detection and asked to indicate which stimulus was presented on the previous trial. The masked and unmasked cues in cue visibility task were uninformative so as to prevent participants from using the target location as an indicator of which gaze cue was presented.

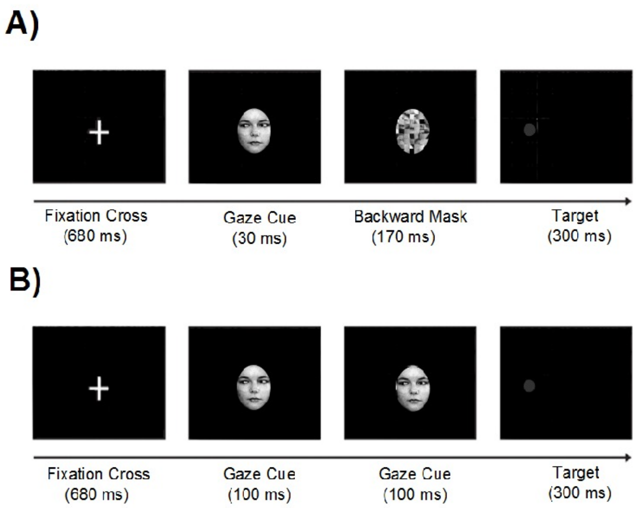

*Figure 1.*This figure reflects the sequence of displays for Experiment 1: masked presentation (**a**) and unmasked presentation (**b**). In particular, the figure represents a valid trial in which the direction of the gaze cue predicts the location of the target disc.

Results

Response latencies. Mean accuracy on the catch trials was 89% (*SD* = 8%), all these trials were discarded from data analysis. The mean error rate on the experimental trials was 1% across all conditions (*SD* = 1.04%). As in Al-Janabi and Finkbeiner (2012), responses that were below 100 ms (2.27%) and greater than 1,000 ms (0.35%) were discarded. Such trials were categorised as anticipations and misses, respectively. The dependent variable was mean reaction time for correct responses. A 2 x 2 ANOVA was conducted on response latencies to detect the disc, with Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated-measures factors. We found a main effect of Cue Validity, $F(1, 12) = 5.18$, $p < 0.05$, $\eta^2 p = 0.30$, with shorter response latencies in the valid (*M* = 282 ms, *SD* = 40 ms) than in the invalid (*M* = 287 ms, *SD* = 41 ms) condition. There was no significant main effect of Cue Masking, $F(1, 12) = 2.21$, $p = 0.16$, $\eta^2 p = 0.16$, but, importantly, there was a significant interaction between Cue Masking and Cue Validity, $F(1, 12) = 5.86$, $p < 0.05$, $\eta^2_p = 0.33$. As can be seen in Fig. 2, when the gaze cue was unmasked, response latencies to detect the disc were shorter when the disc followed a valid gaze cue (*M* = 283 ms, *SD* = 41 ms) than when it followed an invalid gaze cue (*M* = 292 ms, *SD* = 44 ms), $t(12) = 4.22$, $p < 0.001$. In contrast, when the gaze cue was masked, validly cued targets were not responded to faster (*M* = 282 ms, *SD* = 41 ms) than invalidly cued targets (*M* = 282 ms, *SD* = 39 ms), $t(12) = 0.09$, $p = 0.93$.

Inferential statistics do not allow us to quantify evidence in favour of the null (i.e., gaze cues do not produce cueing) or alternative (i.e., gaze cues do produce cueing) hypotheses; hence, given that it is difficult to draw meaningful inferences from a non-significant finding, such as the one above, we have calculated JZS Bayes factors (JZS–BF) for the planned comparisons in Experiment 1. The JZS-BF will determine whether or not there is evidence for the null or alternative hypotheses (Rouder & Morey, 2011). The JZS–BF was 0.03 for unmasked cues and 4.81 for masked cues. These results indicate 33:1 odds in favour of the alternative hypothesis for unmasked cues and 5:1 odds in favour of the null hypothesis for masked cues. Thus, the inferential statistics and JZS-BF results both suggest that, uninformative, unmasked gaze cues produce a cueing effect, but uninformative masked gaze cues do not.

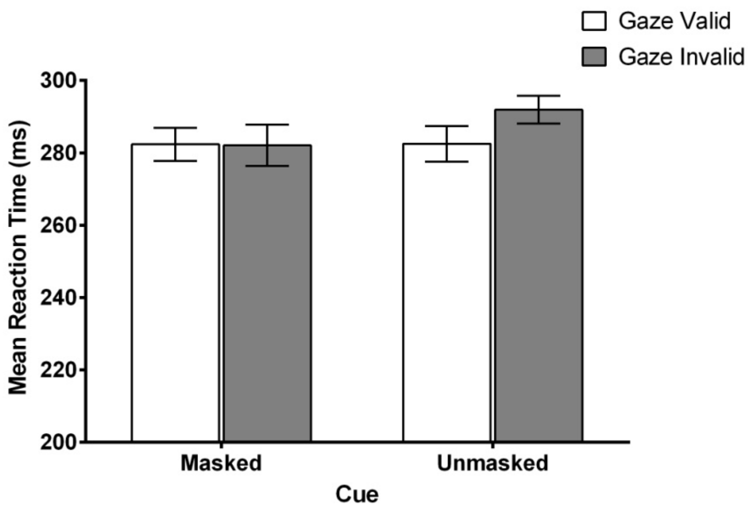

Figure 2. Mean response latencies to detecting the disc, when the target is presented following uninformative masked and unmasked gaze cues (with CI bars) in Experiment 1.

Cue visibility. The mean hit rate for unmasked gaze cues was 93% and *d*' was 2.10 (*SD* = 1.49). The mean hit rate for masked cues was 58% and *d'* was 0.37 (*SD* = 0.49). A one-sample t-test revealed that the *d'* for both unmasked and masked cues was significantly different to 0 (t > 2.5).

Discussion

The results of Experiment 1 reveal a clear disassociation between unmasked and masked gaze cues. The unmasked, highly visible, gaze cues produced a clear gaze-cueing effect. This result nicely replicates previous findings in the literature (cf. Friesen & Kingstone, 1998). In contrast, the masked gaze cues did not produce a gaze-cueing effect. The lack of a gaze-cueing effect for masked gaze cues contrasts with our earlier finding of a masked gaze-cueing effect in a localization task (Al-Janabi & Finkbeiner, 2012). It is important to remember, though, that the masked gaze-cueing effect in that study was limited to an experimental context in which the unmasked gaze cues were informative of target location (80% valid). Thus, to determine whether the masked gaze-cueing effect in the detection task similarly depends on the presence of informative, visible cues, we manipulated unmasked cue predictiveness in Experiment 2, such that they were 80% valid.

Experiment 2

It is well established in the masked priming literature that the successful processing of masked (subliminal) stimuli depends, in large part, on whether or not the participants have included the masked stimulus in their task set (Ansorge & Neumann, 2005; Kunde, et al., 2003). The paradigm example of this dependency comes from a study by Kunde, Kiesel and Hoffmann (2003) in which they asked participants to indicate if a target number (e.g., '1') was bigger or smaller than a reference number (e.g., '5'). In the Kunde and colleagues (2003) study, it was shown that masked primes (e.g., the number '2') produced a masked congruence effect, but only if these stimuli were included within the magnitude range of the target items. For example, the number '2' produced priming when the targets ranged from 1 to 9, but not when the targets ranged from 3 to 7. With this finding in mind, we reasoned that the masked gaze-cueing effect might depend on participants incorporating the gaze cues into their task set. To encourage participants in our study to include the gaze cues in their task set, we ensured that the unmasked gaze cues were informative (80% valid) in Experiment 2. Furthermore, just as in Experiment 1, the masked gaze cues were uninformative (50% valid) and the experimental task was detection. We raised the validity of cues only in the unmasked condition because the masked priming literature suggests that a masked stimulus cannot be strategically used to enhance task performance (Dehaene & Naccache, 2001; Van den Bussche, Segers, & Reynvoet, 2008). It is, therefore, unlikely that raising the validity of masked gaze cues would have affected participants' performance in that condition.

Method

Participants. Thirteen students (4 males and 9 females; mean + SD age, 22 + 4 years) at Macquarie University participated in this study for AUD $15. Informed consent was obtained from all participants. These participants had not participated in Experiment 1.

Stimuli. The stimuli were the same as those used in Experiment 1.

Procedure. The procedure was identical to Experiment 1, except that the unmasked gaze cue was now valid on 80% of trials, whilst the masked gaze cue remained 50% valid.

Results

Response latencies. Mean accuracy on the catch trials was 82% (*SD* =13%), all these trials were discarded from data analysis. The mean error rate on the experimental trials was 1% across all conditions (*SD* = 0.91%). We also discarded responses that were below 100 ms (2.57%) and greater than 1,000 ms (0.12%). Such trials were categorised as anticipations and misses, respectively. The dependent variable was mean reaction time for correct responses. A 2 x 2 ANOVA was conducted on response latencies to detect the disc, with Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated-measures factors. We found no main effect of Cue Masking, $F(1, 12) = 2.35$, $p = 0.15$, $\eta^2 p = 0.16$, or Cue Validity, $F(1, 12) = 3.50$, $p = 0.09$, $\eta^2 p = 0.27$. We did, however, find a significant interaction between Cue Masking and Cue Validity, $F(1, 12) = 6.05$, $p < 0.05$, $\eta^2 p = 0.34$. Fig. 3 shows that when the gaze cue was unmasked, response latencies to detect the disc were shorter when the disc followed a valid gaze cue (*M* = 274 ms, *SD* = 33 ms) than when it followed an invalid gaze cue (*M* = 287 ms, *SD* = 40 ms), $t(12) = 2.39$, $p < 0.05$. However, when the gaze cue was masked, response latencies to detect the disc were not significantly different when the disc followed a valid cue (*M* = 271 ms, *SD* = 26 ms) compared to an invalid cue (*M* = 269 ms, *SD* = 22 ms), t (12) = 0.60, *p* = 0.56.

We quantified the evidence in favour of the null (i.e., gaze cues do not produce cueing) or alternative (i.e., gaze cues produce cueing) hypotheses by, once again, calculating the JZS-BF for the above planned comparisons. The JZS–BF result was 0.52 for unmasked cues and 4.07 for masked cues. These results indicate 2:1 odds in favour of the alternative hypothesis for unmasked cues and 4:1 odds in favour of the null hypothesis for masked cues. Thus, both the inferential statistics and JZS-BF results suggest masked gaze cues do not yield a cueing effect in a detection task, even when presented in the context of predictive unmasked gaze cues.

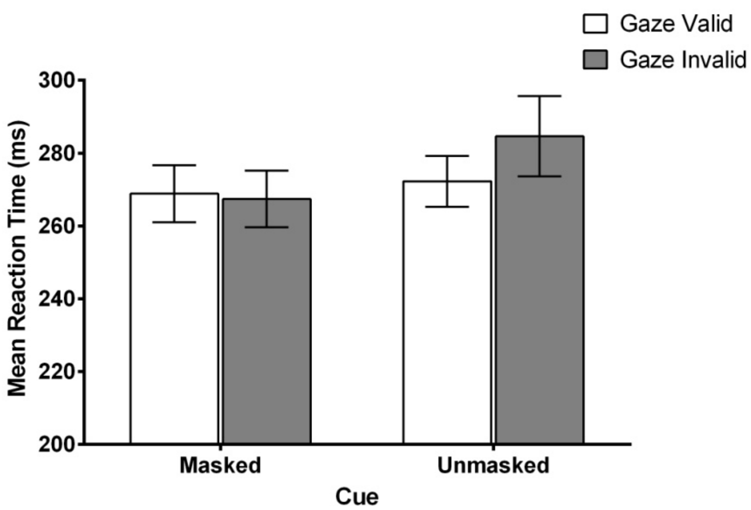

Figure 3. Mean response latencies to detecting the disc, when the target is presented following informative unmasked gaze cues and uninformative masked gaze cues (with CI bars) in Experiment 2.

Cue visibility. The mean hit rate for unmasked gaze cues was 92% and *d*' was 2.68 (*SD* = 1.45). The mean hit rate for masked gaze cues was 66% and *d'* was 0.78 (*SD* = 0.74). A one-sample t-test revealed that the *d'* for both unmasked and masked cues was significantly different from 0 (t > 3.5).

Discussion

The motivation for Experiment 2 was to determine if the gaze-cueing effect with masked gaze cues would emerge in the detection task when the unmasked gaze cues were informative (80% valid). By using informative, unmasked gaze cues, we reasoned that participants would be more likely to include gaze direction in their task set - a prerequisite for observing effects with masked stimuli in many experimental contexts. Somewhat surprisingly, while we once again observed a gaze-cueing effect with unmasked gaze cues, there was no evidence of a gaze-cueing effect with masked gaze cues. This pattern of results stands in sharp contrast to the findings reported by Al-Janabi and Finkbeiner (2012) who found that presenting masked gaze cues in the context of informative, unmasked gaze cues yielded a masked cueing effect. The only difference between the experiments of Al-Janabi and Finkbeiner (2012) and Experiments 1 and 2 here is task type (localisation versus detection, respectively). Thus, in Experiment 3, we explored the possibility that the masked gaze-cueing effect is dependent on task type, such that it emerges in the localization, but not the detection, task.

Experiment 3

In Experiments 1 and 2, in which participants had to detect the presence of a peripheral target by pressing a single button, we observed a gaze-cueing effect with unmasked gaze cues, but not with masked gaze cues. By combining these findings in the detection task with those of Al-Janabi and Finkbeiner (2012), who used a localization task, we are presented with a pattern of results that is not consistent with the attentional orienting account of the masked gaze-cueing effect. Remember, the attentional orienting account predicts a gaze-cueing effect across both the detection and the localization tasks. In contrast, the pattern of results across the two studies suggests that the masked gaze-cueing effect is limited to the localization task.

If this pattern of findings can be reproduced in a within-subjects design then it would lend support to the response priming account of the masked gaze-cueing effect, which holds that the gaze-cueing effect emerges by virtue of participants preparing a covert (left/right) response to the direction of the gaze. Thus, the aim of Experiment 3 was to manipulate the task within participants across two testing sessions. On Day 1, the task was localisation, whereas on Day 2, the task was detection. According to the standard attentional orienting account of the masked gaze-cueing effect, we should observe a gaze-cueing effect in both tasks. In contrast, according to the response priming account, we should observe a gaze-cueing effect in the localization task, but not the detection task. Just as in Experiment 2, the masked gaze cue was uninformative (50% valid) throughout both testing sessions, while the unmasked gaze cue was always informative (80% valid) throughout both testing sessions.

Method

Participants. Thirteen students (4 males and 9 females; mean + SD age, 22 + 5 years) at Macquarie University participated in this study for course credit. Informed consent was obtained from all participants. These participants were naive to the experiment.

Stimuli. The stimuli were the same as those used in Experiment 1.

Procedure. The within-subjects factors manipulated in this task were Task (localisation, detection), Cue Masking (masked, unmasked) and Cue Validity (valid, invalid). The trial structure of Experiment 3 was the same as in Experiment 1 and 2, except that the task type varied across days. For Day 1, participants were asked to localise the disc by pressing one of two horizontally-aligned response buttons. Participants were asked to use one index finger for each response button. There were 20 practice trials and 400 experimental trials. For Day 2, participants were asked to detect the disc by pressing a single response button. There were 20 practice trials and 440 experimental trials. Similar to Experiment 1 and Experiment 2, 10% of trials in the detection task of Experiment 3 were catch trials.

Following the experiment proper was the same cue visibility task that was used in Experiments 1 and 2, except that the task instructions now varied across the days. For Day 1, participants completed 200 trials that required them to first localize the target and then identify the cue. For Day 2, participants completed 220 trials (10% were catch trials) that required them to first detect the target and then identify the cue.

Results

Response latencies. Just as before, responses that were below 100 ms (4.27%) and greater than 1, 000 ms (1.08%) were discarded as anticipations and misses, respectively. In the detection task (Day 2), the mean accuracy on the catch trials was 85% (*SD* =11%) and, as before, these trials were discarded from data analysis. The mean error rate in the experimental trials was 1% across all conditions (*SD* = 1.69%). We submitted the correct mean response latencies to a 2 x 2 x 2 ANOVA with Task (localization, detection), Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated-measures factors. We found a main effect of Task, F (1, 12) = 10.31, $p < .01$, $\eta^2 p$ = 0.46, Cue Masking, F (1, 12) = 18.61, $p < 0.001$, $\eta^2 p$ = 0.61, and Cue Validity, F (1, 12) = 20.96, $p < 0.001$, $\eta^2 p$ = 0.64. We also found significant interaction effects between Task and Cue Validity, F (1, 12) = 7.85, $p < 0.05$, $\eta^2 p$ = 0.40, and Cue Masking and Cue Validity, F (1, 12) = 20.97, $p < 0.001$, $\eta^2 p$ = 0.64. All other two-way interaction effects were not significant (F < 0.01). Importantly, there was a significant three-way interaction with Task, Cue Masking and Cue Validity, F (1, 12) = 20.33, $p < .001$, $\eta^2 p$ = 0.63. To explore the nature of this 3-way interaction, we conducted further analyses separately for each task.

Localization Task (Day 1). A 2 x 2 ANOVA was conducted on response latencies to localise the disc, with Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated-measures factors. The ANOVA revealed a main effect of Cue Masking, F (1, 12) = 18.92, $p < 0.001$, $\eta^2 p = 0.61$ and Cue Validity, F (1, 12) = 17.10, $p < 0.001$, $\eta^2 p = 0.59$. There was also a significant interaction between Cue Masking and Cue Validity, F (1, 12) = 24.41, $p < 0.0001$, $\eta^2 p = 0.67$. As can be seen in Fig. 4, when the gaze cue was unmasked, response latencies to localise the disc were shorter when the disc followed a valid gaze cue (*M* = 256 ms, *SD* = 19 ms) than when it followed an invalid gaze cue (*M* = 299 ms, *SD* = 30 ms), t (12) = 4.41, $p < 0.001$. We also found that when the gaze cue was masked, response latencies to localise the disc were shorter when the disc was preceded by a valid gaze cue (*M* = 264 ms, *SD* = 16 ms) than when it followed an invalid gaze cue (*M* = 270 ms, *SD* = 18 ms), t (12) = 2.27, $p < 0.05$.

Detection Task (Day 2). The same 2 x 2 ANOVA as above was conducted on response latencies to detect the disc. We found a main effect of Cue Masking, F (1, 12) = 9.63, $p < 0.01$, $\eta^2 p = 0.45$ and Cue Validity, F (1, 12) = 9.20, $p < 0.05$, $\eta^2 p = 0.43$. There was also a significant interaction between Cue Masking and Cue Validity, F (1, 12) = 8.05, $p < 0.05$, $\eta^2 p = 0.40$. As Fig. 4 suggests, when the gaze cue was unmasked, response latencies to detect the disc were shorter when the disc followed a valid gaze cue (*M* = 254 ms, *SD* = 29 ms) than when it followed an invalid gaze cue (*M* = 267 ms, *SD* = 29 ms), t (12) = 3.46, $p < 0.01$. In contrast, when the gaze cue was masked, response latencies to detect the disc were not different when the disc was preceded by a valid gaze cue (*M* = 249 ms, *SD* = 26 ms) than an invalid gaze cue (*M* = 251 ms, *SD* = 29 ms), t (12) = 1.04, $p = 0.32$.

To quantify the evidence in favour of the null (i.e., gaze cues do not produce cueing) or alternative (i.e., gaze cues produce cueing) hypotheses, we, once again, calculated the JZS-BF for the planned comparisons in the localization and detection tasks of Experiment 3. In the localisation task, the JZS–BF result was 0.02 for unmasked cues and 0.63 for masked cues. These results indicate 50:1 odds in favour of the alternative hypothesis for unmasked cues and 2:1 odds also in favour of the alternative hypothesis for masked cues. In the detection task, the JZS-BF result was 0.09 for unmasked cues and 2.94 for masked cues. These results indicate 11:1 odds in favour of the alternative hypothesis for unmasked cues and, in contrast, 3:1 odds in favour of the null hypothesis for masked cues. The inferential statistics and JZS-BF results indicate that, in a localisation task, masked gaze cues yield a (small) cueing effect, but, in a detection task, masked gaze cues do not yield a cueing effect.

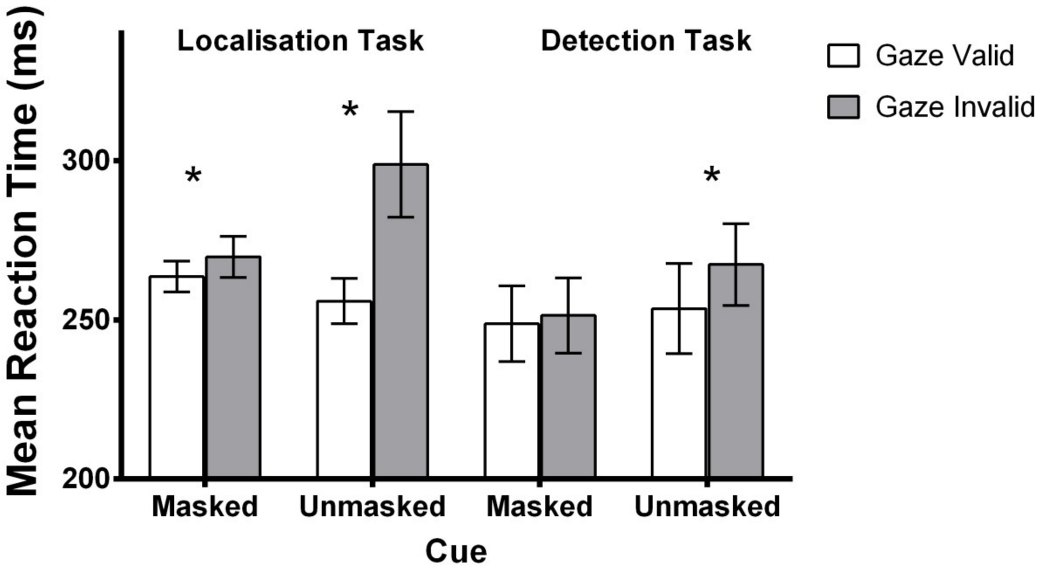

*Figure 4.*Mean response latencies to the localization task (Day 1), and the detection task (Day 2), when the target is presented following informative unmasked gaze cues and uninformative masked gaze cues (with CI bars) in Experiment 3.

Cue visibility. The mean hit rate and *d'* for unmasked gaze cues in the localization task (Day 1) were 97% and 3.14 (*SD* = 1.12), respectively. The mean hit rate and *d'* for masked gaze cues in the localization task were 67% and 0.85 (*SD* = 0.93), respectively. The mean hit rate and *d*' for the unmasked gaze cues in the detection task were 97% and 3.01 (*SD* = 1.07), respectively. The mean hit rate and *d'* for masked gaze cues in the detection task were 68% and 0.86 (*SD* = 0.73), which is comparable to the *d'* scores for the localization task. One-sample t-tests revealed that the *d'* for both unmasked and masked cues in the localisation and detection tasks was significantly different to 0 (t > 3).

Discussion

In Experiment 3 we examined whether or not the masked gaze-cueing effect is task dependent. As outlined above, if we were to find that the masked gaze-cueing effect is limited to the localization task, then this would provide support for the response priming account. If, however, we were to find that the masked gaze-cueing effect emerges regardless of task then this would provide evidence for the attentional orienting account. Experiment 3 yielded two main results. First, we once again observed a gaze-cueing effect for unmasked cues in both localization and detection tasks. This result is consistent with the attentional orienting account (Brignani, Guzzon, Marzi, & Miniussi, 2009; Driver, et al., 1999; Friesen & Kingstone, 1998; Friesen, Moore, & Kingstone, 2005; Friesen, et al., 2004). Second, and more importantly, we found that the gaze-cueing effect for masked cues was limited to the localization task. This result indicates that the masked gaze-cueing effect is task dependent, which is consistent with the response priming account. Specifically, our findings suggest that the previously reported (Al-Janabi & Finkbeiner, 2012; Sato, et al., 2007) masked gaze-cueing effect may be due to participants' covert formulation of a left/right response to the gaze cue, which is only possible in the localization task. Before drawing this conclusion, however, it is important to rule out another, alternative possibility, which is that the detection task is less robust than the localization task in revealing masked gaze-cueing effects. Hence, in Experiment 4, we asked participants to complete the detection task over two days to see if this would lead to a reliable masked gaze-cueing effect. By doubling the number of trials in the Experiment 4, we should increase our chances of observing subtle masked cueing effects.

Experiment 4

In Experiment 4, participants completed a detection task over two days to examine whether or not a masked gaze-cueing effect can be observed with twice the amount of trials. It is possible that we have been unable to observe a masked-gaze cueing effect in the current study because it is weaker in the detection task as compared to the localization task. One way of addressing the possibility of a weaker effect is to increase the number of trials that one averages over. We did this in the present experiment by doubling the number of trials compared to the previous experiments.[2] As in previous experiments, the unmasked gaze cues were informative of target location (80%) and the masked gaze cues were uninformative of target location (50%).

Method

Participants. Thirteen students (3 males and 10 females; mean + SD age, 20 + 1 years) at Macquarie University participated in this study for course credit. Informed consent was obtained from all participants. These participants were naive to the experiment.

Stimuli. The stimuli were the same as those used in Experiment 1.

Procedure. The within-subjects factors manipulated in this task were Day (day 1, day 2), Cue Masking (masked, unmasked) and Cue Validity (valid, invalid). There were 100 experimental trials and 10 catch trials in each of the 8 conditions. The trial structure of

[2] To confirm that this was an effective approach, we ran a simulation of 10,000 experiments with 13 subjects and a 'true' RT effect of 15ms and found that doubling the number of trials from 100 to 200 per condition led to a 15% increase in the probability of rejecting the null hypothesis.

Experiment 4 was the same as in Experiment 3, except that participants completed a detection task on both Day 1 and Day 2. Following the experiment proper was the same cue visibility task used in Experiment 1.

Results

Response latencies. Mean accuracy on the catch trials was 85% (*SD* = 9%) on Day 1 and 83% (*SD* = 11%) on Day 2. These trials were discarded from data analysis. The mean error rate for experimental trials was 1% across all conditions (*SD* = 0.80%). Responses that were below 100 ms (4.48%) and greater than 1, 000 ms (0.83%) were also discarded. Such trials were categorised as anticipations and misses, respectively. The dependent variable was mean reaction time for correct responses. A 2 x 2 x 2 ANOVA was conducted on response latencies, with Day (day 1, day 2), Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated-measures factors. We found a main effect of Day, F (1, 12) = 13.78, $p < 0.01$, η^2p = 0.54, Cue Masking, F (1, 12) = 26.24, $p < 0.0001$, η^2p = 0.69, and Cue Validity, F (1, 12) = 13.56, $p < 0.01$, η^2p = 0.53. We also found a significant interaction effect between Cue Masking and Cue Validity, F (1, 12) = 11.78, $p < 0.01$, η^2p = 0.50. As Fig. 5 indicates, this effect suggests that, for unmasked gaze cues, response latencies to detect the disc were shorter when it followed a gaze valid cue (*M* = 283 ms, *SD* = 52 ms) compared to a gaze invalid cue (*M* = 293 ms, *SD* = 52 ms), t (12) = 4.07, $p < .01$. In contrast, for masked gaze cues, response latencies to detect the disc were not reliably different when the disc followed a gaze valid cue (*M* = 275 ms, *SD* = 51 ms) or a gaze invalid cue (279 ms, *SD* = 50 ms), t (12) = 2.12, $p = 0.06$. No other effects were significant (F < 1).

We quantified the evidence in favour of the null (i.e., gaze cues do not produce cueing) or alternative (i.e., gaze cues produce cueing) hypotheses by calculating the JZS-BF for the planned comparisons in Experiment 4. The JZS–BF result was 0.04 for unmasked cues, which indicates 25:1 odds in favour of the alternative hypothesis for those cues. In contrast, the JZS-BF result was 0.78 for masked cues, which indicates 1.28:1 odds, which cannot be taken as evidence for the alternative nor null hypothesis. Although, this result provides no positive evidence in favour of the null hypothesis, we note that the lack of evidence for the *alternative* hypothesis in the detection task here is consistent with findings in Experiments 1-3. Thus, it is increasingly unlikely that masked gaze cueing effects emerge in the detection task.

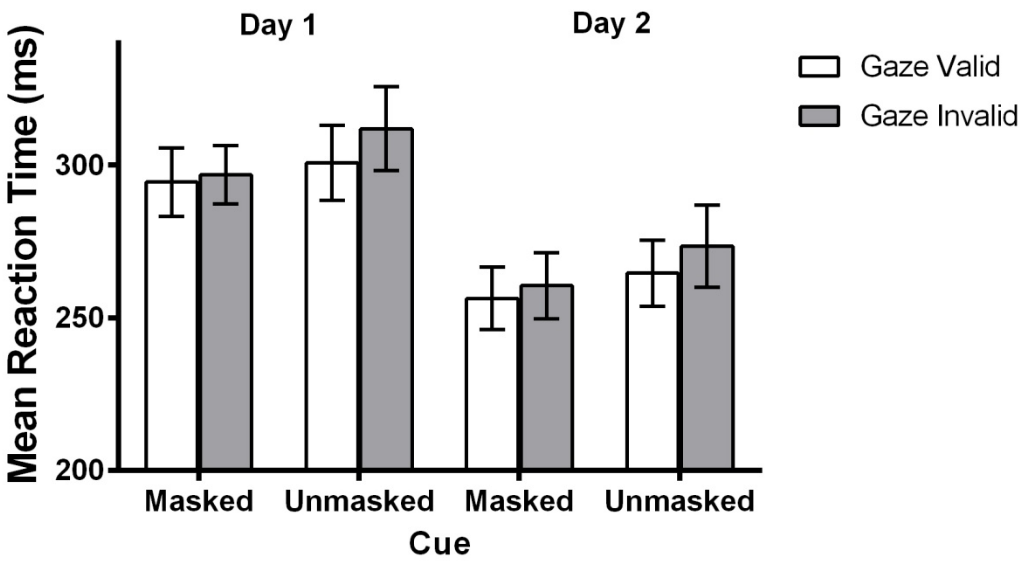

Figure 5. Mean response latencies to detecting the disc on Day 1 and Day 2, when the target is presented following informative unmasked gaze cues and uninformative masked gaze cues (with CI bars) in Experiment 4.

Cue visibility. The mean hit rate and *d'* was 96% and 3.03 (*SD* = 2.32), respectively, for unmasked gaze cues. The mean hit rate and *d'* was 59% and 0.39 (*SD* = 0.45), respectively, for masked gaze cues. A one-sample t-test revealed that the *d'* for both unmasked and masked cues was significantly different to 0 (t > 4).

Discussion

The purpose of Experiment 4 was to address the possibility that the masked gaze-cueing effect is very small in the detection task and that it can only be found in experiments that are designed with this factor in mind. To address this possibility, we doubled the number of trials in the detection task (by testing subjects over two days). Our simulation of 10,000 experiments revealed that doubling the number of trials leads to a 15% increase in (correctly) rejecting the null hypothesis. But once again, we found gaze-cueing effects for unmasked, but not masked gaze cues. These results suggest that the masked gaze-cueing effect might not generalize to detection tasks because it is dependent on response formulation processes. Recall that if the masked gaze-cueing effect is attributed to gaze-triggered shifts of attention, then it should be robust to a change in experimental tasks. If, however, the masked gaze-cueing effect is attributed to response formulation processes, then it should be isolated to the localization task and fail to generalize to the detection task. Our finding that the masked gaze-cueing effect emerges in localization tasks, which map cue direction to a left/right response, but not detection tasks, which do not map cue direction onto a response, is consistent with the response priming account. In contrast, our finding that the unmasked gaze-cueing effect emerges in both the detection and localization tasks is consistent with the attentional orienting account. Thus, the results of Experiments 1 - 4 suggest that the masked gaze-cueing effect depends on stimulus-response mappings not the orienting of spatial attention. In the next experiment, we consider the possibility that the masked gaze-cueing effect did not emerge in a detection task because it does not adequately assess spatial attentional processes.

Experiment 5

In Experiments 1 – 4 we examined whether or not a masked gaze-cueing effect emerges in a task that allows participants to shift attention in response to cue direction (detection task). We found that it does not. In fact, we found that a masked gaze-cueing effect emerges only in a task that allows participants to map cue direction onto a left/right response (localization task). Thus, we have argued that the masked gaze-cueing effect should be attributed to response formulation processes rather than shifts in spatial attention. Before drawing this conclusion, though, it is important to consider the possibility that the detection task we used to investigate attentional cueing did not adequately measure spatial attention (Ristic, Landry, & Kingstone, 2012). There is, for example, some evidence to suggest that detection tasks, unlike discrimination or localization tasks, do not fully engage spatial attention (Luck et al., 1999; Hopf et al., 2002; Hopfinger & Mangun, 1998). It has also been suggested that detection tasks may measure late decision-related processes rather than attentional processing (Shaw, 1978). Detection tasks, therefore, may not be an appropriate task to use when assessing whether or not masked gaze cues produce a shift in spatial attention.

In Experiment 5, to address the possible shortcomings of the detection task employed in Experiments 1 - 4, we made use of a discrimination task. An added advantage of the discrimination task is that it requires participants to use two response effectors, just like the localization task, thereby allowing us to equate the number of response alternatives across tasks. In our discrimination task, participants were asked to identify a target (e.g., is it an ‘X’ or an ‘O’?) by pressing one of two response buttons. Importantly, we positioned the two buttons orthogonally to the direction of the gaze cues to limit the possibility of response priming effects. The discrimination task can, thus, isolate effects that should be attributed to shifts in spatial attention from those that should be attributed to response priming.

Method

Participants. Twenty students (5 males and 15 females; mean + SD age, 24 + 9 years) at Macquarie University participated in this study for course credit. Informed consent was obtained from all participants. These participants were naive to the experiment.

Stimuli. The stimuli used in this experiment were the same as those used in Experiment 1. However, in this experiment, white ‘X’ and ‘O’ stimuli served as targets instead of grey discs. The targets measured 1.57º x 1.18º degrees of visual angle with a viewing distance of 55 cm.

Procedure. The within-subjects factors manipulated in this task were Cue Masking (masked, unmasked) and Cue Validity (valid, invalid). There were 110 trials in each of the 4 conditions. Participants were required to press a response button to begin each of the 40 practice trials and 440 experimental trials. The trial structure was similar to Experiment 1: a centrally-presented white fixation cross appeared for 680 ms, followed by an averted gaze cue in the same locus. In the unmasked condition, the cue was presented for 30 ms, followed by a blank screen for 170 ms. In contrast, in the masked condition, the cue was presented for 30 ms, followed by the backward mask in the same location for 170 ms. It is important to note that in this experiment both the masked and unmasked cues were presented for 30 ms, thus eliminating the difference in cue duration between masked and unmasked conditions that was present in Experiments 1 – 4. The unmasked cue was informative of target location (80%) whereas the masked cue was uninformative of target location (50%). The cues were followed by white ‘X’ or ‘O’ targets. These targets were presented with equal probability on either the left or right side of the screen (5° from the centre) following the offset of the cue-blank (in the unmasked condition) or cue-mask (in the masked condition). Participants were asked to respond to the identity of the target by pressing one of two vertically-aligned response buttons. The buttons were mapped vertically as opposed to horizontally to prevent left/right stimulus-response compatibility effects. Participants were asked to use one index finger for each response button. The mapping between target letter and response button was counterbalanced across participants. The target remained on screen for 300 ms or until a response was made. All trials were presented in a random order. Participants completed a cue visibility task after the experiment.

Results

Response latencies. Incorrect trials (5% across all conditions, *SD* = 3%) were removed from the RT analysis. Trials with responses that were less than 100 ms (0.03%) or greater than 1, 000 ms (3.4%) were also discarded. These trials were categorised as anticipations and misses, respectively. The dependent variable was mean reaction time for correct responses. A 2 x 2 ANOVA was conducted on response latencies with Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated-measures factors. We found a main effect of Cue Validity, F (1, 19) = 5.64, $p < 0.05$, $\eta^2 p$ = 0.22, but not Cue Masking, F (1, 19) = 0.06, p = 0.81, $\eta^2 p$ = 0.001. We also found a significant interaction effect between Cue Masking and Cue Validity, F (1, 19) = 4.67, $p < 0.05$, $\eta^2 p$ = 0.19. As Fig. 6 indicates, this interaction is carried by an effect of Cue Validity for unmasked cues, but not masked cues. Response latencies to discriminate the target letter were shorter following an unmasked gaze valid cue (*M* = 513 ms, *SD* = 121 ms) compared to an unmasked gaze invalid cue (*M* = 530 ms, *SD* = 139 ms), t (19) = 2.59, $p < .05$. In contrast, for masked gaze cues, response latencies to discriminate the target letter were not significantly different when the target followed a gaze valid cue (*M* = 522 ms, *SD* = 119 ms) or a gaze invalid cue (523 ms, *SD* = 118 ms), t (19) = 0.32, *p* = 0.75.

We quantified the evidence in favour of the null (i.e., gaze cues do not produce cueing) and alternative (i.e., gaze cues produce cueing) hypotheses by calculating the JZS-BF for the planned comparisons in Experiment 5. The JZS–BF result was 0.37 for unmasked cues and 5.56 for masked cues. These results indicate 3:1 odds in favour of the alternative hypothesis for unmasked cues and 6:1 odds in favour of the null hypothesis for masked cues. Thus, both the inferential statistics and JZS-BF results suggest masked cues do not yield a cueing effect in a discrimination task, even when presented in the context of predictive unmasked cues.

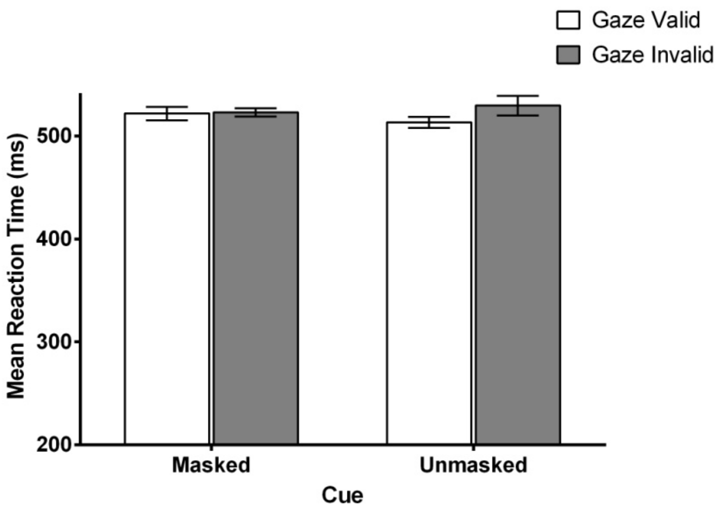

Figure 6. Mean response latencies to discriminating the letter, when the target is presented following informative unmasked gaze cues and uninformative masked gaze cues (with CI bars) in Experiment 5.

Cue visibility. The mean hit rate and *d'* was 89% and 2.36 (*SD* = 1.20), respectively, for unmasked gaze cues. The mean hit rate and *d'* was 57% and 0.28 (*SD* = 0.48), respectively, for masked gaze cues. A one-sample t-test revealed that the *d'* for both unmasked and masked cues was significantly different to 0 (t > 2.6).

Discussion

In Experiments 1 – 4 we have compared findings from the detection task to those from the localization task. The motivation for this comparison was to discover whether the masked gaze-cueing effect should be attributed to attentional cueing or response priming. The virtue of the detection task is that it prevents response priming effects from masquerading as cueing effects. We do not find any evidence of masked gaze-cueing effects in the detection task. The localization task, on the other hand, allows for the possibility of response priming effects and, hence, the opportunity to misinterpret these effects as evidence for attentional cueing. Given that we consistently observe a masked gaze-cueing effect in a localization task, but not a detection task, we have suggested that the masked gaze-cueing effect is really a response priming effect and should be attributed to a modulation of response formulation processes. A concern with this conclusion is that the detection task may not adequately measure spatial attention. Thus, the aim of the present experiment was to employ a task that engaged spatial attention resources. Hence, we used a discrimination task. Given that this experiment once again yielded an unmasked gaze-cueing effect but no masked gaze-cueing effect, we can conclude that whether or not a task allows for a straightforward mapping between gaze cue direction and response location is critical to observing a masked gaze-cueing effect. Only the localization task allows for this mapping, and, thus, we observed a masked gaze-cueing effect. All three tasks that we employed (detection, discrimination, and localization) allowed for attentional-cueing effects, but only the localization task yielded a positive finding. We are, therefore, sceptical that the masked gaze-cueing effect that is observed in the localization task should be attributed to the orienting of spatial attention.

General Discussion

This study investigated whether masked gaze-cueing effects are driven by attentional orienting or response preparation to gaze direction. Recently, Sato et al. (2007) and Al-Janabi and Finkbeiner (2012) have observed that masked cues can produce a gaze-cueing effect. The results of these previous two studies have been taken as evidence for gaze-triggered attentional orienting without awareness. However, these previous studies (Al-Janabi & Finkbeiner, 2012; Sato et al., 2007) conflated spatial attention with response priming by using a localization task, and, hence, the mechanism responsible for the observed masked gaze-cueing effect has been difficult to establish. On the one hand, the observed masked gaze-cueing effect could be explained by an attentional orienting account, wherein participants shift their attention to the gaze cue direction, which facilitates target localization on gaze valid, but not invalid, trials. On the other hand, the observed masked gaze-cueing effect could be explained by a response priming account, wherein participants prepare a left/right motor response to gaze cue direction, which facilitates target localization on gaze valid, but not invalid, trials. Thus, the aim of this study was to adjudicate between these two alternative accounts by ascertaining whether masked gaze-cueing effects can be observed in detection and discrimination tasks, which isolate spatial attention from response formulation processes.

We have observed several important findings in the present study. First, we have found that the gaze-cueing effect for *unmasked* gaze cues emerges in detection, discrimination and localisation tasks. Second, and in sharp contrast, we have found that the emergence of the *masked* gaze-cueing effect is task dependent, such that, for the same participants, it can be observed in a localisation task, but not in a detection task. Third, we have found that the lack of a masked gaze-cueing effect in the detection task is not due to an insufficient number of trials. In Experiment 4, we found that the gaze-cueing effect in a detection task was limited to unmasked cues, despite participants having completed double the amount of trials. Fourth, we have shown how the presence of a masked gaze-cueing effect in the localization task, but not the detection task, is not due to a difference in the number of response effectors between the two tasks. Specifically, in Experiment 5, we asked participants to complete a discrimination task that required two response buttons that were positioned orthogonally to gaze cue direction. Here we again found an unmasked gaze-cueing effect, but no masked gaze-cueing effect. This pattern of results suggests that the masked gaze-cueing effect occurs only when participants are given the opportunity to formulate covert responses to cue direction. Thus, our findings suggest that the masked gaze-cueing effect found in prior studies (which utilised a localisation task; Al-Janabi & Finkbeiner, 2012; Sato, Okada & Toichi, 2007) did not reflect an instance of gaze-triggered attentional orienting without awareness. In fact, our results suggest that the masked gaze-cueing effects observed in prior studies probably arose on the basis of rapidly acquired mappings between the unmasked stimuli and response keys that were then applied to the masked stimuli. The fact that such stimulus-response mappings can be triggered under masked conditions is well established in the masked priming literature (Damian, 2001; Eimer & Schlaghecken, 2002). If the gaze-cueing effect for *masked* cues depends on participants having established and incorporated the appropriate stimulus-response mappings then why do *unmasked* cues produce a gaze-cueing effect in both the detection and localization tasks? In some ways we are in the unfortunate position of having to appeal to two different accounts to explain our pattern of results. The finding that the gaze-cueing effect is limited to the localization task for *masked* cues is consistent with the response priming account and <u>inconsistent</u> with the attentional orienting account. However, the finding that the gaze-cueing effect for *unmasked* cues is robust in the detection, discrimination and localization tasks is consistent with the attentional orienting account and <u>inconsistent</u> with the response priming account. Furthermore, it is already well established in the gaze-cueing literature that the gaze-cueing effect for unmasked cues is best explained by the attentional orienting account not the response priming account (Friesen, et al., 2005). To reconcile these two seemingly contrasting accounts of the gaze-cueing effect for masked and unmasked gaze cues within a single theoretical framework, we turn to a recent proposal by Bayliss, Bartlett, Naughtin and Kritikos (2010) and Zhang, Zhao and Zhan (2011) on gaze-cueing mechanisms.

It has been proposed (Bayliss, et al., 2010; Zhang, et al., 2011) that gaze following proceeds through two stages of processing. The first stage is early visual analysis, which involves the encoding of eye shape, contrast information, and other low-level information, in the inferior occipital gyrus (IOG; Ando, 2002; 2004; Materna, Dicke & Their, 2008). The second stage is gaze perception, which involves extracting and encoding gaze direction by specialized neurons oriented to left, right and direct gaze in the anterior superior temporal sulcus (Calder, et al., 2007). This serial model of gaze following posits that the low-level, visual perception system is blind to input type (i.e., it does not recognize whether the input stimulus is eye-gaze, in particular, or another directional stimulus), whereas the gaze perception system is tuned specifically to eye-gaze. On this account, the gaze-cueing effect is primarily (though not solely) attributed to the gaze perception system, which outputs information to the attention system in the intraparietal sulcus that then results in shifts of spatial attention (Hoffmann & Haxby, 2000; Hooker, et al., 2003; Nobre, et al., 1997; Nummenmaa & Calder, 2009). If this account of how information is exchanged between the cognitive mechanisms responsible for gaze perception and social attention is correct then it is plausible that masked gaze cues, unlike unmasked gaze cues, do not produce classic cueing effects because they do not engage the gaze perception system, which contributes to attention orienting. Below we present three reasons for why masked gaze cues, unlike unmasked gaze cues, might not activate this high-level, gaze perception system.

The first possibility is that the gaze perception system is activated only when a strong percept of the gaze stimulus is formed. The obvious difference between our unmasked and masked gaze cues is that the masked cue is followed by a backward mask, whereas the unmasked cue is not. The presentation of this backward mask disrupts recurrent interaction between higher and lower visual areas for the masked gaze cues (e.g., Enns & Di Lollo, 2000), thus rendering them less visible and, at times, even non-conscious. In contrast, this recurrent interaction remains intact for the unmasked gaze cues, thus rendering them visible and conscious. Hence, given that visibility, or ‘consciousness’, is the property that differentiates unmasked to masked cues, it is possible that spatial encoding and subsequent attentional shifts occur only if gaze direction has been adequately extracted. On this line of thinking, we suggest that gaze cues (such as the unmasked cues in Experiments 1 – 5) produce shifts of attention via the specialized gaze perception system only when a strong percept of the gaze stimulus has formed. This possible link between consciousness and the gaze perception system can then explain our finding that masked cues only produced a gaze-cueing effect in the localization, but not detection or discrimination, tasks. In the detection and discrimination tasks, the only way to observe a cueing effect is through a shift of attention; therefore, the gaze perception system must be engaged for a cueing effect to emerge. We suggest that, although the masked gaze cues used in Experiments 1 - 5 were visible to some extent, participants were unable (on all trials) to form a strong visible percept of gaze direction for those cues. Thus, those cues did not engage the high-level, gaze perception system sufficiently to produce the shift of attention required for gaze-cueing. In the localization task, however, the cueing effect can be observed through shifts of attention *or* response formulation processes; therefore, the gaze perception system need not be engaged for a cueing effect to emerge. We suggest that in this case the masked cues can yield a gaze-cueing effect, but only when participants are encouraged to use the cues to their advantage (as in Experiment 3, for example). Particularly, in a localization task, the low-level perceptual system, which is effective in processing masked cues, can be trained (when those masked cues are presented in the context of informative unmasked cues) to output relevant information along to the response system. This process leads to a masked gaze-cueing effect.

The second possibility, which is not mutually exclusive from the first, is that the gaze perception system is engaged only after the gaze cue is viewed for a sufficient period of time. That is, the critical aspect is not masking strength or visibility of the cue, but, simply, it is cue duration. In line with this reasoning, Lu and colleagues (2012) recently found that attentional orienting effects can be induced by a non-conscious, peripheral chromatic flicker cue, but only when the cue duration was long (376 ms not 94 ms). Following from this finding, the lack of a masked gaze-cueing effect in the detection and discrimination tasks may reflect the relatively weak signal strength of the masked gaze cues, which, again, means that the high-level, gaze perception system is not sufficiently engaged by these cues to produce attentional shifts. It is important to recall, however, that in Experiment 5 we found an unmasked gaze-cueing effect even though those cues were presented for the same duration as the masked cues (30 ms), which did not yield a cueing effect. This result implies that viewing time alone does not affect whether or not the gaze perception system is sufficiently engaged, but, perhaps, it is both viewing time and masking that affect the gaze perception system.

The third possibility is that masked gaze cues *can* orient attention, but the effect of such orienting is short-lived (given that these cues weakly engage the gaze perception system). On that possibility, it can then be assumed that the masked gaze cues used in our task did produce shifts of attention, but, after 200 ms, which is when the target appeared, attention was no longer focused on the cued location. While possible, it is important to note that Reuss, Pohl, Kiesel and Kunde (2011) have recently reported attentional shifts by centrally presented, masked directional cues using a 200 ms SOA. The Reuss et al. (2011) finding indicates that masked cueing effects do not (necessarily) dissipate rapidly, and, therefore, that masked cueing effects can be observed using a 200 ms SOA. Nevertheless, future experiments in this area would benefit from using a wide range of SOAs.

We have shown in this study that masked gaze-cueing effects emerge only in localization, but not detection, tasks. This finding suggests that masked gaze-cueing effects are attributed to response priming not attention orienting. We want to make it clear, however, that this result should not be taken as indication that masked cues (generally) cannot produce cueing effects that are attributed to shifts of attention. In fact, several researchers show evidence of attentional orienting triggered by masked non-social cues (Ansorge, Horstmann, & Worschech, 2010; Ansorge, Kiss, & Eimer, 2009; Fuchs & Ansorge, 2012; Fuchs, Theeuwes, & Ansorge, 2013; Mulckhuyse, et al., 2007). The masked cues used in those studies were, however, peripheral and socially irrelevant. In contrast, the masked cues used in our study were centrally presented and socially relevant. Our finding that masked gaze-cueing effects should be attributed to response priming as opposed to attention orienting further highlights the difference between cueing effects produced by peripheral cues and centrally, presented gaze cues (cf. Rombough, Barrie, & Iarocci, 2012).

CONCLUSION

For some time now, researchers have suggested that averted gaze produces shifts in attention because gaze is a special cue by virtue of its biological significance in everyday life (Galfano, et al., 2012) Recently, the question of whether or not such gaze-triggered attentional orienting can occur without awareness (thus reinforcing the special nature of gaze compared to other centrally presented cue types) has been investigated (Al-Janabi & Finkbeiner, 2012; Sato, Okada & Toichi, 2007). Those studies found that masked cues can produce a gaze-cueing effect, but only when eye-gaze information is incorporated into participants' task set. The purpose of the present study was to establish whether this observed masked gaze-cueing effect should be attributed to attentional orienting or to response formulation processes. Although we found a strong gaze-cueing effect for masked cues presented in the context of informative, unmasked cues, thereby replicating the previous studies of Sato and colleagues (2007) and Al-Janabi and Finkbeiner (2012), we found that this effect was limited to a localisation task and did not extend to detection or discrimination tasks. While our masking procedure did not completely prevent visual awareness, these results imply that the emergence of a masked gaze-cueing effect is <u>not only</u> dependent on top-down factors, as demonstrated by Al-Janabi and Finkbeiner (2012), but also on the presence of stimulus-response mappings. We suggest that the centrally presented, averted eye-gaze cue must activate a covert left/right localisation response that is appropriate for gaze valid trials, but inappropriate for gaze invalid trials, for a masked gaze-cueing effect to emerge. Therefore, the uniqueness of gaze cues over and above other centrally presented stimuli is not evident under masked conditions.

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Study 4

Masked arrow cueing: an attentional or motoric effect?

Abstract

It is claimed that uninformative abrupt-onset cues presented in the periphery can shift attention even when masked. This pattern of results has been taken as evidence for the limited role of top-down factors in such orienting of attention. Recently, interest has turned to whether or not uninformative symbolic cues presented in the centre can also shift attention when masked. In the one study designed to address this question, the researchers found that arrow cues produce a cueing effect when masked. The study, however, utilized a localisation task and, thus, is ambiguous with respect to whether or not the observed masked arrow-cueing effect can be attributed to the shifting of attention or the preparation of a motor response. The purpose of the present study was to investigate this issue by determining whether or not masked arrow cues can affect behaviour in a discrimination task, which isolates spatial attention from response-priming. First, we found an arrow-cueing effect for unmasked cues in a discrimination and localisation task, which indicates that the arrow-cueing effect for visible cues is not task dependent. Second, and in contrast, we found an arrow-cueing effect for masked cues in a localisation task, but not in a discrimination task, which indicates that the arrow-cueing effect for masked cues is task dependent. Third, we found that the emergence of a masked arrow-cueing effect in a localisation task is dependent on participants learning stimulus-response, not stimulus-effector, mappings. Thus, the present study shows that the emergence of arrow cueing is reliant on cue visibility. Moreover, our results indicate that arrow cues can affect behaviour only in tasks that allow stimulus-response mappings.

Masked arrow cueing: an attentional or motoric effect?

It is widely held that our visual environment presents us with far more information than we can process and, thus, that we have devised the means by which to filter out irrelevant information. This selection process is accomplished through selective attention, which can be deployed either exogenously (i.e., involuntarily) or endogenously (i.e., voluntarily; Luck, Hillyard, Mouloua, & Hawkins, 1996; Posner & Petersen, 1990; Theeuwes, 1989; Theeuwes & Van der Burg, 2007). Both forms of selective attention are commonly investigated experimentally using the spatial cueing paradigm. In this paradigm, a cue validly or invalidly signals the location of an upcoming target. Studies typically find that observers respond faster to targets that are validly cued than to targets that are invalidly cued, thus suggesting that attention shifts to the spatial location signalled by the cue (Jonides, 1980; 1981; Posner, 1980). These shifts of attention are classified as exogenous when the cue is peripheral and uninformative of target location and endogenous when the cue is central and informative of target location (e.g., Folk, Remington, & Johnston, 1992; Jonides & Irwin, 1981; Müller & Rabbitt, 1989; Posner & Cohen, 1984; Posner, Cohen, & Rafal, 1982; Theeuwes, 1991; Yantis & Jonides, 1990). There are cases, however, in which shifts of attention are produced by central cues that are uninformative of target location (Driver et al., 1999; Eimer, 1997; Friesen, Ristic, & Kingstone, 2004; Friesen & Kingstone, 1998; Hommel, Pratt, Colzato, & Godijn, 2001; Kunde, Skirde, & Weigelt, 2011; Langton & Bruce, 1999). Those cases indicate that over-learned symbolic stimuli, such as arrows and averted eye-gaze, generate shifts of spatial attention that cannot be solely attributed to endogenous orienting. More recently, several researchers have become interested in whether or not symbolic cues produce exogenous shifts of attention when the cues are masked (Al-Janabi & Finkbeiner, 2012; 2014; Gayet, Van der Stigchel & Paffen, 2013; Reus, Pohl, Kiesel & Kunde, 2011; Sato, Okada & Toichi, 2007).

Numerous studies have shown that uninformative, peripheral cues can capture attention even when they are heavily masked (e.g., Fuchs & Ansorge, 2012; Fuchs, Theeuwes & Ansorge, 2013; Ivanoff & Klein, 2003; McCormick, 1997; Mulckhuyse, Talsma & Theeuwes, 2007). Turning to centrally presented symbolic cues, it has been reasoned that if symbolic cues can orient attention similarly to peripheral cues then they too should have the capacity to orient attention in the absence of awareness. Reuss et al. (2011), for example, asked participants to identify a peripherally presented target that was preceded by central unmasked and (metacontrast) masked arrow cues. The cues were uninformative of target location in Experiment 1 and informative of target location in Experiment 2. Reuss et al. (2011) found an unmasked arrow-cueing effect in both Experiments 1 and 2. Interestingly, however, the researchers found a masked arrow-cueing effect only in Experiment 2. Reuss et al. (2011) took these results to mean that masked symbolic cues can shift attention, but only when they fit the observer's intentions. A potential problem of Reuss et al's (2011) study, however, was that in Experiment 2 they increased the predictive value of *both* masked and unmasked cues. It is, therefore, unclear whether or not masked arrow cues, like peripheral cues, can shift spatial attention when they are uninformative of target location. Gayet et al. (2013) addressed this issue in a subsequent study by manipulating the predictive value of arrow cues in a target localisation task. Specifically, in their study, the (flash-suppressed) masked arrow cues were always uninformative of target location, but the predictive value of the unmasked arrow cues varied between blocks. Gayet et al. (2013) found that masked arrow cues can produce a cueing effect, but only when they appeared in the context of visible and informative (80% valid) unmasked cues. Thus, Gayet et al. (2013) concluded that uninformative, masked arrow cues, like abrupt onset cues, can affect behaviour, but only when unmasked arrow cues provide a context that favours cue utilization.

Although the findings of Gayet et al. (2013) indicate that uninformative masked arrow cues can produce a cueing effect, we still do not know the source of this effect. It could be that the participants in the Gayet et al. (2013) study responded faster to validly cued targets compared to invalidly cued targets due to appropriate shifts of spatial attention in response to cue direction. In fact, this is the standard interpretation of the cueing effect. It could, however, be that participants in the Gayet et al. (2013) study responded faster to validly cued targets because they were covertly *responding* to the cues. We cannot tell which account is correct in the study by Gayet et al. (2013) because they used a localisation task (i.e., press left key for 'left' targets and right key for 'right' targets), which conflates the effects of spatial attention with those of response-priming (Zehetleitner & Muller, 2010). Put differently, there are two possible accounts for the arrow-cueing effects observed in the Gayet et al. (2013) study. The standard account posits that participants in the Gayet et al. (2013) study shifted attention to the direction signalled by the arrow cues, which then facilitated responses to the target on valid, but not invalid, trials. This explanation of the arrow-cueing effect is the standard *attentional-orienting account*. There is, however, an alternative explanation of the arrow-cueing effects observed in Gayet et al's (2013) study, which we refer to as the *response-priming account* (Spence & Driver, 1996). According to the response-priming account, participants activate a covert left/right localisation response to the cue, which then facilitates responses to the target on valid, but not invalid, trials. This response-priming account is not new. In fact, several studies have shown that participants can establish stimulus-response mappings during the course of an experiment, which contribute to the emergence of priming effects (e.g., Abrams & Greenwald, 2000; Eimer & Schlaghecken, 2002; Kunde, Kiesel, & Hoffmann, 2003; Leuthold & Kopp, 1998; Neumann & Klotz, 1994). Hence, given that Gayet et al. (2013) used a localisation task, which conflates attentional orienting with response-priming, they were not able to disassociate between these two possible accounts of their observed cueing effect.

The aim of the present study, therefore, was to determine whether or not uninformative masked arrow cues produce shifts of spatial attention. Unlike Gayet and colleagues (2013), we asked participants to discriminate, rather than localise, the target. In a discrimination task, participants are asked to identify a target (e.g., "is it an X or an O?") by pressing one of two response buttons. The advantage of this task is that spatial location is irrelevant to the task goals. It is, therefore, unlikely that the spatial attributes of the cue can automatically activate a spatial response. The possibility of response-priming was further limited by positioning the two response buttons orthogonally to the direction of the arrow cues. Thus, the discrimination task that was adopted in this study can isolate effects that should be attributed to shifts in spatial attention from those that should be attributed to response-priming. Importantly, if the masked arrow-cueing effect is due to shifts of attention, then it should emerge in the discrimination task. If, however, the masked arrow-cueing effect is attributed to response-priming then it should be limited to the localisation task and fail to emerge in the discrimination task. Hence, to ascertain whether or not the masked arrow-cueing effect is attributed to attentional-orienting or response-priming, we compared the masked arrow-cueing effects obtained in a localization task with those obtained in a discrimination task. In Experiment 1, participants were asked to identify a target, which was preceded by unmasked and masked arrow cues. The unmasked cues were informative (80% valid) of target location, whereas the masked cues were uninformative (50% valid) of target location. To anticipate our results, we found reliable arrow-cueing effects for the unmasked cues, but not for the masked cues. Having established that the masked arrow-cueing effect did not emerge in the discrimination task, even though the unmasked cues were informative, we then pursued the possibility that this masked arrow-cueing effect was limited to tasks that allow for response mapping. To investigate this possibility, we asked participants to complete a localisation task in Experiment 2. We observed here both a masked and unmasked arrow-cueing effect. Based on this result, the purpose of Experiment 3 was to identify whether the masked arrow-cueing effect should be attributed to stimulus-response mappings or to stimulus-effector mappings. To distinguish between these two possibilities, we asked participants to complete a localisation task with their hands crossed in some blocks and uncrossed in other blocks. We observed a similar masked cueing effect across blocks of crossed and uncrossed hands, thereby constraining the response-priming account of these results by suggesting that the source of the cueing effect is due to stimulus-response mappings not stimulus-effector mappings. Taken together, the results of the present study indicate that masked arrow cues, unlike abrupt onset cues, produce a cueing effect only when the task allows for the formation of stimulus-response mappings. Thus, we interpret these results in favour of the response-priming, rather than the attentional-orienting, account.

Experiment 1

The purpose of Experiment 1 was to investigate whether or not masked arrow cues can orient spatial attention in a discrimination task. Participants were asked to identify a target letter ("is it an X or an O?") that was preceded by a central arrow cue that was either backward masked or not. The unmasked arrow cue was informative of target location (that is, 80% valid), whereas the masked arrow cue was uninformative of target location (that is, 50% valid).

Method

Participants. A group of 14 participants (5 males and 9 females; mean + SD age, 24 + 5 years) at Macquarie University participated in the study for AUD$15. Informed consent was obtained from all participants.

Stimuli. The cue was a white double arrow pointing left or right (see Figure 1). This cue subtended a visual angle of 2.01º x 2.01º with a viewing distance of approximately 55 cm. The backward mask consisted of superimposed left – and right – pointing double arrows. The targets were white X and O stimuli, which measured 1.57º × 1.18º degrees of visual angle. The fixation cross was white and measured 1.37º × 1.03º. All stimuli were presented on a black background using a 27-in. LED monitor with a 1,920 × 1080 screen resolution and a 100-Hz refresh rate.

Procedure. The factors manipulated in this task were Cue Masking (masked, unmasked) and Cue Validity (valid, invalid). Participants were required to press a response button to begin each of the 80 practice trials and 640 experimental trials. There were, therefore, 160 test trials in each of the four conditions. The trial structure of Al-Janabi and Finkbeiner (Experiment 5; 2014) was adopted (see Fig. 1): A white fixation cross appeared for 680 ms in the centre of the screen. This fixation cross was followed by an arrow cue in the same locus. In the unmasked cue condition, the cue was presented for 30 ms, followed by a blank screen for 170 ms. However, in the masked cue condition, the cue was presented for 30 ms, followed by the backward mask in the same locus for 170 ms. The unmasked cue was informative of target location (80% valid) and the masked cue was uninformative of target location (50% valid). The arrow cue was followed by white X or O targets. These targets were presented equally on either the left or the right side of the screen (5º from the centre) following the offset of the cue blank (in the unmasked condition) or the cue mask (in the masked condition). Participants were required to indicate the identity of the target by pressing one of two vertically aligned response buttons. The buttons were mapped vertically to eliminate the occurrence of left–right stimulus–response compatibility effects. Participants were asked to respond using the index fingers of each hand. The mapping between target letter and response button was counterbalanced across all participants. The target remained on screen for 300 ms or until a response was detected. All trials were randomized. Participants completed a cue visibility task following the experiment.

The cue visibility task consisted of 160 trials following the experiment proper. The trials were the same as the discrimination task, except that participants were presented with two alternative cue stimuli (the true arrow cue and its opponent) following target identification and asked to indicate which stimulus had been presented in the previous trial. The masked and unmasked cues in this cue visibility task were uninformative of target location so as to prevent participants from using the target location as an index of which arrow cue had been presented.

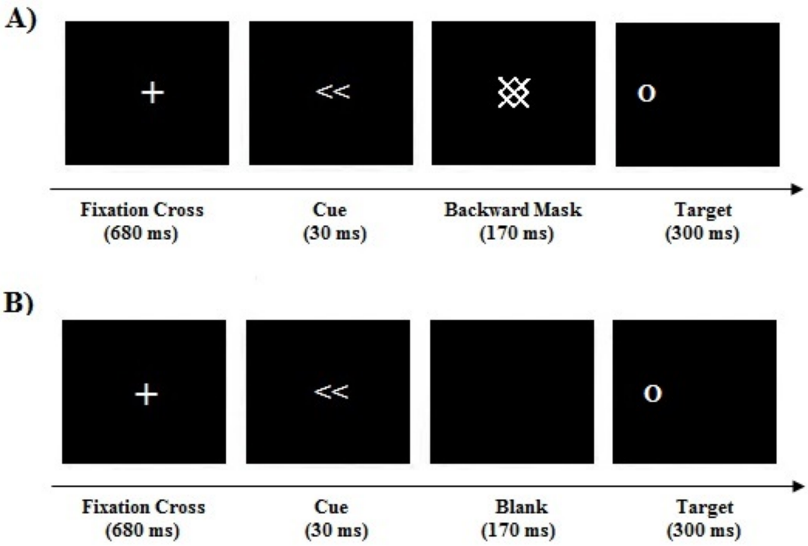

*Figure 1.*This figure reflects the sequence of displays for Experiment 1: masked presentation **(a)** and unmasked presentation **(b)**. The figure, in particular, depicts a valid trial in which the direction of the arrow cue predicts the location of the target.

Results

Response latencies. Incorrect trials (5% across all conditions, *SD* = 4%) were removed from the following analysis. Trials with response latencies that were less than 100 ms (0.08 %) or greater than 1,000 ms (1.90%) were also discarded. These trials were categorized as anticipations and misses, respectively. The dependent variable was the mean reaction time for correct responses. A 2 × 2 ANOVA was conducted on response latencies with Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated measures factors. We found a main effect of Cue Masking, $F\ (1, 13) = 9.23$, $p < 0.01$, $\eta p^2 = 0.42$, and Cue Validity, $F\ (1, 13) = 25.90$, $p < 0.0001$, $\eta p^2 = 0.67$. We also found a significant interaction effect between Cue Masking and Cue Validity, $F\ (1, 13) = 7.67$, $p < 0.05$, $\eta p^2 = 0.37$. As Fig. 2 indicates, this interaction was carried by an effect of Cue Validity for unmasked, but not for masked, cues. Response latencies to discriminate the target were shorter following an unmasked valid arrow cue (*M* = 612 ms, *SD* = 74 ms) than following an unmasked invalid arrow cue (*M* = 629 ms, *SD* = 78 ms), $t\ (13) = 4.40$, $p < 0.001$. In contrast, for masked arrow cues, response latencies to discriminate the target were not significantly different when the target followed a valid (*M* = 630 ms, *SD* = 70 ms), or an invalid, (*M* =632 ms, *SD* = 67 ms) arrow cue, $t\ (13) = 0.84$, $p = 0.42$.

We quantified the evidence in favour of the null (i.e., masked arrow cues do not produce cueing) hypothesis by calculating the JZS Bayes factors (JZS-BF) for the planned comparison in Experiment 1. This analysis allows us to draw meaningful inferences from non-significant findings, such as the one found in the masked arrow cue condition, by allowing us to determine how well the evidence supports the null or the alternative hypothesis (Rouder & Morey, 2011). The JZS-BF result was 3.58 for masked arrow cues. This result indicates 4:1 odds in favour of the null hypothesis for those cues. Thus, taken together, the lack of a positive effect (using inferential statistics) and the positive evidence in favour of the null (JZS-BF results) suggest that uninformative, masked arrow cues do not yield a cueing effect in a discrimination task, even when presented in the context of informative, unmasked arrow cues.

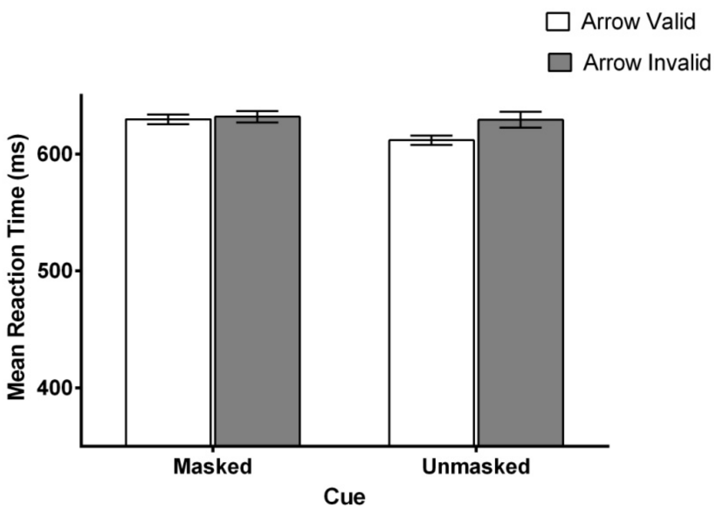

Figure 2. Mean response latencies to identifying the target, when it is presented following uninformative masked and informative unmasked arrow cues (with CI bars) in Experiment 1.

Accuracy rates. We analysed the accuracy rates using the same repeated-measures ANOVA as above. The mean accuracy rates for the masked valid and invalid conditions were 96% (*SD* = 3%) and 95% (*SD* = 5%), respectively. The mean accuracy rates for the unmasked valid and invalid conditions were 95% (*SD* = 4%) and 95% (*SD* = 4%). For these accuracy scores, the ANOVA revealed no significant main effect of Cue Masking, F (1, 13) = 2.86, p = 0.12, ηp^2 = 0.18, or Cue Validity, F (1, 13) = 0.93, p = 0.35, ηp^2 = 0.07. Importantly, there was no significant interaction between Cue Masking and Cue Validity, F (1, 13) = 0.45, p = 0.51, ηp^2 = 0.03.

Cue visibility. The mean hit rate for unmasked cues was 93%, and *d*' was 2.35 (SD = 1.23). The mean hit rate for masked cues was 55%, and *d*' was 0.20 (SD = 0.26). A one sample t-test revealed that the *d'* for the unmasked cues was significantly different from 0, t =

7.18, $p < 0.0001$. The *d'* for masked cues was also significantly different from 0 ($t = 2.83$, $p < 0.05$), suggesting that, while the cues in Experiment 1 were masked, they were not subliminal.

Discussion

We sought to investigate in Experiment 1 whether or not the masked arrow-cueing effect should be attributed to attentional orienting or response preparation. This question was investigated by determining whether or not masked arrow-cueing effects can be observed in a discrimination task. The value of this task is that it prevents response-priming effects from masquerading as attentional effects. Our results indicate that masked arrow cues do not produce a cueing effect, but that unmasked cues do produce such an effect. The lack of a masked arrow-cueing effect in this experiment stands in sharp contrast to the findings reported by Gayet and colleagues (2013) in a localisation task. The obvious difference between the experiment of Gayet and colleagues (2013) and Experiment 1 here is task type (localization vs. discrimination, respectively). Thus, in Experiment 2, we explored the possibility that the masked arrow-cueing effect emerges only in tasks that allow for stimulus-response mapping.

Experiment 2

In Experiment 1 we found that masked arrow cues do not influence behaviour in a discrimination task. This pattern of results is at odds with the attentional orienting account of cueing effects observed in the localization task. Thus, in Experiment 2, we tested the possibility that masked arrow cues can produce a cueing effect in a task that allows participants to prepare a left/right response to arrow direction (localisation task). This reasoning follows from the findings reported by Gayet et al. (2013). Specifically, the researchers found that masked arrow cues influence behaviour in a localisation task. If this pattern of findings can be reproduced in our study, it would lend support to the response-priming account of the masked arrow-cueing effect. Just as in Experiment 1, the masked cue was uninformative of target location (50% valid), whereas the unmasked cue was informative of target location (80% valid).

Method

Participants. A group of 14 participants (7 males and 7 females; mean + SD age, 21 + 8 years) at Macquarie University participated in the study for course credit. Informed consent was obtained from all participants.

Stimuli. The stimuli were the same as Experiment 1, except that the target was a small, dark grey disc that measured approximately 0.98° x 0.74°.

Procedure. Participants pressed two keys to initiate each of the 80 practice trials and 640 experimental trials. The trial structure was the same as Experiment 1 except that now a grey disc was displayed as a target in either the left or right side of the screen (5° from the centre) with equal probability. Participants were asked to localise this target by pressing one of two response buttons using the index finger of each hand. The response buttons were aligned horizontally. The target remained on screen for 300 ms or until participants made a response. All trials were randomised. A cue visibility task of 160 trials followed the experiment proper.

Results

Response latencies. Incorrect trials (10% across all conditions, SD = 5%) were removed from the following analysis. Trials with response latencies that were less than 100 ms (0.08%) or greater than 1,000 ms (1.17%) were also discarded. These trials were categorized as anticipations and misses, respectively. The dependent variable was the mean reaction time for correct responses. A2 × 2 ANOVA was conducted on response latencies with Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated measures factors. We found a main effect of Cue Validity, F (1, 13) = 107.44, $p < 0.001$, $\eta p^2 = 0.89$, but not a main effect of Cue Masking, F (1, 13) = 3.07, $p = 0.10$, $\eta p^2 = 0.19$. We did, however, find a significant interaction effect between Cue Masking and Cue Validity, F (1, 13) = 82.41, $p < 0.001$, $\eta p^2 = 0.86$. As shown in Fig. 3, this interaction was carried by a larger effect of Cue Validity for unmasked cues. Response latencies to localise the target were shorter following an unmasked valid arrow cue (*M* = 404 ms, *SD* = 93 ms) than following an unmasked invalid arrow cue (*M* = 504 ms, *SD* = 99 ms), t (13) = 9.89, $p < 0.0001$. But, importantly, for masked arrow cues, response latencies to localise the target were also significantly shorter when the target followed a valid arrow cue (*M* = 459 ms, *SD* = 86 ms) as compared to an invalid arrow cue (*M* = 463 ms, *SD* = 85 ms), t (13) = 2.12, $p< 0.05$. Thus, while the cueing effect for unmasked cues was significantly larger than it was for masked cues, both cues nevertheless produced a reliable cueing effect.

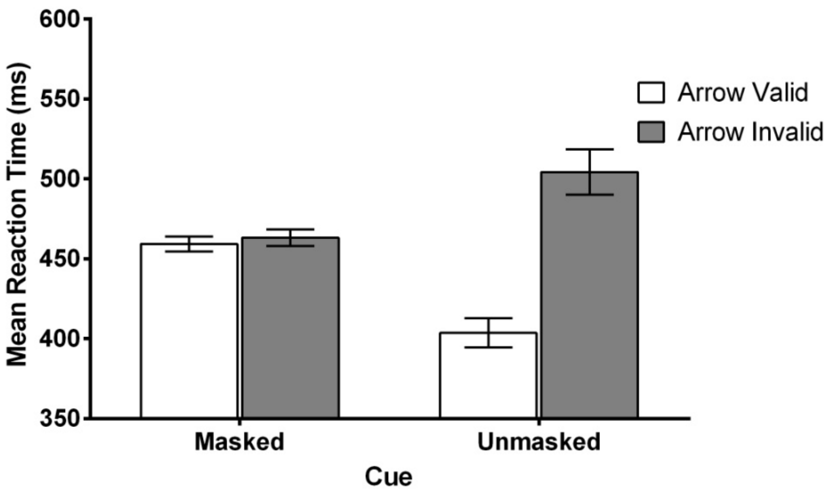

Figure 3. Mean response latencies to localising the target, when it is presented following uninformative masked and informative unmasked arrow cues (with CI bars) in Experiment 2.

Accuracy rates. We analysed the accuracy rates using the same repeated-measures ANOVA as above. The mean accuracy rates for the masked valid and invalid conditions were

97.91% (*SD* = 1.80%) and 96.75% (*SD* = 0.30%), respectively. The mean accuracy rates for the unmasked valid and invalid conditions were 98.61% (*SD* = 0.82%) and 65.33% (*SD* = 18.14%). For these accuracy scores, the ANOVA revealed a significant main effect of Cue Masking, $F(1, 13) = 46.40$, $p < 0.0001$, $\eta p^2 = 0.78$, and Cue Validity, $F(1, 13) = 47.08$, $p < 0.0001$, $\eta p^2 = 0.78$. There was also a significant interaction between Cue Masking and Cue Validity, $F(1, 13) = 47.94$, $p < 0.0001$, $\eta p^2 = 0.79$. This interaction was carried by a larger effect of Cue Validity for unmasked arrow cues as compared to masked arrow cues. Participants' accuracy in identifying the target was significantly better following an unmasked valid arrow cue than following an unmasked invalid arrow cue, $t(13) = 6.92$, $p < 0.0001$. The analysis also showed that, for masked arrow cues, participants' accuracy in identifying the target was significantly better when the target followed a valid arrow cue as compared to an invalid arrow cue, $t(13) = 2.28$, $p < 0.05$.

Cue visibility. The mean hit rate for unmasked arrow cues was 93%, and *d'* was 2.60 (*SD* = 1.49). The mean hit rate for masked arrow cues was 51%, and *d'* was 0.06 (*SD* = 0.23). A one sample t-test revealed that the *d'* for the unmasked cues was significantly different from 0, $t = 6.55$, $p < 0.0001$, and the *d'* for masked cues was not significantly different from 0, $t = 0.92$, $p = 0.37$.

Discussion

We sought to examine in Experiment 2 whether or not the masked arrow-cueing effect would emerge in a localization task, which allows participants to prepare a covert (left/right) response to arrow direction. We found that both masked and unmasked arrow cues produced a cueing effect in this task. The fact that we found a masked arrow-cueing effect in the localisation task of Experiment 2, but not in the discrimination task of Experiment 1, suggests that the masked arrow-cueing effect is reliant on the learning of left-right mappings. This pattern of results is consistent with the response-priming account, and inconsistent with the attentional-orienting account, of masked arrow-cueing. Our findings, therefore, suggest that the masked arrow-cueing effect reported by Gayet et al. (2013) may be due to participants' covert formulation of a left/right response to the arrow cue, which can only modulate performance in a localisation task. Although we have shown that the masked arrow-cueing effect is task dependent, it is not yet clear whether the emergence of masked arrow-cueing is a function of participants learning a mapping between the stimuli and the responses, or the stimuli and the position of the effectors. Thus, in Experiment 3, we wanted to investigate whether the source of the masked arrow-cueing effect found here is a stimulus-response mapping or a stimulus-effector mapping.

Experiment 3

In the experiments reported above, we have shown that the masked arrow-cueing effect is task- dependent, such that it can be observed in a localisation task, but not in a discrimination task. Given this pattern of results, we suggest that the masked arrow-cueing effect is due to response-priming, and should be attributed to a modulation of response formulation processes. This account of our results yields an important question: what is the exact response formulation process afforded to participants in a localisation task, but not a discrimination task? On the one hand, it is possible that the emergence of the masked arrow-cueing effect in Experiment 2 depended on participants learning to encode the spatial relationship between stimuli and the position of the effectors (e.g., index fingers; Wallace, 1972). On the other hand, it is possible that the emergence of the masked arrow-cueing effect in Experiment 2 depended on participants learning to encode the spatial relationship between stimuli and the position of the response goals (e.g., response keys; Brebner et al., 1972). We could not answer this question in Experiment 2, where a left and a right key were pressed with the corresponding index finger, because the position of the effectors and the position of the response goals were conflated.

The purpose of Experiment 3 was, therefore, to constrain the response-priming account by disentangling the relative contribution of these two factors (stimulus-effector mappings vs. stimulus-response mappings) in bringing about the masked arrow-cueing effect. We asked participants to complete the same localisation task as in Experiment 2, but with their hands uncrossed in some blocks, such that the effectors and response goals occupied the same locations, and crossed in other blocks, such that the effectors and response goals occupied opposite locations. It was reasoned that if the determining factor for the masked arrow-cueing effect was the position of the effectors then the magnitude of the masked arrow-cueing effect should be reduced when the hands are crossed in comparison to when the hands are uncrossed. In contrast, if the determining factor for the masked arrow-cueing effect was the position of the response goals, then the magnitude of the effect should be unchanged when the hands are crossed in comparison to when the hands are uncrossed. We also expected that participants would respond faster to the target when their hands were uncrossed as compared to crossed.

Method

Participants. A group of 14 participants (4 males and 10 females; mean + SD age, 27 + 3 years) at Macquarie University participated in the study for $15. Informed consent was obtained from all participants.

Stimuli. The stimuli were the same as Experiment 2.

Procedure. Participants pressed two keys to initiate each of the 80 practice trials and 640 experimental trials. The procedure of Experiment 3 was the same as Experiment 2 except that we manipulated finger position (uncrossed vs. crossed): half of the participants began the experiment with their hands uncrossed (i.e., the right finger depressed the right-side key and the left finger depressed the left-side key), whereas the other half of participants began the experiment with their hands crossed (i.e., the right finger depressed the left-side key and the left finger depressed the right-side key). All participants were required to switch hand position half-way through the experiment. All participants completed the cue visibility task, which followed the experiment proper, with their hands uncrossed, akin to previous experiments.

Results

Response latencies. Incorrect trials (11% across all conditions, SD = 11%) were removed from the following analysis. Trials with response latencies that were less than 100 ms (0.02%) or greater than 1,000 ms (0.47%) were also discarded. These trials were categorized as anticipations and misses, respectively. The dependent variable was the mean reaction time for correct responses. A2 x 2 × 2 ANOVA was conducted on response latencies with Hand Position (uncrossed, crossed), Cue Masking (masked, unmasked) and Cue Validity (valid, invalid) as repeated measures factors. We found a main effect of Hand Position, $F(1, 13) = 34.11$, $p<0.0001$, $\eta p^2 = 0.72$ and Cue Validity, $F(1, 13) = 201.33$, $p<0.0001$, $\eta p^2 = 0.94$, but not a main effect of Cue Masking, $F(1, 13) = 1.09$, $p = 0.32$, $\eta p^2 = 0.08$. The two-way interaction between Cue Masking and Cue Validity, $F(1, 13) = 108.42$, $p<0.0001$, $\eta p^2 = 0.89$, was the only significant interaction effect (all other *Fs* < 0.89). To explore the nature of this two-way interaction, we conducted paired t-tests separately for masked and unmasked arrow cues. This analysis (see Fig. 4) revealed that the cueing effect was larger for unmasked cues than it was for masked cues. Specifically, participants' response latencies to localise the target were shorter following an unmasked valid arrow cue ($M = 403$ ms, $SD = 74$ ms) than following an unmasked invalid arrow cue ($M = 520$ ms, $SD = 86$ ms), $t(13) = 12.57$, $p < 0.0001$. The analysis also indicated that, for masked arrow cues, response latencies to localise the target were significantly shorter when the target followed a valid arrow cue (*M* = 463 ms, *SD* = 67 ms) as compared to an invalid arrow cue (*M* =471 ms, *SD* = 64) ms, t (13) = 2.77, $p < 0.05$. This pattern of results suggests that the masked arrow-cueing effect was similar across blocks of crossed and uncrossed hands.

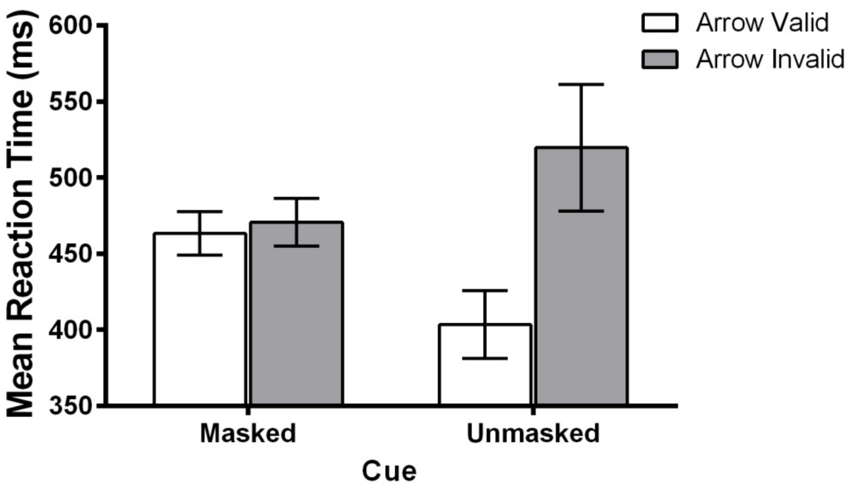

Figure 4. Mean response latencies to localising the target, when it is presented following uninformative masked and informative unmasked arrow cues (with CI bars) in Experiment 3.

Accuracy rates. We analysed the accuracy rates using the same repeated-measures ANOVA as above. The mean accuracy rates for the masked valid and invalid conditions were 97% (*SD* = 5%) and 94% (*SD* = 9%), respectively. The mean accuracy rates for the unmasked valid and invalid conditions were 98% (*SD* = 2%) and 69% (*SD* = 26%). For these accuracy scores, the ANOVA revealed a significant main effect of Cue Masking, F (1, 13) = 23.62, $p < 0.0001$, $\eta p^2 = 0.65$, and Cue Validity, F (1, 13) = 17.46, $p < 0.001$, $\eta p^2 = 0.57$, but no main effect of Hand Position, F (1, 13) = 1.90, $p = 0.19$, $\eta p^2 = 0.13$. The two-way interaction between Cue Masking and Cue Validity, F (1, 13) = 20.43, $p < 0.001$, $\eta p^2 = 0.61$, was the only significant interaction effect (all other *Fs* < 0.27). This interaction was carried by an effect of cue validity for the unmasked, but not masked, cues. Participants' accuracy in identifying the target was significantly better following an unmasked valid arrow cue than following an unmasked invalid arrow cue, t (13) = 4.40, $p < 0.001$. Interestingly, for masked arrow cues, participants' accuracy in identifying the target was no different when the target followed a valid arrow cue as compared to an invalid arrow cue, t (13) = 1.79, *p* = 0.10.

Cue visibility. The mean hit rate for unmasked arrow cues was 97%, and *d'* was 2.84 (*SD* = 1.34). The mean hit rate for masked arrow cues was 53%, and *d'* was 0.11 (*SD* = 0.24). A one sample t-test revealed that the *d'* for the unmasked cues was significantly different from 0, t = 7.94, *p*< 0.0001, and the *d'* for masked cues was not significantly different from 0, t = 1.79, *p* = 0.10.

Discussion

The purpose of Experiment 3 was to examine whether or not the masked arrow-cueing effect is dependent on the relation between a stimulus and a particular response goal, or a stimulus and a particular effector. Hence, we asked participants to complete the same localisation task as in Experiment 2, but with their hands uncrossed in half of the blocks and crossed in the other half of blocks. We found that the magnitude of the unmasked and masked arrow-cueing effects was maintained when the hands were uncrossed and crossed. This result suggests that the arrow-cueing effect depends on the relation between a stimulus and a particular response mapping.

General Discussion

It is well-established that uninformative peripheral cues can exogenously shift attention when masked (e.g., Fuchs & Ansorge, 2012; Ivanoff & Klein, 2003; McCormick, 1997; Mulckhuyse, Talsma & Theeuwes, 2007). Recent studies have, therefore, reasoned that if symbolic cues (i.e., arrows and eye-gaze) can orient attention in a manner similar to peripheral cues then they too should shift attention when masked. Gayet and colleagues

(2013), specifically, found that uninformative arrow cues can produce a cueing effect when presented under masked conditions. Although the findings of Gayet and colleagues (2013) show that uninformative masked arrow cues can affect behaviour, they, however, are ambiguous with respect to whether or not the observed masked arrow-cueing effect can be attributed to the shifting of attention or the preparation of a motor response. It is unclear in the Gayet and colleagues (2013) study which account of the masked arrow-cueing effect is correct because they used a localisation task. Such tasks conflate the effects of spatial attention with those of response-priming. Thus, the aim of the present study was to investigate whether or not cueing effects produced by uninformative arrow cues are driven by attentional orienting or response preparation mechanisms to stimulus direction. We examined this issue by establishing whether or not cueing effects produced by uninformative arrow cues can be observed in a discrimination task, which isolates spatial attention from response formulation.

We have observed several important findings in the present study. First, we have found that the arrow-cueing effect for unmasked arrow cues emerges in both discrimination and localisation tasks (Experiments 1 and 2). Second, and in contrast, we have found that the arrow-cueing effect for masked arrow cues emerges in localisation tasks, but not discrimination tasks (Experiments 1 and 2). This pattern of results indicates that the masked arrow-cueing effect, unlike the unmasked arrow-cueing effect, is task dependent. Third, we have found that the masked arrow-cueing effect emerges in a localisation task, but not a discrimination task, because the former affords participants the opportunity to develop stimulus-response mappings (Experiment 3). This pattern of results indicates that the masked arrow-cueing effect occurs only when participants are provided with the opportunity to encode the spatial relationship between stimuli and the position of the response goals. The fact that such stimulus–response mappings can develop under masked conditions is well established in the masking literature (Al-Janabi & Finkbeiner, 2014; Damian, 2001; Eimer &

Schlaghecken, 2002). Thus, the results of the present study suggest that the masked arrow-cueing effect observed by Gayet et al. (2013) did not reflect an instance of arrow-triggered attentional orienting without awareness. Indeed the findings of the present study suggest that the masked arrow-cueing effect, unlike effects produced by peripheral cues, can emerge only when participants formulate mappings between the unmasked cues and the response goals, which they then apply to the masked cues.

Our findings demonstrate a disassociation between unmasked and masked arrow cues (this was also the case for unmasked and masked gaze cues; Al-Janabi & Finkbeiner, 2014). This observed disassociation raises the following question: if the masked arrow-cueing effect emerges only in localisation tasks (because they afford participants the opportunity to develop stimulus-response mappings) then how can unmasked arrows produce cueing in localisation *and* discrimination tasks? To answer this question, we turn to an account put forward by Al-Janabi and Finkbeiner (2014). These researchers explained the disassociation between unmasked and masked gaze cues by referring to a proposal on gaze-cueing mechanisms (Bayliss, Bartlett, Naughtin & Kritikos, 2010; Zhang, Zhao & Zhan, 2011). This proposal posits that gaze-triggered orienting proceeds serially through two stages: early visual analysis (i.e., encoding eye shape, contrast information, etc.) and gaze perception (i.e., extracting and encoding gaze direction). The gaze-cueing effect, according to the model, is primarily attributed to the gaze perception system, which outputs information to the attentional system that then results in the orienting of attention. On this account, Al-Janabi and Finkbeiner (2014) suggested that, in a discrimination task, masked gaze cues cannot produce a cueing effect because (as compared to unmasked cues) gaze direction cannot be adequately extracted for those cues. Thus, the gaze perception system is insufficiently engaged and passes on very little information to the attentional orienting system. In contrast, the researchers suggested that, in a localisation task, masked gaze cues can produce a cueing effect by virtue of direct mappings between the early visual analysis system and the motor system. These mappings can only be established through training; hence, the emergence of masked gaze-cueing depends on the uninformative masked cues being presented in the context of informative unmasked cues.

Turning now to the present study, we similarly suggest that masked arrow cues, unlike unmasked cues, do not produce cueing effects in a discrimination task because masked cues do not yield enough information to drive a response in the attentional orienting system. In contrast, in a localisation task, masked arrow cues can produce cueing (in the context of informative unmasked cues) because it is possible for participants to learn and establish direct mappings between the outputs from an early visual analysis to the motor system, which are then "run off" even without any conscious appreciation of the cue.

CONCLUSION

It has been previously suggested that uninformative central cues, such as arrows, reflexively orient attention (e.g., Friesen, Moore, & Kingstone, 2005; Hommel, Pratt, Colzato, & Godijn, 2001; Langton & Bruce, 1999). Recent studies have investigated whether or not such cues can exogenously orient attention by presenting them under masked conditions (Gayet, Van der Stigchel & Paffen, 2013; Reus, Pohl, Kiesel & Kunde, 2011). Those studies showed that uninformative masked arrow cues can produce a cueing effect, but only when participants have an incentive to utilize such information. The purpose of the present study was to establish whether or not the previously observed masked arrow-cueing effect should be attributed to attentional orienting or response-priming. We have shown that uninformative masked arrow cues can indeed produce a cueing effect, but that the phenomenon is restricted to a localisation task, and does not emerge in a discrimination task. Specifically, our results imply that the emergence of a masked arrow-cueing effect is not only dependent on participants learning to utilize such information based on the predictive value of unmasked cues, as was shown by Gayet et al. (2013), but also on participants' ability to develop stimulus-response mappings. Indeed our findings indicate that the centrally presented, uninformative arrow cue must activate a covert left/right localization response that is appropriate for valid, but inappropriate for invalid, trials, in order for a masked arrow-cueing effect to emerge. Given that uninformative arrow cues do not orient attention under masked conditions (and neither do uninformative masked gaze cues; Al-Janabi & Finkbeiner, 2014), the results of the present study suggest that attentional orienting by uninformative symbolic cues may be limited to consciously perceived stimuli.

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General Discussion

Extant literature indicates that abrupt onset and symbolic (i.e., averted eye-gaze and arrows) cues produce rapid validity effects that emerge even when the cueing stimulus is uninformative, or counter-predictive, of target location. This pattern of results has been taken to indicate that such cues exogenously (i.e., involuntarily) orient attention (e.g., Breitmeyer & Ganz, 1976; Driver et al., 1999; Eimer, 1997; Friesen & Kingstone, 1998; Friesen, Ristic & Kingstone, 2004; Galfano et al., 2012; Jonides, 1981, 2010; Tipples, 2002). The aim of the present thesis was to clarify the extent to which the orienting of attention by abrupt onset and symbolic cues is involuntary by investigating the role of intentions and awareness on such shifts. To examine this issue, I compared the ability of masked and unmasked cues to orient attention. The task relevance of those cues was manipulated within each study. The purpose of this design was to establish the relative contribution of each factor (intentions and awareness) on the ability of abrupt onset and symbolic cues to produce exogenous shifts of attention. If I were to find that the selected cues produce a validity effect independently of intentions and awareness then that would suggest the orienting of attention by those stimuli is not contingent on at least two of the four 'horsemen of automaticity' (Bargh, 1989, 1992). Below I will provide an overview of the results for each of the studies presented in this thesis. I will then discuss the implications of those findings to our understanding of the constraints imposed on exogenous attentional orienting generated by abrupt onset and symbolic cues.

Overview of findings: Study 1

The purpose of Study 1 was to determine the propensity to which intentions and awareness can modulate attentional capture by abrupt onset cues. In a spatial cueing paradigm, I asked participants to detect a peripheral target. This target was preceded by a peripheral abrupt onset cue that was either unmasked or masked. The cues were not informative of target location. I expected that if the effect of abrupt onset cues on attention is truly involuntary then they should produce a biphasic effect (facilitation followed by inhibition of return) under masked conditions, even though the experimental context did not favour cue utilization.

Several important findings were observed in Study 1. First, I found that the masked abrupt onset cues facilitated responses to the target in the short SOA condition. This effect emerged even though participants had no incentive to use the information provided by the cues. Second, and in contrast, I found that the masked abrupt onset cues did not inhibit responses to the target in the long SOA condition. This pattern of results indicates that exogenous capture of attention, as reflected by early facilitation, is not necessarily followed by inhibition of return. Third, I found that the unmasked abrupt onset cues produced facilitation at the short SOA condition that was followed by inhibition of return at the long SOA condition, thus indicating that inhibition of return may depend on awareness of the cue.

Implications of Study 1: the role of intentions and awareness on attentional capture by onsets

Given that I limited cueing effects from being driven by intentions and conscious awareness, the first conclusion that can be drawn from Study 1 is that the involuntary capture of attention by abrupt onsets is not contingent on those two factors. The preceding conclusion raises an important question. That is, how do abrupt onset cues, whether conscious or non-conscious, involuntarily shift attention? This question can best be answered by a recently proposed account on conscious and non-conscious orienting of attention (Mulckhuyse & Theeuwes, 2010). It is assumed in this account that visual information is processed serially in two stages (Lamme, 2003, 2004, 2006). The first temporal stage involves feeding forward information via the parallel pathways from lower to higher visual areas. This feedforward sweep of information is a non-conscious process. The second temporal stage involves feeding back information through backward and horizontal connections. This feedback sweep of information is instrumental in raising the contents of vision into consciousness. On this account, the exogenous orienting of attention by abrupt onset cues may be primarily attributed to feedforward processing via the subcortical pathway, wherein visual information is rapidly outputted to attentional areas, such as the superior colliculus, frontal eye fields and parietal cortex (Lamme, 2003; Lamme & Roelfsema, 2000). Thus, the finding in Study 1 that abrupt onset cues can produce an involuntary (facilitation) response that manifests as exogenous capture of attention, even when masked (i.e., only feedforward sweep of information is intact; Enns & Di Lollo, 2000), can be explained by the Mulckhuyse and Theeuwes (2010) account. This emphasis on the feedforward sweep not only explains the manner in which unmasked and masked abrupt onset cues can produce an exogenous shift of attention, but it can also explain the reason for which prior studies show that search sets can, under certain conditions, modulate the shifts of attention produced by those cues (e.g., Ansorge, Horstmann & Scharlau, 2011; Ansorge & Neumann, 2005; Folk, Remington & Johnston, 1992; Held, Ansorge & Muller, 2010). It is well established in the masked priming literature that effects yielded by information processed solely in the feedforward sweep are susceptible to modulation by search sets set up in advance of stimulus presentation (i.e., pre-emptive control), but they are not affected by search sets initiated reactively in response to stimuli (e.g., Ansorge, Fuchs, Khalid, & Kunde, 2011; Ansorge & Horstmann, 2007; Ansorge et al., 2009; Kiefer, 2007; Kiefer & Martens, 2010; Reuss, Kiesel, Kunde & Hommel, 2011). Hence, according to these findings, the propensity to which abrupt onset cues (involuntarily) capture attention can be affected by search sets, but, specifically, only when those top-down sets were formed prior to the task.

The second (tentative) conclusion that can be drawn from Study 1 is that inhibition of return appears to rely on conscious awareness of the abrupt onset cue. Importantly, for the present purposes, removing awareness of the onset cue does not affect the facilitatory effects produced at early SOAs by attentional capture, but it does affect the inhibitory effects at longer SOAs (inhibition of return). Hence, exogenous capture of attention is not necessarily followed by inhibition of return. This conclusion is not surprising given that extant literature indicates active inhibition requires conscious awareness of the stimulus for which a response must be inhibited (e.g., Dehaene, & Naccache, 2001; Eimer & Schlaghacken, 2003). However, given that recent studies show that inhibition of a motor response can occur for stimuli with which participants have no conscious awareness (e.g., Bermeitinger, Frings, &Wentura, 2008; Eimer & Schlaghecken, 1998; Hughes, Velmans, & De Fockert, 2009; Schlaghecken & Eimer, 2006; van Gaal, Ridderinkhof, van den Wildenberg, & Lamme, 2009), the pattern of results observed in Study 1 may indicate that it is inhibition of a cued location, in particular, that cannot occur for task-irrelevant stimuli with which participants have no conscious awareness. This conclusion suggests that exogenous capture of attention and inhibition of return are probably phenomena that are not dependent on the same information processing mechanism (cf. Prinzmetal et al., 2011), or brought about by a shared two-phase process in the superior colliculus (cf. Mulckhuyse & Theeuwes, 2010).

In summary, the purpose of Study 1 was to tease apart the relative contribution of intentions and conscious awareness on the orienting of attention by abrupt onset cues. This aim was achieved by using visual masking and controlling the task-relevance of cues. The pattern of results observed in this study indicates that intentions and awareness play a limited role in the orienting of attention by abrupt onset cues. Hence, akin to previous studies (for a review see Corbetta & Shulman, 2002), the findings observed in Study 1 demonstrate that abrupt onset cues can produce a shift of attention that is not contingent on goals or visibility.

Overview of findings: Studies 2, 3 and 4

The purpose of Studies 2, 3 and 4 were to determine the role of intentions and awareness on the propensity to which symbolic cues (i.e., averted gaze and arrows) orient attention. In a spatial cueing paradigm, I asked participants to localise, detect or discriminate a peripheral target. The targets were preceded by centrally-presented symbolic cues that were either unmasked or masked. The overall validity of the cues was varied between experiments. I expected that if the effect of symbolic cues on attention is truly involuntary then they should yield a validity effect under masked conditions even when participants have no incentive to use the information that they provide. This validity effect should emerge regardless of task.

Several important findings were observed in Studies 2, 3 and 4. First, I found that the validity effect for masked symbolic cues was limited to contexts in which the unmasked symbolic cues were informative of target location. This result implies that the intention of a participant is a core determinant of whether or not a masked symbolic cue affects behaviour. Second, I found that the emergence of this validity effect for masked symbolic cues was task-dependent, such that it can be observed in a localisation task, but not a detection or discrimination task. This pattern of results indicates that the ability of a masked symbolic cue to affect behaviour is not only dependent on participants evaluating the task-relevance of the cue, but also on formulating stimulus-response mappings. Third, I found that the unmasked, unlike the masked, symbolic cues produced a validity effect in all tasks. Hence, given that the only way to observe a validity effect in detection and discrimination tasks is through a shift of attention, the disassociation between unmasked and masked cues indicates that the orienting of visuo-spatial attention by symbolic cues requires conscious appreciation of the stimulus.

Implications of Studies 2 - 4: the role of intentions and awareness on orienting by symbolic cues

The first conclusion that can be drawn from Studies 2, 3 and 4 is that the effect of a masked symbolic cue on behaviour depends on an experimental context that favours cue utilization, as deduced from visible statistical evidence. This selective utilization of masked cues can be explained by the stimulus-response activation account (e.g., Abrams & Greenwald, 2000; Damian, 2001; Elsner, Kunde & Kiesel, 2008; for a review see Kiesel, Kunde & Hoffman, 2007). According to this account, the processing of masked stimuli is limited, such that only low-level perceptual features can be processed. Thus, a masked stimulus can only activate a motor response when its perceptual features have been linked to an associated response goal. Crucially, however, this linking between stimulus and response must first occur for unmasked stimuli to which one has responded before it can automatically be applied to masked stimuli. Hence, on the basis of this stimulus-response activation account, it is conceivable that the masked symbolic cues in the present studies affected behaviour in localisation tasks, but not in discrimination and detection tasks, because they were mapped to a particular response goal. The adequate response to those masked symbolic cues was, however, triggered only when unmasked symbolic cues provided an experimental context that favoured cue utilization. This caveat indicates that a strategy to expect and use the stimulus-response mapping is needed in order for masked symbolic cues to produce a reliable validity effect.

Perhaps most importantly, the second conclusion that can be drawn from Studies 2, 3 and 4 is that the shift of attention produced by symbolic cues depends on awareness. An obvious question that follows from this conclusion is: why do unmasked, but not masked, symbolic cues shift attention? To answer this question, I turn to a proposal by Bayliss, Bartlett, Naughtin and Kritikos (2010) and Zhang, Zhao and Zhan (2011) on gaze-cueing mechanisms. The researchers suggest that gaze following proceeds serially through two stages of processing. The first stage is early visual analysis, which involves the encoding of contrast and other low-level information. The second stage is gaze perception, which involves extracting and decoding gaze direction then passing on that information to an attention system that acts upon this information. I suggest that this model can be applied to understand the reason for which unmasked, but not masked, symbolic cues shift attention in various contexts. Simply, unmasked symbolic cues are visible, or conscious, thus directional information can be adequately extracted for those cues. This directional information is then passed on to the attentional orienting system, which produces a cue validity effect. In contrast, directional information cannot (at least not on all trials) be extracted for masked symbolic cues. Hence, as previously explained, masked cues can produce a validity effect by virtue of direct mappings between the early visual analysis system and the motor system. These mappings, however, can only form through training (i.e., when masked cues are presented in a context that favours cue utilization). Thus, the findings observed in Studies 2 - 4 constrain models of social attention (e.g., Bayliss, Bartlett, Naughtin & Kritikos, 2011) by indicating that accounts of symbolic orienting must allow for task sets, and take into account the role of awareness.

In summary, the purpose of Studies 2 – 4 was to tease apart the relative contribution of intentions and awareness on the orienting of attention by symbolic cues. This purpose was achieved by using visual masking and manipulating the task-relevance of cues. The results of Studies 2 - 4 indicate that the ability of masked symbolic cues to affect behaviour is dependent on intentions, whereas the propensity to which such cues can shift attention is reliant on awareness. If the shift of attention produced by symbolic cues were truly involuntary then it would have emerged without these two factors. Hence, the findings of the studies presented in this thesis demonstrate that those cues can be used with a degree of flexibility.

Future Studies

The findings of Studies 1 – 4 are novel because they establish the role of intentions and awareness on the exogenous orienting of attention by abrupt onset and symbolic cues. Specifically, the pattern of results observed in this thesis indicates that abrupt onset cues are not reliant on intent or awareness to shift attention, whereas the ability of symbolic cues to affect behaviour and attention depends on perceived task relevance and cue awareness, respectively. Although the current research has extended the findings of prior studies in terms of elucidating the role intentions and awareness on exogenous orienting, further studies can be conducted to enhance our understanding of the constraints imposed on attentional shifts.

In Studies 2 – 4, masked symbolic cues were able to produce a validity effect in a localisation task only when the unmasked cues were informative of target location. This experimental context led participants to include the symbolic cues in their task set because it favoured cue utilization. The effect of masked symbolic cues on behaviour in this particular context raises an important question: how is the task relevance of a masked cue determined? Is it solely determined by the predictive value of an unmasked cue with the same identity, or does it also rely on there being a perceptual match with the unmasked cue? Future studies can examine the conditions required to transfer task relevance from unmasked to masked cues by manipulating the perceptual match between cues, whilst keeping the identity of cues consistent. For example, in an arrow cueing task, one can measure the difference in the magnitude of cueing for masked cues (e.g., <<) that perceptually match the unmasked cues (e.g., <<) and perceptually do not match the unmasked cues (e.g., ⇦⇦). If determining the task relevance of masked symbolic cues does not depend on a perceptual match with unmasked cues, then the magnitude of the validity effect should be similar in both conditions. This investigation is not foreign to masking priming studies. In fact, prior results suggest that the transfer of task instructions to masked primes that are perceptually dissimilar to visible stimuli is limited (Elsner, Kunde & Kiesel, 2008; Kiesel, Kunde, Pohl & Hoffman, 2006).

The findings of Studies 2 – 4 also showed that symbolic cues do not shift attention without awareness. It is possible, however, that masked symbolic cues do shift attention, unlike what was observed in Studies 2 – 4, but not up to the level of affecting a motor response (i.e., response latencies). Thus, future studies should seek to confirm this result by using event-related potentials. Research with unmasked abrupt onset cues has shown that event-related potentials and response latency measures of attentional capture can be disassociated, such that, for instance, evidence of attentional shifts can be obtained for event-related potential measures even when there is no evidence for such orienting in response latency measures (e.g., Ansorge & Heumann, 2006; Handy, Green, Klein, & Mangun, 2001).

CONCLUSION

The visual system has a limited capacity, thus it cannot process all visual inputs. Instead, the visual system relies on spatial attention to bring salient information into focus and filter out irrelevant information. Spatial attention can be directed in one of two ways: endogenously by task-relevant objects in the environment and exogenously by abrupt onset or highly-learned (i.e., averted eye-gaze and arrow) objects in the environment. The difference between these two forms of spatial attention is generally boiled down to whether or not they depend on three factors; that is, intent, effort and awareness (Bargh, 1989). Exogenous shifts of attention, unlike endogenous shifts of attention, are typically classified as occurring regardless of these three factors, hence such orienting is considered truly involuntary. Recent research, however, suggests that exogenous attention, much like endogenous attention, entails a complex combination of factors related to both sensory inputs and experimental context. The purpose of the present thesis was, therefore, to examine the relative contribution of intentions and awareness on the orienting of attention produced by abrupt onset and symbolic cues. This aim was achieved by using visual masking and manipulating the task-relevance of cues. It was expected that if abrupt onset and symbolic cues orient attention in a truly involuntary manner then such stimuli should produce a validity effect independently of intent and awareness. The pattern of results observed in the current research has two main consequences. First, abrupt onset cues can exogenously capture attention regardless of intentions and awareness. Second, and in contrast, the shifts of attention generated by symbolic cues are dependent on conscious awareness, but not intentions. These findings suggest that the role of intentions and awareness on exogenous attention varies between cue types, such that it is not necessarily the case that all objects which seem to exogenously orient attention can do so irrespective of two horsemen of automaticity: intentions and conscious awareness.

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Final Ethics Approval

ethics amendment for HE22FEB2008-R05671 Inbox x

ethics secretariat <ethics.secretariat@vc.mq.edu.au>
to matthew.finkbe., me

Dear Matthew

Thank you for your email regarding 'Attention, intention and automaticity'. The following amendment has been approved:

1. The addition of Miss Shahd Al-Janabi as a co-investigator on the project. Miss Al-Janabi will be conducting the research for a PhD.

2. The information and consent form has been amended to reflect the above change.

Please do not hesitate to contact me if you have any questions or concerns.

Regards
Fran

Ms Frances Thorp
Ethics Officer (Human Research)

****

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