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Visual Orienting
and Conscious Perception

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Abstract

Much research supports the dichotomy model of visual covert orienting which suggests that attention shifting occurs either exogenously or endogenously. The present study attempts to suggest an alternative model that can accommodate evidence of endogenously cued orienting that may not necessarily involve consciousness. The first part of the present study (Experiment 1-3) examined whether or not the perceptual awareness of visual cue stimuli is essential in Posner's cue-target orienting paradigm. Lowering the cue luminance had differential effects in orienting and cue identification tasks, in that the performance in the orienting task was relatively unimpaired in comparison with the performance in the cue identification task which was greatly affected by the decrease in the cue luminance. It was suggested that the orienting system uses the dorsal visual pathway, which is resilient to luminance decrease. In Experiment 4, a flicker adaptation procedure was included before the orienting task trials in order to over stimulate the M pathway which has been suggested to be important in luminance contrast processing and in orienting. The flicker adaptation affected the orienting process suggesting the involvement of the M pathway in the attentional mechanism, but contrary to hypothesis the effect was facilitatory rather than inhibitory. Lastly, the effects of the eccentricity (peripheral or central, Experiment 5), number (single or double, Experiment 5) and the size (big or small, Experiment 6) of visually symmetric cues on visual orienting were investigated. The results showed that neither the eccentricity nor the size of the cues interacted with cue validity. It was suggested that the attentional system first uses the spatial correspondence between cue and target in visual orienting. This hypothesis was further explained in terms of the visual orienting system exploiting both space-based and symbolic-meaning-based attention strategies depending on the efficiency of each strategy in a given task. The findings in the current study show evidence against the endogenous-exogenous dichotomy attentional model and suggest the necessity of an attentional model that accommodates a form of orienting that is neither purely exogenous nor purely endogenous.

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First and foremost, I would like to express my gratitude to my supervisor, Assoc. Prof. Tony Lambert, for his guidance on this topic and confidence in me. Your encouragement and patience enabled me to keep focused and motivated throughout the PhD years. I also thank Dr. Jeff Hamm for his invaluable ideas and support.

Thanks to my friends for being there when I really needed them.

Lastly, my deepest gratitude to my parents who have always loved and believed in me.

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Preface

Some of the material in this thesis was presented at the following journals and conferences:

Shin, M.J., Marrett, N. & Lambert, A. J. (2011). Visual orienting in response to attentional cues: spatial correspondence is critical, conscious awareness is not. *Visual Cognition*, 19(6), 730-761.

Lambert, A. J., & Shin, M. J. (2010). The hare and the snail: dissociating visual orienting from conscious perception. *Visual Cognition*, 18(6), 829-838.

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Shin, M.J. & Lambert, A.J. Dissociation of non-conscious orienting and conscious perceiving of cue and target stimuli. Conference presentation (April, 2010). Toward a Science of Consciousness. Tucson, Arizona.

Shin, M.J. & Lambert, A.J. The effect of luminance change in precue and target in covert orienting. Poster presentation (April, 2009). Experimental Psychology Conference, University of Wollongong, Australia.

Chapter 1

General Introduction

1. Attention and orienting

Stimuli of interest are likely to be attended. Attention enhances the processing of stimuli in our visual field as shown in Posner (1980), where the knowledge of the probable location of a target increased the speed and accuracy of the perception of a target. Attention shifting has been suggested to be a rapid process that occurs as early as 0-50ms (Shepherd & Muller, 1989), and this enables us to reallocate our attention constantly and interact with environmental stimuli as we move. Although attention shifting applies to all five senses, a majority of orienting research has involved visual stimuli because much of the information we receive is visual. The literature divides visual orienting into two categories, overt and covert, where the former involves eye movements whereas the latter does not.

2. Covert orienting

Definition and the course of exogenous and endogenous orienting

It has been suggested that there are two different types of covert orienting – exogenous and endogenous orienting. Exogenous orienting is characterized as direct, reflexive and stimulus-driven. The cues for exogenous orienting are often non-predictive of target location and presented peripherally usually in a form of flash (Posner, Snyder, & Davidson, 1980). Endogenous orienting, on the other hand, is characterized as voluntary and goal-driven (Posner & Cohen, 1984). The cues for endogenous orienting are usually predictive of target location and presented centrally in a form of symbol (Posner, et al., 1980).

In a typical covert orienting paradigm (Posner, 1980), a cue precedes a peripheral target. In *exogenous* orienting, a non-informative peripheral cue is followed by a target to which participants respond, while maintaining fixation in the middle of a screen (Fig. 1. top panel).

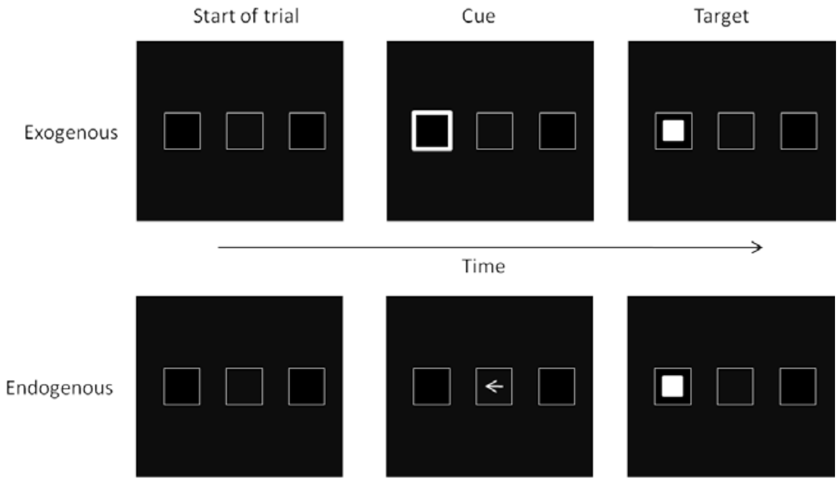

Figure 1. Basic covert cueing paradigm (Posner, 1980).

Although the cue is non-predictive of the probable target location, a benefit in reaction time is observed at the cued location in comparison with the uncued location (Jonides, 1981; Posner, 1980), as early as at the SOA (stimulus onset asynchrony) of 50ms (Shepherd & Muller, 1989) after the cue presentation. The initial benefit at the cued location is, then, replaced by an inhibition (IOR: inhibition of return) at approximately 2-300ms after the cue presentation. That is, when the interval between cue and target presentation, SOA, is greater than 300ms, response times are *slower* at the cued location compared to the uncued location (Posner & Cohen, 1984). The IOR is suggested to maximize the efficiency of target search when the location of a target object is uncertain (Wang & Klein, 2010; Lupianez, Klein, & Bartolomeo, 2006; Taylor & Klein, 1998, 2000). In *endogenous* orienting, on the other hand, an informative cue predicts the location of the target (i.e. a central cue, such as an arrow, see Fig. 1. bottom panel). An attentional facilitation at the cued location starts at a longer SOA (at about 150-300ms) (Shepherd & Muller, 1989).

A combination of these two processes, exogenous and endogenous orienting, could be also elicited by cues, such as cues that are peripherally presented *and* predictive of target location. Mǘller and Rabbitt (1989) have shown that peripherally presented *informative* cues elicited endogenous effects as well as exogenous effects, a rapid facilitation followed by a more stable facilitation. In their study, participants were presented with informative peripheral flashes and centrally presented arrows. The peripheral cues induced a rapid orienting effect which peaked at the SOA of 175ms and faded out to be replaced by a more stable facilitation. Thus, two different forms of orienting effect were found with the informative peripheral cues, where the initial rapid facilitation effect was attributed to an exogenous orienting to the peripherally presented flash whereas the later slower facilitation was thought to arise from an endogenous orienting based on the informativeness of the cues. The central arrow cues elicited only the later facilitation shown with the informative peripheral cues.

3. Critical factors in eliciting exogenous or endogenous effects

For several decades, this dichotomy of exogenous and endogenous orienting has been the foundation on which orienting research has developed.

Anderson, Laurent and Yantis (2011) write:

> Two modes of attentional control are widely believed to determine perceptual priority: a voluntary, goal-directed mode, in which attention is guided by contextually appropriate goals and intentions, and an involuntary, stimulus-driven mode, in which attention is captured by physically salient stimuli or by task-irrelevant stimuli that share identifying features with a searched-for target. (p.10367)

The physical characteristics of cues that elicit exogenous effects include the eccentricity (central and peripheral) of cues (Jonides, 1981), cue being a feature singleton (Theewes, 1991a) and abrupt-onset presentation of cues (Yantis & Jonides, 1984). The factors that trigger endogenous effects, on the other hand, include the symbolic meaning of cues and the mental set with which a participant approaches a given task (Yantis & Jonides, 1990; Baylis, Baylis, & Gore, 2004). However, previous studies investigating exogenous and endogenous effects using these properties of cue in orienting often showed contrasting results.

Exogenous effects

a. Eccentricity of visual cues

Expanding Posner’s work, Jonides (1981) investigated the orienting processes involved with centrally and peripherally presented informative cues. It was shown that orienting towards peripheral cues, compared to that in response to central cues, exhibited more characteristics of exogenous orienting. That is, participants found it harder to ignore peripherally presented cues, and the performance was less disturbed by a concurrent memory load task (Jonides, 1981). The results were attributed to peripheral cues being more closely positioned to the target location, that is, the cues marked the target location in a direct way. In contrast, the central cueing design was suggested to involve a signal interpretation process which delayed the orienting process. Jonides (1981) argued that these spatial characteristics of the cues, peripheral or central, are sufficient in determining whether orienting in response to the cue is to be either exogenous or endogenous. For this reason, researchers have often referred peripheral and central cues as exogenous and endogenous cues respectively. Since then, however, a number of studies have cast doubt on the distinction made between exogenous and endogenous orienting depending on the physical characteristic of cues - the cue location. Evidence of both exogenous and endogenous effects have been shown in one orienting behaviour, by presenting informative cues peripherally as discussed earlier, in which the informativeness of the cue elicited endogenous effects and the peripheral presentation triggered exogenous effects (Műller & Rabbitt, 1989).

b. Abrupt onset

A sudden onset of a visual stimulus captures attention exogenously. In Yantis and Jonides (1984), abrupt-onset letters were formed by illuminating the segments of figure eights (as in a digital clock) and off-set letters were formed by removing previously illuminated segments. Participants were instructed to indicate whether a target letter, either abrupt-onset or off-set, was present among a set of other letters. Even though the target letter was rarely the onset letter, participants responded faster to the target when it was abrupt-onset, and the RT was independent of the display size (refer to Contingency involuntary orienting hypothesis, pg. 7, Folk, Remington and Johnston, 1994, for contradictory findings). When the target was an off-set letter, the RT was slower and increased as the display size increased (Miller, 1989). An abrupt onset of a cue was suggested to induce exogenous orienting by stimulating the sub-cortical visual pathway that directs attention to a potentially important event (Breitmeyer & Ganz, 1976).

The finding of Yantis and Jonides (1984) and its interpretation was later questioned by Miller (1989) who suggested that offset letters as well as onset letters are able to attract attention, although offset letters are not as powerful as onset letters. Miller argued that the presentation of offset letters requires the removal of two out of the seven line segments whereas the presentation of onset letters requires the addition of five line segments, making the visual change of the onset letters more noticeable. The pop out effect by onset letters among offset letter distracters was eliminated when offset letters were manipulated so that the total line segment changes were similar to onset letters. Nevertheless both Yantis and Jonides (1984) and Miller (1989) emphasize the powerful role of the luminance change of visual stimuli in attracting attention exogenously.

Interestingly, however, abrupt-onset visual stimuli have been found to fail in attracting attention when attention is already focused endogenously elsewhere suggesting that abrupt onset itself is not sufficient to induce exogenous orienting. In Yantis and Jonides (1990), targets were presented, either on the left or right side of central fixation, in the segments of figure eights (as in a digital clock), in which the target (E or H) was either abrupt-onset or no abrupt-onset. On the other side of the target, a distracter (e.g. S) appeared, which was also either abrupt-onset or no abrupt-onset. An arrow near the fixation indicated where the target would appear and participants were instructed to indicate which target letter (E or H) appeared. If an abrupt onset exogenously attracts attention, the exogenous effect triggered by the abrupt onset of the target should not be affected by the endogenous effect of the arrow cue, because exogenous orienting is supposed to be more reflexive than endogenous orienting. The endogenous effect of the arrow cue, however, affected the exogenous orienting effect of the abrupt onset, showing a shorter RT in valid than in invalid trials with respect to the arrow cues for both abrupt-onset and non abrupt-onset targets. The results showed that the effectiveness of an abrupt onset (exogenous process) in orienting for the target was largely determined by the validity of the arrow cue (endogenous control) in the target location.

c. Feature singletons

Being a *"feature singleton" also attracts attention exogenously.* A feature singleton is a stimulus which is unique in colour or shape, and which is thought to capture attention exogenously. Improved performance has been observed when a target was a feature singleton and impaired performance has been observed if a distracter was a feature singleton (Theeuwes, 1991a; Treisman & Gelade, 1980). The unique feature in the feature singleton was suggested to 'pop out', as all features of visual stimuli are thought to be processed in parallel preattentively (Treisman & Gelade, 1980). In the study of Theeuwes (1991a), 5, 7 or 9 circles were in a display where each circle had a line segment in it. Participants were to indicate whether the line segment in a target was either vertical or horizontal. The target differed either in luminance intensity or colour from other circles. Performance in the task was disturbed by other distracter circles that were feature singletons themselves but did not share the same feature characteristics as the target (i.e. when the target differed in colour, the performance was disturbed by a feature singleton distracter differing in intensity, see Folk, Remington & Johnston, 1992, for contradictory findings). This was interpreted in terms of the involvement of an exogenous bottom-up process (See Bacon & Egeth, 1994, for criticism).

d. Contingent involuntary orienting hypothesis (CIOH)

Interestingly, however, contingent involuntary orienting hypothesis proposed by Folk, Remington and Johnston (1992) is in contrast with the studies that have suggested that cue being a feature singleton or abrupt onset presentation of cue attracts attention exogenously. Folk, Remington and Johnston (1992) proposed that the exogenous attention capture by a feature singleton cue or abrupt-onset cue in a cue-target paradigm is contingent on the condition that cue and target share a property (such as a discontinuity in colour or luminance) which participants would use for an orienting task. For example, if a cue is distinguished by a change in luminance, the target also needs to be presented as a change in luminance to be able to attract attention exogenously. If the cue is distinguished by its unique colour, the target would need to be unique in colour for the attention to be captured exogenously. CIOH shows that the expectation of participants affects the performance in an orienting task.

In a recent study by Folk and Remington (2008), four peripheral boxes were presented around a fixation marker, where each box was surrounded by a set of four dots. In a trial, one of the peripheral boxes was cued by the colour of the surrounding dots, either red or green, while the dots surrounding the other peripheral boxes were white. Either ‘X’ or ‘=’ appeared inside each peripheral box, and only one of these was either green or red (a target) when the others were white. Participants were instructed to respond to the colour singleton “X” or “=” (target) and press one of two keys depending on whether the target was ‘X’ or ‘=’. A cueing effect, a faster RT for the colour singleton target at the cued peripheral box, was observed regardless of the congruency between the colour of the target (green or red) and the cue (green or red). When the colours between the cue and target matched, the cueing effect was bigger compared to when they mismatched, showing evidence of bottom up processing. More importantly, when participants were instructed to respond only to a particular colour target (either green or red), only the cues that matched the colour of target elicited a cueing effect, an example of top down processing. Folk and Remington (2008) showed that feature singleton colour cues were effective in target perception only when participants were uncertain which cue colour is associated with targets. When they knew what colour to link to the target, hence when encouraged to use top-down control, the irrelevant cue colour failed to trigger an orienting effect. Findings such as these suggest that bottom up processes interact with top down processes and that bottom up processes previously thought as automatic are often influenced by top down processes (Eimer & Kiss, 2010; Kim & Cave, 1999).

Endogenous effects

For the past decade, more and more studies have suggested that not only the physical property of presented visual stimuli, an external factor, but also an internal one such as participants' strategy in using given visual stimuli in a task is important in determining the type of visual orienting.

a. Participants' mental set

It has been suggested that whether the allocation of attention is space or object based depends on participants' mental set in a specific task. In Baylis et al. (2004), three visual neglect patients were presented with a letter target in one of four possible target locations. Of the four locations, two locations were on the left and the other two locations on the right side of a fixation mark on a mid-horizontal line. Two simple shapes (either triangle, circle, diamond or square) were drawn, one in the left and the other in the right visual field, around the two possible target locations in each visual field. The patients were asked either, "Is there an O in the display?” or “Is there an O in the triangle?”. The performance for each of the four locations differed remarkably for each task instruction. They showed neglect for the contralateral hemifield of the display (i.e. left side of the fixation) if the question was about the display, and neglect for the contralateral hemifield of the shape (i.e. left side of the shape) if the question was about the shape.

Bacon and Egeth (1994) supported the importance of participants’ mental set in visual orienting and argued that attention could be tuned to exogenous singleton feature search or endogenous task-defined search depending on what mental set participants choose to employ in a given task. In the study of Bacon and Egeth (1994), as in Theeuwes (1991a), participants were instructed to indicate whether a line segment was either vertical or horizontal in a green *circle* target. In a no-distracter condition the target circle was presented among other green *diamond* non-targets, hence the target was distinguished from the distracters by its form. In a distracter condition, one of the diamond non-targets was red, hence it was a colour feature singleton. They were able to replicate the finding of Theeuwes (1991a) in that attention was exogenously pulled towards the irrelevant colour feature singleton (i.e. red) distracter. When there were three different colours (e.g. red, blue, white) among non-targets - colour feature singleton search was not an effective strategy anymore, as the distracters were not homogenous. In this situation, the red distracter failed to attract attention. The findings of the study suggest that orienting is greatly influenced by participants’ strategy in a task, although exogenous bottom up processing by an irrelevant distracter cannot be entirely suppressed by top-down endogenous control.

b. Mental representation of numbers and orienting

Studies have suggested that there is a close relationship between how numbers and spatial information are processed. We tend to put numbers on a horizontal mental number line, with smaller numbers on the left and bigger numbers on the right side of the line (Dehaene, Bossini, & Giraux, 1993; Hubbard, Piazza, Pinel, & Dehaene, 2005; Ranzini, Dehaene, Piazza, & Hubbard, 2009). In Dehaene et al. (1993), participants were asked to differentiate between even and odd numbers using a left hand key and a right hand key. Left hand responses were quicker than right hand responses for small numbers (0-1) and right hand responses were quicker than left hand responses for big numbers (7-9). The effect was interpreted as spatial-numerical association of response codes (SNARC), that is an association between the left and right side of the spatial mental number line and the responding limb. Later, Fischer, Castel, Dodd and Pratt (2003) argued that centrally presented numbers (e.g. 1, 2 or 8, 9) are associated with a certain symbolic meaning, a spatial representation. The numbers thus act as a spatial cue and aid spatial shifts of attention. Even though participants were aware that the number cues did not predict the target location, they responded faster to targets on the left after the number cues, 1 and 2, and to targets on the right after the number cues, 8 and 9. However, this spatial orienting by number cues was shown to be not as automatic and inflexible as it had seemed. Galfano, Rusconi and Umilta (2006) demonstrated that the ‘number mediated orienting’ by Fischer et al (2003) can be reversed if participants were explicitly told to orient towards the left for big numbers (e.g. 8-9) and the right for small numbers (e.g. 1-2). Ristic, Wright and Kingstone (2006) also showed that the ‘mental number line mediated orienting’ can be reversed by simply instructing participants to imagine a number line running from right to left. Galfano et al. (2006) suggested that number mediated orienting is elicited only when there is no other incentive to orient otherwise and the effect is easily overridden by endogenous control, which might suggest that the effect is endogenous in the first place. It was also suggested that the exogenous effect of number cues was weaker than the effects of abrupt onset cues or eye gaze to one side.

4. Problems for a two process model of attention

Competition between exogenous and endogenous orienting

The competition between endogenous and exogenous orienting (top-down and bottom up processes) such as in studies using feature singleton (Bacon & Egeth, 1994) and abrupt onset (Yantis & Jonides, 1990), has led researchers to wonder about the definition of these endogenous and exogenous orienting processes, and where the boundary between these two forms of orienting lies. A truly automatic response is elicited unintentionally and is unable to be suppressed (Jonides, 1981). Studies, however, showed that the stimulus which has been suggested to capture attention, such as abrupt onset or feature singleton, often failed to elicit exogenous orienting effect when attention was endogenously focused on elsewhere (Yantis & Jonides, 1990; Theeuwes, 1991a).

The second criterion of true automaticity, load insensitivity, concerns the limited processing capacity of the attentional system. A truly automatic response does not demand any attentional resources and should not be affected by the mental load of any concurrent task (Jonides, 1981). However, Santangelo, Finoia, Raffone, Belardinelli and Spence (2008) suggested that the exogenous effect of a cue is often affected by the attentional or perceptual load of an attention task. It was demonstrated that increased perceptual load, such as changing from performing a single task to performing concurrent tasks, or introducing more visual features, such as having to differentiate size and colour and make respective responses, reduces or eliminates an exogenous effect of a cue. It was concluded, therefore, that it is unlikely that any human response could meet the strict definition of a purely automatic response (Santangelo & Spence, 2008). Recent studies, therefore, consider the exogenous-endogenous distinction to be relative rather than absolute. An integrated model of the two forms of orienting examines a mixture of the two forms of orienting where they continuously compete or operate synergistically during visual exploration (Bartolomeo, Decaix, & Sieroff, 2007; Most & Simons, 2001; Berger, Henik, & Rafal, 2005). The rest of this section discusses the studies which have shown exogenous and endogenous effects that are problematic for a clear cut, two process exogenous and endogenous orienting model.

Symbolic meaning of central cues

Endogenous orienting effects were initially associated with central cues as it was thought that one needs to interpret the symbolic meaning within the cue for orienting. However, conventionally used central cues, especially arrow cues, have been shown to elicit not only endogenous effects but also exogenous effects. Ristic and Kingstone (2006) demonstrated that the much used predictive central arrow cues showed an interaction between exogenous and endogenous orienting. Four different central cues were used: non-predictive numbers (NN), predictive numbers (PN), non-predictive arrows (NA) and predictive arrows (PA). Number cues were suggested to elicit pure endogenous orienting when predictive (PN), and no orienting when they were non-predictive (NN). An exogenous effect was expected to be most prominent with NA as they are non informative and less so with PA or PN as they were informative. The orienting effect of NA was compared to PA to see if the effect of PA was purely exogenous, and the orienting effect of PN was compared to PA to see if the effect of PA was purely endogenous. The orienting effect of PA was bigger than NA at all SOAs (100, 300, 600, 900 ms), which the researchers interpreted as evidence that PA was not purely exogenous. The effect of PA was also bigger than that of PN, and hence not solely endogenous either. Moreover, the effect of PA was bigger than the sum of the effects of NA and PN. It was suggested that PA triggered an orienting effect that is a combination of endogenous and exogenous orienting (Olk, Cameron, & Kingstone, 2008). The finding showed that the orienting effect driven by arrows is not purely endogenous and the researchers reasoned that arrows are over-learned symbols readily associated with directional behaviour, hence the orienting inevitably contains a degree of exogenous effect.

Similarly, Hommel, Pratt, Colzato, & Godijn (2001) have shown that over learned direction words, such as ‘left’, ‘right’, ‘top’ or ‘bottom’, also elicit an exogenous effect. An exogenous effect, a faster RT was observed for the cued location, was observed even when the word cues were non-predictive of target location. It was suggested that conventional, over-learned communicative symbols trigger exogenous orienting, involuntarily attracting attention to the cued location. Furthermore, there seem to be many different types of exogenous orienting effects. Tipples (2008) suggested that the exogenous effects induced by arrows or eye gaze cues are different from the exogenous effects by abrupt onset peripheral cues in that the exogenous effects of the former is, to some degree, strategy driven, hence affected by individual differences, whereas the latter show relatively less individual differences, thus more exogenous.

Spatial correspondence and derived attention

Another study that argues against the idea that central cueing effects are driven purely by symbolic encoding is Lambert and Duddy (2002). It was suggested that the benefit of both central and peripheral cues in orienting towards a target is determined by the spatial correspondence between the cue and target presentation in the visual field, not by the eccentricity of cues or what they symbolically mean. Informative bilateral letter cues were presented on both sides of fixation centrally and peripherally in the study in order to investigate whether the symbolic meaning or eccentricity of cues is crucial in visual orienting. There were two experimental conditions in the study. In a spatial correspondence condition, participants responded to targets that were likely to appear on the same side as a particular cue letter (for ½ the participants targets usually appeared next to the letter X and for the other ½ targets usually appeared next to the letter T). In a spatial translation condition, participants had to translate the information carried by cues into spatial terms. In this condition the same letter cues were presented on both sides of fixation (e.g. Xs on both sides meant targets on the left and Ts on both sides meant target on the right). The responses for valid cues were faster than invalid cues at a shorter SOA in the spatial correspondence condition regardless of whether the presentation of cues was central or peripheral. In addition, at both brief and long SOAs, the overall magnitude of cueing effects was larger for spatial correspondence cues, in comparison with spatial translation cues. In both the spatial translation and spatial correspondence conditions, participants needed to discriminate between cue stimuli in order to orient effectively. The presence of strong orienting effects in the brief SOA condition of the spatial correspondence condition, regardless of whether cues were presented centrally or peripherally, indicated that cue discrimination was *not* a crucial factor associated with a slow pattern of attentional effects, thought to be characteristic of endogenous orienting. Rather, it appeared that spatial correspondence, indexed by the contrast between the cueing effects elicited by the spatial correspondence cues and the cueing effects elicited by the spatial translation cues, was the critical factor which determined the strength and speed of visual orienting in this situation.

The learned association between cues and target locations (e.g. the letter ‘X’ for the target on the left) shown in Lambert and Duddy (2002) enabled rapid orienting toward the target. This finding is consistent with William James (1890/1983)’ associative learning in *derived attention* where orienting is *derived* by the association between two different visual stimuli. According to William James both exogenous and endogenous orienting could be derived. A rapid orienting elicited by the informative cue letters in Lambert and his colleagues could be classified as derived attention as the effect is the combination of exogenous and endogenous orienting.

In order to further examine the importance of inter-stimulus spatial correspondence in visual orienting, Lambert et al. (2006) compared the effects of symmetric and asymmetric single letter cues, both presented centrally. The results again showed that the spatial correspondence between cue and target was crucial in the orienting towards targets. Spatially symmetric cues, such as x or o, did not elicit a validity effect, whereas asymmetric cues, such as d or b, showed a clear validity effect, which was consistent with Lambert and Duddy (2002). Like arrows, spatially asymmetric letter cues such as ‘d’ and ‘b’ possess the feature of spatial correspondence, because spatial features of the asymmetric letter (the lower, curved portions of b and d) are correlated with spatial features of the target display – whether the target appears on the left or right. Visually symmetric letters such as x, v, or o do not possess this feature. Lambert et al. (2006) suggested that the finding of spatial correspondence as a factor in visual orienting is important as it implies that the orienting by informative central symbolic cues could be stimulus driven, governed by the asymmetry of the cue and its spatial relation with the target.

Implicit learning

Attention and awareness are closely linked (James, 1890/1983). It is often the case that we are explicitly aware of visual stimuli we attend to. It is possible, however, that we also attend to a stimulus implicitly without having the knowledge of it. The idea of implicit processing of the relationship between cue and target in visual orienting research has gained a steady support over many years. One of the traditional implicit learning tasks is an artificial grammar learning task. In Reber and Lewis (1977), participants were to perform an artificial grammar task in which strings of letters were formed following a unique rule. Participants learnt the logic behind the complex synthetic grammar and the performance improved dramatically after 4 days of learning, although they were unable to explicitly provide the structure of the language system. Evidence of implicit learning is also found in visual orienting. Nissen and Bullemer (1987) demonstrated implicit learning of spatial locations in a serial reaction time (SRT) task in which participants learned a sequence of light positions without any awareness of the learning. Participants were instructed to press one key out of four keys that corresponded to four light positions. When the presented sequence of light positions was fixed, participants were able to learn the sequence of the light positions after only six repetitions of the sequence in the absence of sequence knowledge. When the sequence of the light positions was random, there was little improvement in the performance in the task. Interestingly, patients with amnesia were also able to perform this task, showing an improvement after 10 repetitions of the sequence despite the lack of the awareness of the repeating pattern. Nissen and Bullemer suggested that a SRT task involves implicit learning of new associations independent of conscious remembering.

More recent work on implicit learning of spatial information is a contextual cueing task, introduced by Chun and Jiang (2003). Participants were to search for a target (rotated letter T) among multiple meaningless distracters (rotated letter L). A cue was embedded around a target in the form of distracters, which prevented participants to explicitly encode the cue. Participants were able to learn the repeated informative configuration between the target and distracters around it, in the absence of any awareness of the relationship between the configuration and target, and use the configuration for efficient target search. Chun and Jiang reasoned that the spatial layout of the cue provided the global visual context for the target, which enabled the participants implicitly use the cue for the target. Contextual cueing is an interesting finding in visual orienting research as it is neither strictly exogenous as it involves top-down processing, nor endogenous as it is unconscious. In Brady and Chun (2007), a contextual cueing effect was shown when the cueing configuration was minimal, such as just with two distracters (Experiment 1), suggesting the encoding of the context stimuli near the target was very specific and localized. The result was further supported by subsequent experiments (2 and 3) where the benefit of contextual cueing did not differ between local context cueing and global cueing. Context cueing occurred even when contextual cues were presented prior to the target (Kim, Kim, & Chun, 2010), hence the spatial representation of cue context stimuli could be stored in working memory to be used for a later target search. The representation, however, was domain specific (i.e. specific to spatial information) as context cueing using colour did not improve the performance in the target search task.

Another example of implicit learning in orienting is the proportion valid effect. The proportion valid effect refers to a cueing effect which increases in magnitude as the proportion of valid trials increases in a cue-target orienting task. Risko and Stolz (2010) showed that the proportion valid effect occurred regardless of participants' awareness of the proportion of the valid trials in the task, suggesting that attentional orienting may reflect implicit learning of the cue-target contingency. In their study, participants were asked to verbally estimate the proportion of valid trials in a task so that participants' explicit strategy in respect to cue-target contingency could be measured. The probable target location was cued either by a peripherally presented rectangle or a central arrow. The results showed that, in both cue conditions, the proportion valid effect was independent of participants' estimate of the percentage of valid trials (See Lambert, Naikar, McLachlan & Aitken, 1999, for evidence on implicit learning that is dependent of participants' subjective beliefs on the cue-target relationships). This finding was interpreted as an example of implicit learning rather than endogenous strategic control of attention. It was argued that the proportion valid effect, which is independent of participants' awareness, could not be considered to be endogenous orienting, which is thought to involve a slower intentional form of attention shifting. A similar finding was reported by Bartolomeo, Decaix and Sieroff (2007) where the proportion of valid trials differed across experimental blocks (50% to 50%, 50% to 80%, 50% to 20%). Participants were uninformed of the cue-target contingency and were asked about the cue-target relationship at the completion of the task. The results showed that participants were able to orient towards the target using the cues, showing a more exogenous pattern of effects when the proportion of valid trials was 50/50 and a more endogenous pattern effects as the proportion of valid trials increased, without being explicitly aware of the contingency.

Implicit learning and subjective belief

The findings of Risko and Stolz (2010) and Bartolomeo et al. (2007) regarding the proportion valid effect present a contrast to the study of Lambert, Naikar, McLachlan and Aitken (1999) in which the pattern of implicit learning was dependent on participants' strategy in using cues in an orienting task. Participants performed an orienting task using letter cues in the absence of the knowledge of the cue-target relationship in the study. Although the cue was predictive of target location the effect resembled exogenous orienting with initial facilitation later replaced by inhibition (IOR) when the participants remained unaware of the cue-target relationship. This orienting effect was explained in terms of implicit learning of the cue-target relationship and was distinguished from exogenous orienting as the orienting was not possible without the learning of association between cue and target. When the participants were explicitly informed of the cue-target relationship, an endogenous orienting effect, facilitation at a long SOA, was observed, which was distinct from the implicitly learned orienting.

Perceptual awareness and orienting

Lambert et al. (1999) also showed an orienting effect in an experimental setting where participants oriented towards a target in the absence of perceptual awareness of cues. The target was presented in one of the two peripheral boxes, each in the left and right side of a fixation cross. The target was informatively cued by dots presented inside the upper inner corner of one of the peripheral boxes. The number of the dots increased as cue level increased. When the cue was below threshold (e.g. one dot), the response showed an exogenous effect, and an endogenous effect was apparent when the cue was above threshold (e.g. more than two dots). The authors suggested that whether the pattern of orienting resembled that of exogenous or endogenous orienting depended on the subjective belief of the participants regarding the relationship between the cue and target, even if with low confidence. When one considers that the validity of all the cues in predicting target location was 80% in both studies, these results imply that the awareness or subjective beliefs on cue-target relationship dictated the allocation of attention in the visual field, subsequently influencing the course of the orienting.

Similarly, in McCormick (1997), subjective awareness of cues was shown to be a crucial factor in determining whether orienting effects resemble either the exogenous or endogenous pattern. There were two possible target locations, either on the left or right side of a fixation. The opposite side of the likely target location was cued by a vertical bar which varied in intensity. When participants reported that they were unaware of the cues, a faster RT was observed at the cued location (the unlikely target location), and when they reported being aware of the cues a faster RT was observed at the uncued location (the likely target location) at the SOA of 80ms (Experiment 3) and 500ms (Experiment 1). It was suggested that the visual orienting was under exogenous control when participants were unaware of the cues, and was under endogenous control when they were aware of the cues.

The evidence of implicit learning (i.e. proportion valid effect, contextual cueing) and the effect of participants' awareness or subjective belief of the cue-target contingency in a visual orienting task (Lambert, et al., 1999; McCormick, 1997) indicate that the simple dichotomy model is insufficient in representing the sophistication of human orienting mechanism as the model only takes into account of observer's explicit voluntariness in visual orienting tasks. These findings, along with the evidence of the competition between exogenous and endogenous orienting, further emphasize the necessity of a newer, more flexible model of visual orienting.

5. Cognitive neuroscience approaches to visual orienting

Early and late selection theory

The neurological level at which orienting is processed in visual system is still much debated. Early selection theory proposes that attention selects the visual features to be prioritized at an early sensory level based on spatial location, colour or orientation (Posner, 1980; Spence & Parise, 2010; Luck et al., 1994; Treisman & Gelade, 1980). Having an attentional selection at an early stage is beneficial as it reduces the computational load in the system, which enables an efficient response (Vidyasagar, 1999). Orienting effects have been shown during simple feature perception and feature integration processes (Briand, 1998), and have also been shown to interact with luminance and colour (Lambert, Wells, & Kean, 2003). Late selection theory, on the other hand, suggests that visual perception is processed pre-attentively and automatically in a parallel fashion with unlimited capacity. Selection occurs at a later more cognitive stage where information processing capacity is limited, based on object identities as well as lower level visual properties. It was suggested that attentional selection occurs at the post-perceptual level, in which memory retrieval, response selection and decision making are processed (Norman, 1968).

More recent studies have suggested that the selective processes of attention are not exclusive to either early or later stages of visual processing. Lavie (1995) argued that early selection occurs only when perceptual load reaches its limit at the early stage. Thus, if there is attentional resource available at an early stage of visual processing, irrelevant stimuli can exogenously attract attention. The selection of relevant information takes place at the later stage, after filtering irrelevant information, for an appropriate response. Moreover, there is consensus that attentional selection takes place early along the visual cortical areas in the lower areas (e.g. V1, V2) and also in the higher areas (e.g. MT) at multiple levels, biased by both bottom up and top down processes interacting with each other (Kastner & Ungerleider, 2000).

The processing in the magnocellular (M) and parvocellular (P) cells of the lateral geniculate nucleus (LGN), and subsequently along the dorsal and ventral cortical pathways have been suggested to be crucial areas in visual orienting and perception system respectively. Bullier (2001) proposed an integrated model of visual processing where the initial fast feed-forward and then feedback processing of visual information between the M cells and V1 act as a 'fast brain'. The faster M pathway feed-forwards input along the dorsal pathway enables the higher cortical areas, such as MT, MST and FEF, to efficiently send feedback to the lower areas, V1 and V2, and to spotlight the location of interest, facilitating subsequent P pathway processing for more detailed information. The fast M pathway via V1 is relayed to MT whereas the later mixed projection of both M and P cells is received in V2 (Nassi & Callaway, 2007; Maunsell et al., 1999; Laycock, Crewther, & Crewther, 2007). Vidyasagar (1999) suggested that filtering the information from the lower sub-cortical areas with feedback from the higher cortical area reduces attentional overload, efficiently directing attention towards the most relevant information.

Distinction of orienting and perception

Posner (1980) differentiated orienting from perception as orienting is "aligning of attention with a source of sensory input or an internal semantic structure stored in memory" (p.4). When a location is covertly attended, visual information in the area is more rapidly processed (Posner, 1980) and is perceived at a lower threshold (Reynolds, Pasternak, & Desimone, 2000). The function of covert orienting is to prepare and guide the eye and the focus of attention to a certain location in the visual field. When the location of an object is cued perception latency is reduced (Posner, 1980). For the detection or perception of an object, on the other hand, one needs to process and *understand* the information so that one can respond to the object. Orienting is faster than perception for which more detailed information is needed. Researchers have suggested that neurological correlates of the orienting system are distinct from those of object perception (Hillyard & Anllo-Vento, 1998). The distinction between orienting and perception system has been explored in studies using psychophysiological measurements including single cell recording, EEG, fMRI and TMS.

a. Single cell recording

Many early neurological studies on orienting and perception have involved invasive single cell recording in monkeys. One of the early studies is the work of Mountcastle (1978) which showed parietal lobe involvement in visual attention and eye movements. Monkeys were trained to fixate on, track and make saccades to target lights while their parietal lobe cells were being recorded by microelectrodes inserted in the cells. The magnocellular (M) cells in the lateral geniculate nucleus (LGN) have been shown to be sensitive to low contrast stimuli and pattern perception (Shapley & Perry, 1986). The M cells directly receive the information projected from the retina (Laycock, Crewther, & Crewther, 2008) and send information to the parietal cortex along the dorsal stream where space, motion and depth are processed (Ungeleider & Mishkin, 1982). Blocking the magnocellular part of the LGN led to a dramatic decrease in responses in area MT, suggesting that the M pathway plays an important role in the dorsal stream with its dominant influence on MT (Maunsell, et al., 1999).

Goldberg and Wurtz (1972) examined the enhancement of the activation in the superior colliculus (SC) when monkeys made saccades to a visual stimulus. The enhanced activity in the SC was shown even before the initiation of the saccades, and was suggested to occur by the input from the higher level attentional system that selects what stimuli to be attended. The enhancement in the SC cells was also shown to be dependent on a stimulus presentation and starts 200-300ms before a saccade (Wurtz & Mohler, 1976). The activation was suggested to combine the visual inputs of the superficial layer cells and movement-related input of the intermediate layer cells of the SC (Mohler & Wurtz, 1976).

The single cell studies above suggest the M cells of the LGN and the SC as important areas in the attentional system. The finding that a majority of the M cell input is projected to MT, magno-recipient part and the posterior part of the parietal cortex indicate the close connection between attention and motion. Similarly, the SC is suggested as a critical area in the attentional system that is highly correlated with eye movements that follow a shifting of attention (Vidyasagar, 1999). Although the single cell recording technique provides the highest resolution in the brain, most studies using the technique involve monkeys as it is highly invasive in humans.

b. EEG

Event-related potentials (ERPs) provide a non-invasive recording of neural activity that reflects the time course and location of stimulus processing and selection in the human brain. Several characteristic voltage deflections have been identified to be critical in visual processing, labelled as C1 (50-90ms), P1 (80-130ms), N1 (140-200ms) and P300 (250-500ms) components. The early C1 component is localized to the primary visual cortex, the P1 component over the bilateral occipital scalp and the temporal areas, and the N1 component over the frontal and parietal and occipital scalp areas (Clark & Hillyard, 1996; Noesselt et al., 2002).

Much research in visual orienting has been unable to observe the C1 component in attentional modulation (Hopfinger & West, 2006). Kelly, Gomez-Ramirez and Foxe (2008) suggested that the C1 component is highly variable across individuals and this may be the reason why the C1 component was often absent when averaging of the C1 component across subjects. Jin et al. (2010) has showed that professional badminton players exhibited a bigger C1 component compared to non players when they were to predict where the shuttlecock would land during their training video clip. The C1 component was shown to be bigger for bilaterally presented visual stimuli than unilaterally presented stimuli, and was not influenced by attentional load (Fu, Fedota, Pamela, & Parasuraman, 2010; Noesselt, et al., 2002).

Attending to a spatial location usually leads to an enhancement of P1 and N1 components (Brignani, Guzzon, Marzi, & Miniussi, 2009). In Hopfinger and West (2006), an exogenous cue, an offset of peripheral box (non predictive), affected early stages of visual processing, producing a modulation of late P1 (125-175ms). An endogenous cue was an image of superimposed arrowheads ("<" and ">"), and the arrowhead in yellow opposed to cyan indicated the probable target location. The endogenous cue influenced not only early but also later higher order processing, enhancing both the early P1 (80-120ms) and N1 (150-210ms) components.

In Brignani, et al. (2009), both P1 and N1 have been shown to be modulated by arrow cues, eye gazing cues and texture cues (a purely endogenous cue because one type of texture was associated with a target on the left and a different type with a target on the right). The amplitude of the waveforms was influenced in all these cases, which was suggested to imply that these cues activate the same network. As visual information reached later stages of P300 component (300-400ms) in visual processing, endogenous control of attention was dominant (Hopfinger & West, 2006). A concurrent presentation of an exogenous cue was ignored and did not affect the P300 component where attention is endogenously focused in the probable target location (Hopfinger & West, 2006).

EEG experiments are beneficial in visual orienting studies using cueing paradigms as it records the neural activities associated with a visual cue, a target and the response, with excellent temporal resolution (Luck, Woodman, & Vogel, 2000). However, this technique does not provide a detailed spatial map of the activities. Recent EEG studies on visual orienting are often conducted in conjunction with PET (Heinze et al., 1994; Mangun, Hopfinger, Kussmaul, Fletcher, & Heinze, 1997) or fMRI (Natale, Marzi, Girelli, Pavone, & Pollmann, 2006; Noesselt, et al., 2002; Mantini, Corbetta, Perrucci, Romani, & Del Gratta, 2009) to constrain the source locations of ERPs.

c. fMRI evidence

Functional neuroimaging techniques do not record information on the processing of visual orienting with high temporal resolution but instead provide very specific 3D images of the brain with high spatial resolution (Luck, et al., 2000).

Corbetta, Kincade, Ollinger, McAvoy and Shulman (2000) suggested two different attentional networks, a dorsal attention network and a ventral attention network, which reflect endogenous control and exogenous control of attention, respectively (Fox, Corbetta, Snyder, Vincent, & Raichle, 2006). The dorsal attention network, DAN, includes intraparietal sulcus (IPs), superior parietal lobule (SPL), and dorsal frontal cortex along the precentral sulcus, near or at the frontal eye field (FEF). The ventral attention network, VAN, includes the activation in the temporo-parietal junction (TPJ), the ventral part of the supramarginal gyrus (SMG), ventral frontal cortex (VFC), parts of middle frontal gyrus (MFG), inferior frontal gyrus (IFG), frontal operculum, and anterior insula.

Corbetta, Patel and Shulman (2008) write:

> A dorsal frontoparietal (or dorsal attention) network enables the selection of sensory stimuli based on internal goals or expectations (goal-driven attention) and links them to appropriate motor responses. A ventral fronto-parietal (or ventral attention) network detects salient and behaviourally relevant stimuli in the environment, especially when unattended (stimulus-driven attention). (p.306)

In Corbetta, et al. (2000), participants were presented with informative arrow cues and were instructed to respond to a target, an asterisk. Corbetta, et al. (2000) suggested that the IPs in DAN, in conjunction with the occipital cortex and the frontal cortex, plays a role in spatial bias towards the cued location, engaging attention voluntarily at the cued location. The study showed that cue presentation triggered a sustained activation in the IPs that lasted for 4.72 seconds. The results were replicated in their later study (Corbetta, Kincade, & Shulman, 2002) where the IPs and superior frontal cortex near the frontal eye field (FEF) were activated for endogenously directed attention that lasted during a 7 s delay when participants were instructed to do so (Shulman et al., 2009). The result is consistent with Kincade, Abrams, Astafiev, Shulman and Corbetta (2005) where activations in the bilateral areas of the putative human FEF and the bilateral IPs were observed by an endogenous cue, a brightening of the left or right half of a central diamond. The IPs and FEF were suggested to be involved in the bilateral dorsal system where endogenous orienting by top-down control is processed (Fox, et al., 2006).

Corbetta et al. (2000) also showed a right TPJ activation in the VAN locked into target perception which was stronger on invalid trials than valid trials. The right TPJ activation was suggested to play a role in stimulus-driven reorienting when a target appears at unattended location, an adaptive behaviour (He et al., 2007; Astafiev, Shulman, & Corbetta, 2006; Shulman et al., 2010). The right TPJ along with the right ventral frontal cortex (VFC) was shown to be inactive until a target appears and only active after a target presentation, filtering irrelevant distracters, ensuring targets to be detected (Shulman, Astafiev, McAvoy, Davossa, & Corbetta, 2007).

The SMG, a part of the ventral-fronto-parietal network, responded to the distracters that shared the same attributes as targets (Serences et al., 2005). The TPJ and SMG were shown to prevent attention from being attracted to irrelevant stimuli and the deactivation of these areas was shown to correlate with increased visual short term memory (VSTM) (Todd, Fougnie, & Marois, 2005). The second main component of the VAN, the right inferior frontal gyrus (IFG) was shown to be activated by stimulus-driven reorienting only when the reorienting was unexpected.

The two dissociable attentional networks, DAN and VAN, have distinct functional systems but also interact in the process of attentional selection. When attention is focused the DAN is activated and the VAN is suppressed so that reorienting towards irrelevant distracters does not occur (Corbetta, et al., 2008). The DAN and VAN have been shown to work together in processing relevant stimuli and making appropriate responses via areas that are connected to both networks, such as the posterior MFG (Fox, et al., 2006).

d. TMS

Transcranial magnetic stimulation (TMS) is the application of a brief magnetic pulse to the scalp, which causes changes in the local electrical field in the underlying surface of the brain. The current form of TMS was first administered by Barker and Jalinous (1985) who successfully stimulated human motor cortex. TMS stimulation in the FEF enabled monkeys to perceive smaller changes in target luminance among distracters at the early SOA of 50-175 ms, showing that the stimulation increased the sensitivity to luminance (Moore & Fallah, 2004). The benefit of the stimulation was comparable to the sensitivity to the target luminance when the distracters were removed. The result was interpreted as the FEF playing an important role in selective attention as well as in planning and executing saccades.

Hilgetag, Theoret and Pascual-Leone (2001) showed that repetitive TMS of the parietal cortex impaired the perception of a visual stimulus in the visual field contralateral to the stimulated hemisphere by causing an attentional deficit in the visual field. More recently, Harris, Benito, Ruzzoli and Miniussi (2008) have shown that the parietal cortex processes the spatial property of an object, but does not have a direct influence on the processing of object identity. The result was that the stimulation in the inferior parietal lobe/IPS, compared to the vertex of the head, impaired orientation judgements of rotated objects but enhanced object identification performance. Harris et al. suggested that a disturbance in the attentional effect in the parietal cortex eliminated the suppression in the ventral network, leading to an enhanced performance in an object identification task. The result is consistent with Corbetta, et al. (2008) in which the activation of DAN is accompanied by the deactivation of VAN. The interactive relationship between the ventral and dorsal networks is also shown by Chambers, Stokes, & Mattingley (2004), in which the SMG, the area involved both in the DAN and VAN networks, was suggested to be involved in impairment in orienting effects (Fox, et al., 2006).

The intricate interaction between the VAN and DAN is further supported by Thut, Nietzel and Pascual-Leone (2005) who showed that endogenous visuo-spatial control could be relatively spared in patients with a dorsal posterior parietal cortex (PPC) lesion. After a repetitive TMS on the right parietal lobe, endogenous orienting to the left visual field was possible but there was an overall increase in reaction times for target perception. The disturbance in the PPC was also associated with impairment in target perception when targets appeared at unattended locations. Hence, impairment by a disturbance in DAN is not restricted to attention/space based deficit and can also be associated with impairment in target perception, disengaging and reorienting (Posner, Walker, Friedrich, & Rafal, 1984). The results of TMS studies (Chambers, et al., 2004; Harris, et al., 2008) are overall in agreement with fMRI studies (Corbetta & Shulman, 2002), in that, initially the dorsal network is activated and the ventral network is suppressed for orienting, but both dorsal and ventral networks are activated during target perception and reorienting.

e. *Neuropsychological evidence*

Posner and Peterson (1990) explained that studying attention from a neuroscience point of view has dramatically increased the understanding of attention which has been thought as a vague notion. It was suggested that the attention system involves a network of specific brain areas, and is distinct from the sensory or motor system (Posner & Raichle, 1995; Posner & Petersen, 1990).

Spatial neglect studies provide direct evidence for how the areas in the brain influence the specific attentional behaviours that are associated with the areas. Spatial neglect is a neuropsychological disorder of spatial cognition, often caused by damage in the right hemisphere (Halligan & Marshall, 2001). Although neglect patients show many qualitatively different patterns of neglect, they share, in common, omission and distortion of the space in the left visual field (Halligan, Fink, Marshall, & Vallar, 2003). The rightward biased behaviour of neglect patients can be egocentric in that patients have difficulty allocating attention towards the left side of the midline of their body or body parts (Marshall & Halligan, 1990). The responses of neglect patients were ipsilesionally deviated to the right side when asked to point their trunk midline (Heilman, Bowers, & Watson, 1983). The spatial bias in neglect also applies to object-centred space, and when asked to copy an object, patients sometimes drew only the right part of the object (Olson & Gettner, 1995). This asymmetry of activation was attributed to the left hemisphere having a stronger tendency to shift attention in the contralateral hemispace in comparison with the right hemisphere which distributes attention more evenly in both hemispaces (Mesulam, 1999; Corbetta, et al., 2002; Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005).

Attention deficits shown by neglect patients can be corrected by helping the patients attend to the neglected side by cueing. In Urbanski and Bartolomeo (2008), neglect patients with right hemisphere damage were instructed to mark the midpoint and the end point of a perceived and an imaginary line. In a conventional line bisection task, patients were to just reach out and mark the points of a perceived line. In an imaginary line task, they were asked to imagine a line that was similar to the line they had seen in the conventional line bisection task. They were to start either from the left or from the right of the line when marking the mid and end points of the imaginary line. Eliminating any distracting visual stimuli on the right side of the visual field by not having any visible line in the imaginary line task and starting from the left of the imaginary line abolished the right ward deviation usually observed with neglect patients. Urbanski and Bartolomeo (2008) suggested that, in a line bisection task, the right and left portion of the line compete until the equity between the two is reached. Leftward neglect is due to the overestimation of the right side of the line compared to the left side of the line. This attentional bias increases the perceptual salience of the right side of the line, and the performance is biased towards the right side of the line. When the line is imaginary, thus no longer perceptual, neglect patients need to bisect the line based on its representation in memory, which is not affected by the attentional bias towards the right side. The absence of rightward bias in the imaginary line bisection task with neglect, compared to the rightward bias in the conventional line bisection task, supports this interpretation (cf. Bisiach, Brouchon, Poncet, & Rusconi, 1993).

6. Present study

Since Posner (1980), who pioneered the investigation of visual orienting with his cue-target paradigm, much visual orienting research has had its foundation in the dichotomy model of exogenous and endogenous orienting (Jonides, 1981; Corbetta & Shulman, 2002). Within the model, various aspects of cue and target have been investigated in order to uncover the critical factors that determine whether the course of orienting is to be exogenous or endogenous (Yantis & Jonides, 1984; Theeuwes, 1991a). Recent studies, however, have shown that these exogenous and endogenous components are relative and not absolute in orienting, and that the two components compete or interact with each other (Olk, et al., 2008). It was suggested that participants’ mental set in a given task is important in deciding the relative roles of exogenous and endogenous components in an orienting task (Folk, et al., 1992; Folk & Remington, 2008). It was shown that the processing of cues (McCormick, 1997) or the learning of the cue-target contingency could be implicit (Bartolomeo, et al., 2007; Risko & Stolz, 2010). Moreover, participants’ perceptual awareness or subjective belief of cue-target relationship have been shown to affect the course of covert orienting (Lambert, et al., 1999). These findings of recent orienting studies suggest the insufficiency of the theoretical dichotomy model of endogenous and exogenous orienting in explaining visual processing (Risko & Stolz, 2010; Lambert & Duddy, 2002; Bonato, Priftis, Marenzi, & Zorzi, 2009).

The current study has subjected the dichotomous model of visual orienting to further empirical scrutiny. The findings obtained from these experiments provide pointers toward a newer orienting model that is capable of encompassing the recent findings on orienting that are problematic in the dichotomous model. Experiments 1-3 examined the importance of perceptual awareness of the cues in eliciting visual orienting. Experiments 1-3 manipulated the perceptual awareness of the cues by varying the luminance contrast of cue and target stimuli to above and near visual threshold. The magnitude and speed of the cueing effect in relation to the perceptual awareness of the cues were measured.

The neurological process underlying the orienting mechanism was also examined (Experiment 4). A flicker adaptation procedure was administered in order to over-stimulate the magnocellular cells. A dramatic difference in the performance observed in an Attention and a Perception task after the flicker adaptation procedure implicated the fast magnocellular pathway in the dorsal stream as an important area for visual orienting process. The orienting observed was relatively rapid regardless of cue eccentricity or size (Experiment 5 and 6). The results of the six experiments to be described below beg for a newer orienting model that surpasses the dichotomy of the endogenous and exogenous orienting model.

Chapter 2

Experiment 1

Introduction

The effects of attention on the luminance processing of a visual stimulus are well documented in the literature. Attention alters and enhances perceptual sensitivity to the luminance contrast of a target by lowering the energy threshold of the target at a probable location by approximately 50% (Talgar, Pelli, & Carrasco, 2004). Reynolds, et al. (2000) proposed a contrast gain model where attentional enhancement is greatest for a visual target stimulus that is at or just below the perceptual threshold, amplifying the neuronal response for an attended stimulus that is too faint to elicit a response when unattended. The attentional effect was shown to be bigger for a lower contrast stimulus than for a high contrast stimulus because the high contrast stimulus was already at its saturation point where there was not much room left for an improvement in performance (Reynolds & Chelazzi, 2004; Reynolds, et al., 2000; Carrasco, Ling, & Read, 2004). Reynolds, et al. (2000) argued that attention changes the efficacy of a stimulus, and the result is as if attention strengthened the pre-synaptic signal boosting the actual stimulus contrast perceived (Carrasco, et al., 2004).

A lowered threshold for attended compared to unattended visual stimuli has been observed behaviourally both when a target is attended exogenously by uninformative cues (Carrasco, et al., 2004) and endogenously by informative cues (Liu, Abrams, & Carrasco, 2009). In Carrasco, et al. (2004), participants performed an orientation discrimination task. There was an uninformative peripheral cue, followed by two Gabor patches, each on the left and right side of central fixation on a grey background. The contrast of one of the Gabors was fixed at a contrast of 6% (near threshold level) whereas the contrast of the other Gabor varied from 2.5 to 16% from trial to trial. Participants were asked to report the orientation of the Gabor patch that appeared higher in contrast. The patches were reported brighter in a cued location than an uncued location. A sub-threshold contrast stimulus, with a contrast of 3.5%, appeared as if it were a more discriminable stimulus, with a contrast of 6%.

A similar result was shown in a subsequent study using informative cues. Liu, et al. (2009) employed a similar design as Carrasco et al. (2004) but used informative cues and a rapid serial visual presentation (RSVP) to endogenously engage participants' attention at one side of the visual field. Endogenously engaged attention improved the perception of cued target contrast from 29% to 32%, suggesting that endogenous allocation of attention benefits luminance processing. The result is consistent with neurophysiological evidence by Luck, Chelazzi, Hillyard and Desimone (1997) which showed that the firing rate of cells in V2 and V4 was greatly influenced when attention was directed to the cell's receptive field, 30%-40% higher when attended than when unattended, implying that attention increases neuronal sensitivity.

Although there are a number of studies on the effects of attention on target luminance processing in literature, the effect of cue luminance processing on attentional effects is relatively unknown. Most attention studies on cue processing have involved symbolic value (e.g. letters, words, see Hommel, et al., 2001) and spatial properties of the cues (e.g. the eccentricity of cues, see Cheal & Lyon, 1989; Jonides, 1981). The effect of the luminance properties of the cue on visual orienting is interesting because lowering the cue luminance allows for the manipulation of the perceptual awareness of the cue. Orienting in response to below-threshold-cues would suggest that orienting is possible without the perceptual awareness of cues, thus the cue processing could be unconscious and exogenous. Previous studies have examined implicit learning of spatial locations (Nissen & Bullemer, 1987), an orienting without the awareness of cue-target contingency (Risko & Stolz, 2010; Bartolomeo, et al., 2007; Lambert, et al., 1999 McLachlan, & Aitken, 1999) or the awarenss of visual stimuli as being cues (Reber & Lewis, 1977; Chun & Jiang, 2003; Risko & Stolz, 2010; Lambert, et al., 1999). More relevant to the current experiment is the work of Lambert et al. (1999) and McCormick (1997) who have reported an orienting effect without the perceptual awareness of cues. In Lambert et al. (1999), probable target location was cued by a single pixel or multiple pixels in the inner corner of one of two peripheral boxes in which a target was presented. The number of pixels increased as the degree of perceptual salience of the cue level increased. Although the conscious detection of a 2 pixel cue remained at chance, an orienting effect was observed with the cues. The result was interpreted in terms of implicit learning of spatial locations between below threshold cues and targets. McCormick (1997) reported a similar finding in his study where targets were presented in the opposite side of a cued location. A vertical bar varying in intensity was used as below or above threshold cues. It was reasoned that if participants were unaware of the cue they would orient towards the cued location with the vertical bar and if they were aware of the cue they would orient towards the uncued location where the target was likely to appear. A faster response was observed at the cued location when the cues were below threshold and at the uncued location when the cues were above threshold, which showed that participants used the below threshold cues unconsciously in orienting. The current experiment extends the findings of these two studies in that letters varying in luminance intensity were employed as near threshold cues. Letter cues require relatively more top down control in processing compared to pixels (Lambert, et al., 1999) or vertical bars (McCormick, 1997). Obtaining an orienting effect with these letter cues that are below threshold would suggest that the letter cues could be unconsciously processed and that the resulting top down control could be implicit. However, if one considers that spatial correspondence between the asymmetry of cues and target was suggested to be important in orienting using letter cues (Lambert & Duddy, 2002), it is possible that letter cue processing itself in orienting is a result of both endogenous and exogenous processes. The processing could be endogenous in that the cue needs to be processed by top down control and exogenous in that the shape (asymmetry) processing, bottom up control, may contribute much to its utilization as a spatial cue.

The current study attempted to replicate and extend Lambert and Duddy (2002) where a rapid orienting was observed by informative asymmetric letter cues. The study further explored the cue-asymmetry-driven orienting in Lambert and Duddy (2002) by examining the dynamics of the visual spatial orienting by manipulating the perceptual awareness of letter cues and targets. The luminance contrasts of cues and targets were manipulated from low to high as a means of manipulating the perceptual awareness of the stimuli. It was initially expected that participants would need to be consciously aware of the cues to use them to orient towards targets.

The SOA between letter cues and the target were either, 0, 150 or 500ms. With high luminance cues, orienting was expected to start earlier, at a shorter SOA, than with low luminance cues as the cue perception processing would be minimal with high luminance cues. When cue luminance is low, orienting would need to wait for the processing of the low luminance cue, which would result in a delay in the following orienting, and this would attenuate the cueing effect. Thus, it was expected that an orienting effect would be observed at a later SOA in trials with low cue luminance compared to that with high cue luminance. The magnitude of orienting effect was also expected to be bigger with high luminance cues than that with low luminance cues as the effect with low luminance cues will take time to have a full effect on orienting process. As for target luminance, a bigger cueing benefit was expected with lower luminance targets than with higher luminance targets on the basis of the work of Reynolds and Chelazzi (2004) and Reynolds et al. (2000).

Methods

Participants. Twenty-eight undergraduate students in the University of Auckland aged 18-40 participated in the present experiment. All had normal or corrected-to-normal vision acuity.

Apparatus. An IMB-compatible 486 PC and VGA monitor (a graphic resolution of 640×350 pixels) were used in the study. Turbo Pascal 7.0 was used to write the software for display presentation and timing. The testing room was dimly lit by an incandescent light lamp directed at one of the walls of the room. A chin-rest was used to prevent any unnecessary head movements and to maintain the head at a distance of approximately 57 cm from the monitor.

Display and stimuli. All stimuli were presented in grey against a grey background. The luminance of the grey background was 8.03 cd/m^2. A fixation cross subtending 0.6° ×0.6° was presented in the centre of the screen (Fig. 2.). Cue stimuli were the letter X and T subtending 1° × 0.8° presented on either side of the fixation cross. The location of the cue letters varied randomly across trials (i.e. T $_{\text{left}}$ + X $_{\text{right}}$ or X $_{\text{left}}$ + T $_{\text{right}}$). The centre of each letter was presented at 5.7° from the fixation cross. The target stimulus was a grey filled square subtending 0.4° × 0.4° presented 5.7° (centre to centre) either to the left or to the right of the fixation cross. For 12 participants, the luminance of the cue stimuli changed randomly across trials in three levels (low-14%, medium-40% and high-142.9%) and the luminance of the target in two levels (low-14% and high-142.9%). For 16 participants the cue and target levels were constant in each block (i.e. a blocked design) (Further discussed in *Design*). At the end of each testing session, there was a discrimination task to check if participants were able to discriminate the cue letters at each luminance level. Weber contrast was used for the calculation of the stimuli contrast.

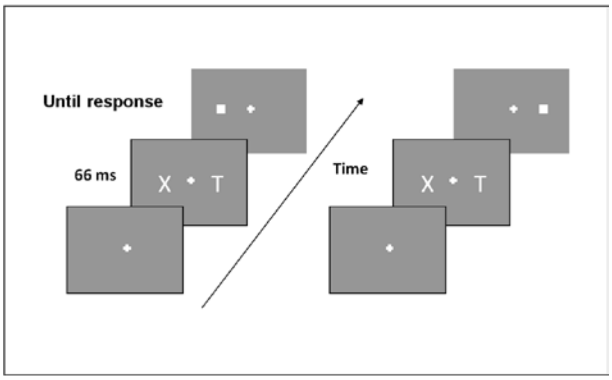

Figure 2. An example of a valid (left) and invalid (right) trial where targets were likely to appear on the same side as letter cue X.

Procedure. All participants read the information sheet about the experiment and signed the consent form. Then, the participants were told that the sequence of a trial would be the appearance of a fixation cross, then cues (X and T on either side of the fixation) followed by a target (either the left or right of the fixation). Participants were instructed to press the spacebar as soon as they detected the target on the left or right of the screen. Participants were instructed to fixate their eyes on the fixation cross and not to move their heads or eyes throughout the experiment. For every trial, the fixation cross disappeared for 100ms one second before the cues were presented in order to draw the participants' attention to it (i.e. the fixation cross blinked at the beginning of every trial). Then, the two cue letters, X and T, were presented for 66ms.

The cue letters were followed by a target on 90.9% of the trials. For a half of the participants, the targets usually appeared on the same side as the X and the opposite the T. For the other half of the participants, the contingency was reversed (i.e. the targets usually appeared on the same side as the T and opposite the X). The participants were told to use the cue letters, X or T, in order to predict the probable location of the target. On trials with a target, the stimulus onset asynchrony (SOA- delay between cue onset and target onset) was 0ms, 150ms or 500ms. The target stimulus disappeared when participants responded to the target. After an interval that varied randomly from 500ms to 1000ms, the fixation cross blinked again to signal the beginning of the next trial.

There were 9.1 % of the trials were catch trials on which cue letters were presented without a target. There was an interval of 2.1s to 2.6 s between the offset of the letter cues and the “blink” of the fixation cross in the catch trials. Participants were instructed to press the space bar only when a target was presented and to refrain from pressing the space bar if there is no target. If they responded to catch trials, a warning message, “Warning! Catch Trial Error”, was presented for 1s at the bottom of the screen. The participants were asked to avoid any anticipatory errors. If participants pressed before the presentation of a target, a warning message, ”Warning! Anticipation Error”, was presented for 1s at the bottom of the screen.

There were 12 practice trials so that participants could familiarize themselves with the task. The task comprised four blocks of 99 trials. At the beginning of each block, there was a message that emphasized the importance of central fixation during the experiment.

Design. Of 90.9% of the trials in a block in which the cue letters were followed by a target, 80% were valid trials where the location of the cue letter (X or T) and the target matched. 20% were invalid trials where the location of the cue letter (X or T) and the target mismatched. The location of the target (the right and left visual field) and three different SOAs (0ms, 150ms and 500ms) were varied randomly throughout the valid and invalid trials.

Target and cue luminance levels changed either within a trial block (i.e. a mixed design) or between trial blocks (i.e. a blocked design)[1]. For 12 participants, the luminance changes of target (high and low) and cue letters (high, medium and low) were varied randomly from trial to trial throughout the four blocks in the task. For 16 participants, the target and cue

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[1] Both blocked and mixed designs were compared in the initial analysis in order to see if the experimental condition has an effect in cue validity effect. Hawkins, Shafto and Richardson (1988) have shown that whether target luminance varies between or within trial blocks has an effect on cue validity effect because participants tend to change their strategy in using cues depending on the experimental conditions.

luminance contrast levels were constant in a block. There was a block of trials at each target and cue luminance contrast levels, all six blocks (2 target and 3 cue levels) in total. The orders of the cue and target luminance levels were randomized.

Data analysis. A 2×2×3×3 repeated measures design analyses of variance was performed on the data using Validity (valid and invalid), Target luminance level (high and low), Cue luminance level (high, medium and low) and SOA (0ms, 150ms and 500ms) as the within-subjects variables. An initial analysis had included experimental design (mixed vs. blocked design) as a between-subjects variable. This variable, however, was dropped from subsequent analysis as there were no significant effects or interactions involving this factor.

Results

Responses that were less than 100 ms were regarded as anticipation errors and were excluded from the analysis. The average rates of anticipation errors and catch trial errors were 1.4% and 5% respectively. The differences in mean reaction times between valid and invalid trials in terms of cue and target levels are illustrated in Figure 3 and 4. The mean response times were entered into a four way analysis of variance using validity (valid vs. invalid trials), target luminance level (high and low), cue luminance level (high, medium and low) and SOA (0, 150 and 500ms). There was a main effect of SOA (F(2,54)=69.27, p<.001). Mean RT at the SOA of 0ms (M=407ms, S.E.=9.8) was significantly slower than that at 150ms (M=355ms, S.E.=9.7) or 500ms (M=352ms, S.E.=9.7). There was also a main effect of Cue luminance level (F(2,54)=4.23, p=.02). Mean RT for medium luminance cues (M=366ms, S.E.=9.89ms) was faster than for high luminance cues (M=374ms, S.E.=9.03ms). Mean RTs for low luminance cues (M=373ms, S.E. =9.3) did not differ from that of medium luminance cues (M=366ms, S.E. =9.9) (p=.114) or high luminance cues (M=374ms, S.E. =9) (p=1). There was a main effect of target luminance level (F (1, 27) =277.98, p<.001). Mean RT for low luminance targets (M=396ms, S.E=9.9) was significantly slower than that for high luminance targets (M=345ms, S.E. =8.8) (p<.001).

There was a main effect of validity (F (1, 27) =21.05, p<.001). Mean RT in valid trials (M=368ms, S.E. =9.14) was faster than for invalid trials (M=375ms, S.E. =9.44).

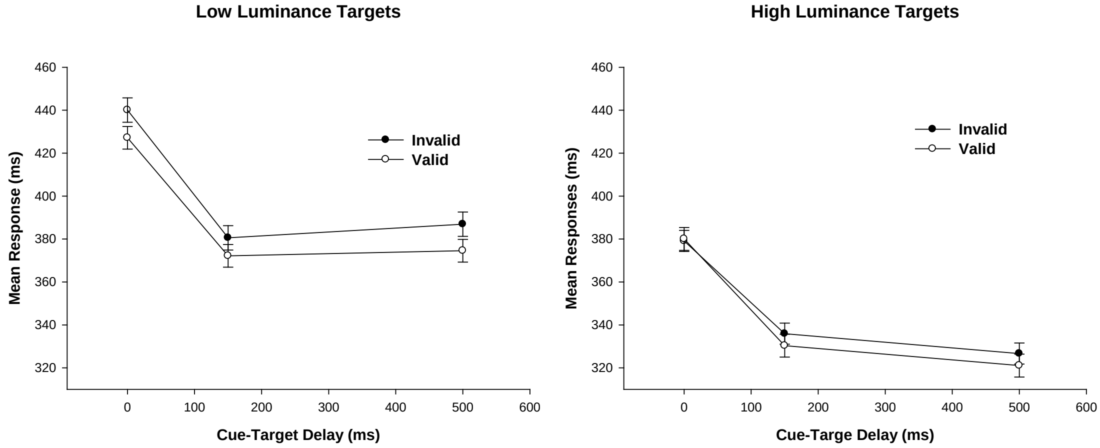
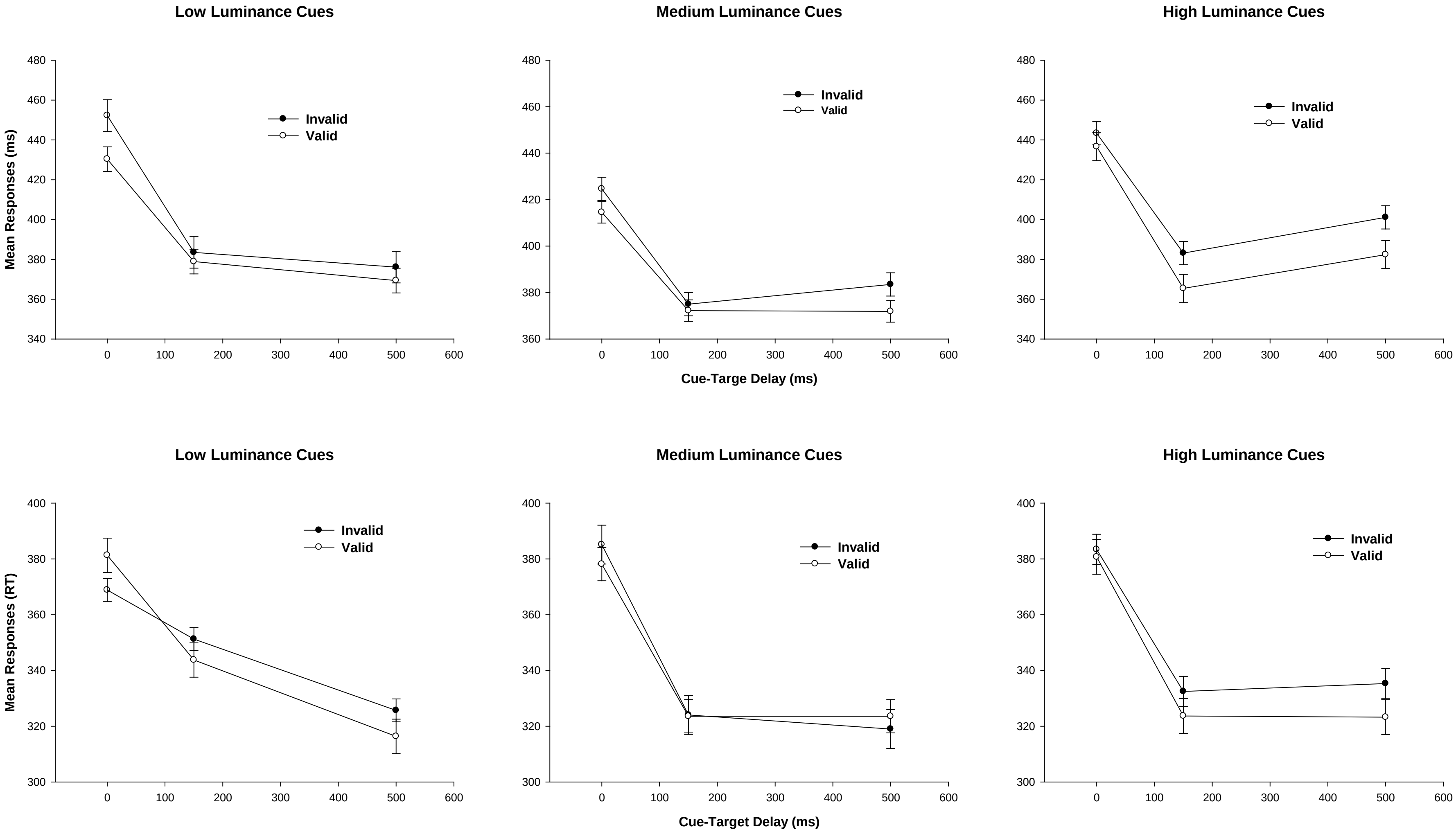


Figure 3. Mean difference in reaction times between valid and invalid trials with low (left) and high (right) target luminance contrast (the error bars are the standard error of the means)

There was an interaction between target luminance and validity (F (1, 27) =6.48, p=.017) (Fig. 3.). The validity effect was mainly from low luminance targets in which the mean RT in valid trials (M=391ms, S.E. =9.8) was significantly faster than invalid trials (M=402ms, S.E. =10.2**).**

Further analysis on high and low luminance targets In order to explore the interaction between validity and target luminance, two further analyses were carried out, which examined data from the high and low luminance target conditions separately. Each analysis involved a 3 (Cue luminance) × 2 (Validity) × 3 (SOA) repeated measures design ANOVA. The first analysis, which examined data from the high luminance target condition confirmed that there was no main effect or interactions involving validity with high luminance targets (F (1, 27) =2.71, p=.11) (see Fig. 3. right panel). In the second analysis, there was, however, a significant validity effect with low luminance targets (F (1, 27) =23.01, p<.001) (see Fig. 3. left panel). A full breakdown of data from the low luminance target condition is shown in Figure 4 (top panel), showing the contrast between valid and invalid trials separately for each of three cue luminance conditions. A 2 (Validity) × 3 (SOA) repeated measures design ANOVA showed a validity effect with low luminance cues (F (1, 27) =8.1, p=.008) (Fig. 4. top panel), although there was no interaction between validity and cue luminance with low luminance targets. A further analysis revealed that a significant validity effect was apparent as early as at the SOA of 0 ms (F (1, 27) =13.67, p=.001).


Low Luminance Cues

Medium Luminance Cues

High Luminance Cues

Low Luminance Cues

Medium Luminance Cues

High Luminance Cues

Figure 4. Mean difference in reaction times between valid and invalid trials with low, medium and high cue luminance contrast with low (top panel) and high (bottom panel) target luminance contrast (the error bars are the standard error of the means)

Back to the omnibus analysis, there was an interaction between Target luminance and SOA (F (2, 54) =5.45, p=.007), Cue luminance and SOA (F (4,108) = 5.19, p=.001) and a significant three way interaction between target luminance, cue luminance and SOA (F (4,108) =4.41, p=.002). Further analyses were not performed on these results, because the effect of SOA as a warning signal is typically found in most of cue-target paradigm tasks, and the interactions did not include any effects of validity. The ANOVA also revealed a four way interaction between target luminance, cue luminance, validity and SOA (F (4,108) =3.07, p=.019). However, it was not further analyzed as there was no clear pattern of an interaction between validity and the other factors (refer to *Appendix*).

Discussion

The current study demonstrated the differential effects that levels of cue and target luminance have on visual orienting. The luminance levels of the cues did not have a direct influence on the orienting per se whereas the luminance level of the target had a big impact on the orienting effect. The results overall showed an orienting effect for low luminance targets but not for high luminance targets. A rapid orienting effect was observed at the SOA of 0ms. Generally, a faster response was observed when the luminance contrast of the cue or target was high than when it was low. Participants responded faster when SOA was longer.

The finding of a faster response time for higher luminance target stimuli, and a clearer orienting with low luminance target stimuli is consistent with Reynolds et al. (2000). The lack of an attentional effect with high contrast targets has been attributed to the likelihood of high contrast stimuli attracting attention independently of cue validity (Reynolds, et al., 2000).

The orienting effect was rapid as it was observed at the SOA of 0ms and the cues being letters did not hinder the orienting process. The asymmetry of the cue display (X and T on each side) may have helped elicit the rapid orienting as the asymmetry of a visual stimulus, a spatial feature, is processed faster than the meaning it conveys (e.g. X for left and T for right) (Lambert & Duddy, 2002). There was a warning effect, a quicker RT at a longer SOA, by the presentation of cue (FernandezDuque & Posner, 1997).

It was expected that cue luminance would have a big effect on orienting as participants were expected to consciously use the cues in order to efficiently orient towards the target. If this was the case, the processing of a low luminance cue, which takes a longer time than that of a high luminance cue, would have delayed the orienting. Contrary to the hypothesis, the low cue luminance did not impair the performance in the orienting task implying that the conscious encoding of the identity of the letter cues may not have been necessary in performing the Attention task. The processing of the low luminance cue was just as fast and efficient as that of the high luminance cue, and the rapid orienting with low luminance cues resembled the fast orienting effect by high luminance cues and high luminance targets in Lambert and Duddy (2002). The fast orienting observed shows that even a slight increase in luminance of visual stimuli was sufficient in affecting participants’ orienting behaviour (Lambert, et al., 1999; Theeuwes, 1995). The absence of an interaction between cue luminance level and cue validity further supports that a change in low cue luminance did not delay the utilization of cues in orienting, and this result is in contrast to the perception of targets which was directly influenced by the lowered target luminance. The current results imply that the processing of a cue in visual orienting may involve a mechanism that is different from conscious perception of a target. Experiment 2 employed lower luminance cue levels in order to further investigate the possibility that cue processing is qualitatively different from target processing in cued orienting.

Experiment 2

Introduction

The results of Experiment 1 confirmed that target luminance is crucial in visual orienting, showing that low luminance targets elicited a stronger orienting effect than high luminance targets. Lowering cue luminance, on the contrary, did not have a direct influence on orienting. The result was surprising, as we expected participants to consciously use the cues in orienting and lower cue luminance to delay orienting process.

The distinction between the processes of visual orienting and perception in the cortical areas is well documented in the literature. Ungeleider and Mishkin (1982) had proposed two separate visual pathways where spatial localization and object identification are processed respectively in the parietal area in the dorsal stream and temporal areas in the ventral stream. Monkeys with lesions in the infero-temporal cortex performed poorly in visual pattern discrimination and recognition tasks, compared to spatial landmark tasks in which the performance was not impaired (Ungeleider & Mishkin, 1982). Later Goodale and Milner (1992) made a distinction between two pathways where visually guided action is processed in one and object identification is processed in the other. The damage in the parietal area was shown to cause an inability to use information about the size, shape and orientation of an object for visually guided reaching and grasping, even though the ability to use the same information for the identification of the object was intact (Goodale & Milner, 1992; Foxe, McCourt, & Javitt, 2003; Fink et al., 2000).

The parietal cortex, much highlighted as a critical area in the dorsal stream (Ungeleider & Mishkin, 1982; Goodale & Milner, 1992), has been suggested to receive a majority of the inputs from the magnocellular (M) cells of the LGN (Sclar, Maunsell, & Lennie, 1990). The M cells have been shown to be sensitive to a luminance contrast change (Shapley & Perry, 1986). Cheng, Eysel and Vidyasagar (2004) demonstrated a greatly improved performance in a serial search task when only 2% of luminance contrast was added to the visual stimuli, compared to an isoluminant condition. Chapman, Hoag and Giaschi (2004) showed that a disturbance in the M cell processing by an administration of luminance flickers resulted in a disruption in motion perception in the dorsal stream. The dorsal pathway system involving the M cells is a good candidate for processing a rapid and clear orienting with low luminance cues in Experiment 1 as it has the characteristic of being rapid (more so than P cell processing as discussed in *General Introduction*, Bullier, 2001) and is luminance contrast sensitive, that is, it responds well to low contrast stimuli.

In Kveraga, Boshyan and Bar (2007), participants were presented with M cell biased stimuli which were low luminance contrast and achromatic, and P cell biased stimuli which were chromatically defined and isoluminant. The activation by the M cell biased stimuli was different from the activation by the P cell biased stimuli (Miki, Siegfried, Liu, Modestino, & Liu, 2008). It was shown that the M biased stimuli were processed faster and activated the orbito-frontal cortex (OFC) more than the P biased stimuli. Faster M cell projections are also suggested to facilitate object recognition by linking the early visual areas and orbitofrontal cortex (Bullier, 2001). The P biased stimuli were shown to activate the ventro-temporal regions for object recognition.

The current study attempted to investigate the effects of lowering cue luminance on visual orienting and perception systems by manipulating the luminance of cues. The number of cue luminance levels that randomly varied from trial to trial was reduced to two levels (one low and one high luminance level) to better examine and compare the effects of the different cue luminance levels in orienting task - an Attention task. Experiment 2 was divided into two sections. In Experiment 2-a, the luminance contrast of low luminance cues was 16% and in

Experiment 2-b, it was 10%. Only low target luminance was included in each section to elicit a clear orienting effect, as observed in Experiment 1.

Experiment 2 also included a Perception task, in addition to the Attention task, to see whether or not participants consciously detected and discriminated the cues in Experiment 1, and to assess whether or not cue utilization for orienting and perception are dissociable. The configuration of the Perception task resembled the Attention task except that participants were to indicate the location of one of the cues (either the X or the T) after the cue presentation. Error rate and reaction time were measured in the Perception task in Experiment 2.

Experiment 2-a

Methods

Participants Eighteen undergraduate students in the University of Auckland participated in the present experiment. All had normal or corrected-to-normal vision acuity.

Apparatus The experiment was conducted on a Generic PnP Monitor controlled by an Intel Core 2 Duo CPU. The screen resolution was 640×480. E-Prime 2.0 was used to write the software to control the presentation and timing of visual stimuli. A chin-rest was used to prevent any unnecessary head movements and to maintain the head at a distance of approximately 57 cm from the monitor.

Display and stimuli The display and stimuli were the same as Experiment 1 except for the following changes. The background luminance of the screen was 29.9cd/m^2. The size of the letter cues were 1.4° (height) × 1.2° (width). There were two cue luminance levels, one low (16%) and one high (71%). Target was a grey filled square subtending 0.5° and the luminance of the target was 16%. Weber contrast was used for the calculation of the contrast.

Procedure The procedure in the Attention task was the same as Experiment 1 except for the following changes. In the Attention task, there were sixteen practice trials followed by four blocks of 72 experimental trials. 16.7% of the latter were ‘catch trials’, in which letter cues were not followed by a target. Participants were presented with low cue luminance of 16% and high cue luminance of 71 % which randomly changed. In the Perception task, participants who oriented towards ‘X’ in the Attention task were required to indicate whether ‘X’ was on the left or right of the display, by pressing ‘z’ or ‘/’ respectively. Participants who oriented towards ‘T’ in the Attention task indicated whether ‘T’ was on the left or right. There were 8 practice trials followed by two blocks of 40 experimental trials in the Perception task. The inter-trial interval between each response and onset of the next letter pair varied randomly from 2600ms-3100ms.

Design Validity (valid/invalid) and three different SOAs (0ms, 150ms and 500ms) were varied randomly throughout the valid and invalid trials. The luminance levels of cue (low or high) were varied randomly from trial to trial.

Data analysis A 2 (Validity) × 2 (Cue luminance) × 3 (SOA) mixed design analyses of variance was performed on the data using Validity (valid and invalid), Cue luminance (low and high) and SOA (0ms, 150ms and 500ms) as the within-subjects variables.

Results

Attention task The average rates for anticipation and catch trial errors were 2% and 8% respectively. Mean response time results from the Attention task are summarized in Figure 5. There was a main effect of SOA (F (2, 34) =36.27, p<.001). Mean reaction time at the SOA of 0ms was significantly slower than that of 150ms and 500 ms (all p<.001). Mean reaction times at 150ms and 500ms did not differ (p=.342). There was a main effect of validity (F (1, 17) =10.15, p=.005) (Fig. 5.). Mean reaction time on invalid trials (M=492ms, S.E=15.52) was significantly slower than that on valid trials (M=471ms, S.E. =14.87). There was neither an interaction between SOA and Validity (p=.5) nor an interaction between Cue luminance and validity (p=.6). There was no main effect of cue luminance (p=.152).

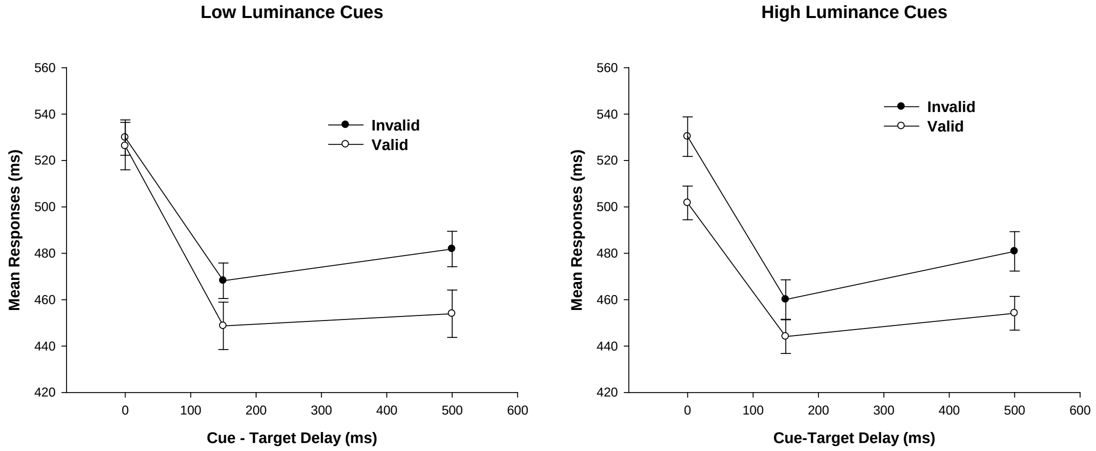


Figure 5. Effects of cue luminance contrast on response time in the Attention task (the error bars are the standard error of the means)

Further analysis on validity as a function of SOA In order to investigate validity effect, which was of most interest, a further analysis was performed on the interaction between validity and other variables as a function of SOA. A 2 (cue luminance) × 2 (validity) repeated ANOVA on each SOA revealed a marginal validity effect at the SOA of 0ms (F (1, 17) =4.42, p=.051). The mean reaction time was faster on valid trials (M=514ms, S.E. =16) than invalid trials (M=530ms, S.E. =16). The validity effect was also observed at the SOA of 150ms (F (1, 17) =7.38, p=.015), showing a faster response on valid trials (M=446ms, S.E. =15.7) than invalid trials (M=464ms, S.E. =18). The effect persisted till the SOA of 500ms (F (1, 17) =6.32, p=.022), with a faster response on valid trials (M=454ms, S.E. =15) than invalid trials (M=481ms, S.E. =16). There was no interaction between cue luminance and validity at any of the SOAs.

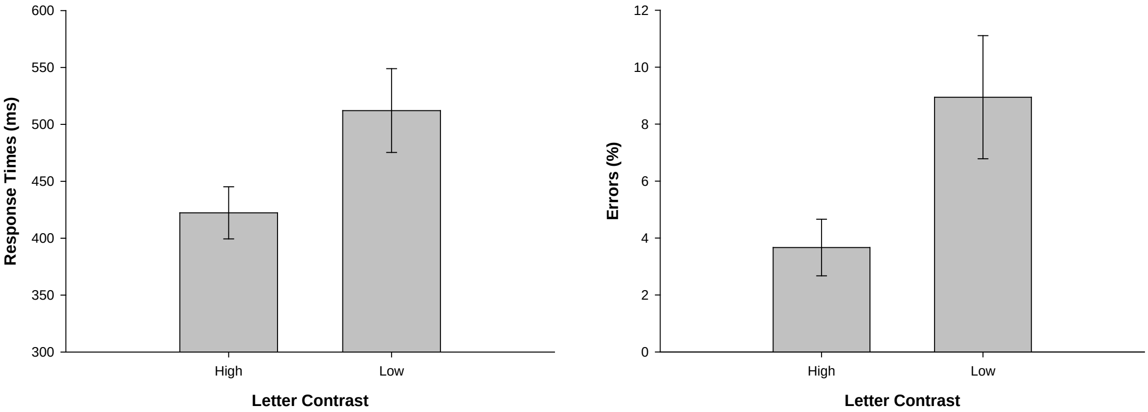


Figure 6. Effects of cue luminance contrast on response time in the Perception task (the error bars are the standard error of the means)

Perception task Mean response times and accuracy results in the Perception task are shown in Figure 6. Mean reaction time for high luminance cues (M=422ms, S.E.=22.89) was significantly faster than that for low luminance cues (M=512ms, S.E.=37) (F(1,17)=8.058, p=.011), and the error rate for high luminance cues (M=3.7%, S.E.=1) was significantly lower than low luminance cues (M=8.9%, S.E.=2.2)(F(1,17)=6.251, p=.023).

Experiment 2-b[2]

Methods

Participants Fifty-two undergraduate students in the University of Auckland participated in the present experiment. All had normal or corrected-to-normal vision acuity.

Display and stimuli The display and stimuli were the same as Experiment 2-a. There were two cue luminance levels, one low (10%) and one high (71%).

Procedure The procedure was the same as Experiment 2-a.

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[2] This experiment was published in Lambert and Shin (2010).

Results

Attention task The average rates for anticipation and catch trial errors were 2% and 6% respectively. Mean response time results from the Attention task are illustrated in Figure 7 and 8. There was a main effect of cue luminance (F (1, 51) =96.58, p<.001). High luminance cues (M=479ms, S.E. =7.71) elicited faster reaction times than low luminance cues (M=514ms, S.E. =9.33). There was an interaction between cue luminance and SOA (F (2,102) =10.77, p<.001). High luminance cues elicited a faster mean reaction time than low luminance cues at all SOAs (all p<.013). With both high and low luminance cues, a slower mean reaction time was observed at the SOA of 0ms than at the SOA of 150ms or 500ms (all p<.002). A faster mean reaction time was observed at the SOA of 150ms than that of 500ms (p=.001) only with high luminance cues.

There was a main effect of SOA (F (2,102) =49.13, p<.001). Mean reaction time at the SOA of 0ms was significantly slower than those of 150ms and 500ms (all p<.001). Mean reaction time at the SOA of 150ms and 500ms did not differ (p=.7). There was a main effect of validity (F (1, 51) =17.42, p<.001). Mean reaction time in valid trials (M=487ms, S.E. =7.94) was significantly faster than that in invalid trials (M=506ms, S.E. =9.37) (Fig. 7). There was also an interaction between SOA and validity (F (2,102) =5.97, p=.004). Valid trials elicited a faster mean reaction time than invalid trials at the SOA of 150ms and 500ms (all p<.002).

Further analysis on cue, validity as a function of SOA In order to investigate validity effect, which was of most interest, a further analysis was performed on the interaction between validity and other variables as a function of SOA**.** A 2 (cue luminance) × 2 (validity) repeated ANOVA on each SOA (Fig. 7 and 8) revealed a validity effect at the SOA of 150ms (F (1, 51) =13.75, p<.001). The mean reaction time was faster in valid trials (M=467ms, S.E. =8) than invalid trials (M=489ms, S.E. =11). At the SOA of 500ms, a validity effect (F (1, 51) =15.54, p<.001) and also an interaction between validity and cue luminance (F (1, 51) =5.06, p=.029) were observed at the SOA of 500ms, showing that the cueing effect was larger with high contrast cue (46ms) than with low contrast cue (19ms) (Fig. 7 and 8). However, there was no interaction between cue luminance and validity (p=.11) in the omnibus analysis.

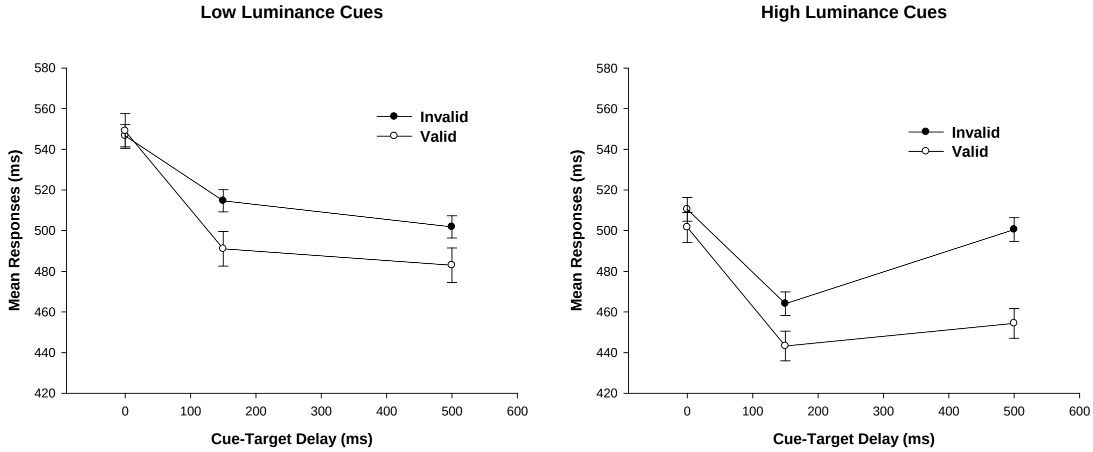


Figure 7. Effects of cue luminance contrast on response time in the Attention Task (the error bars are the standard error of the means)

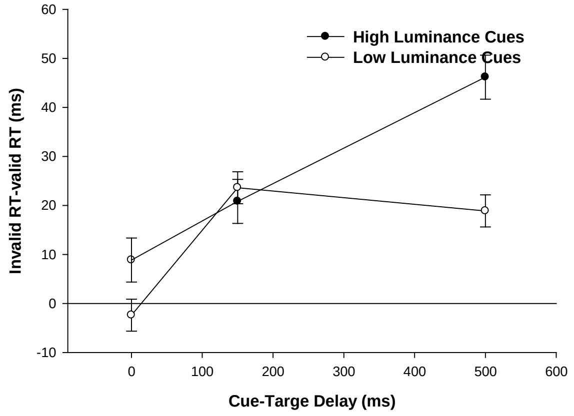


Figure 8. Effects of luminance contrast on visual orienting in the Attention Task. As indicated on the y-axis, the visual orienting effect is indexed by the response time difference between valid and invalid trials(the error bars are the standard error of the means).

Perception task Mean response time and error rate results from the Perception task are shown in Figure 9. Mean reaction time for high luminance cues (M=455ms, S.E.=15.5) was significantly faster than that for low luminance cues (M=733ms, S.E.=37) (F(1,51)=82.44, p<.001), and the error rate for high luminance cues (M=4.3%, S.E.=1.9) was significantly lower than low luminance cues (M=11.2%, S.E.=2.15) (F(1,51)=32.67, p<.001).

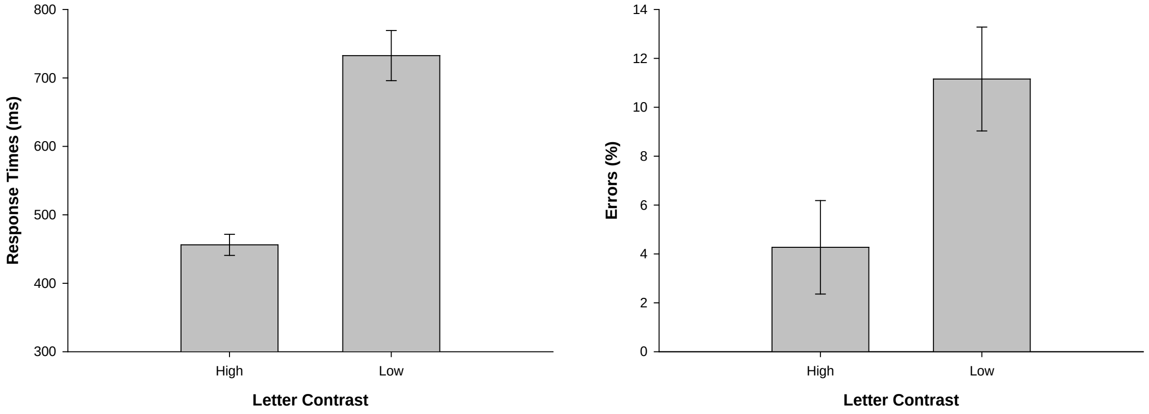


Figure 9. Effects of luminance contrast on performance in the Perception Task (the error bars are the standard error of the means)

Discussion

A clear dissociation was shown in the performance between the Attention and Perception tasks in Experiment 2. In both Experiment 2-(a) and 2-(b), a cueing effect was observed with both low and high luminance cues, and the magnitude of the effect was relatively unaffected by the different cue levels. In Experiment 2-(a), an orienting effect started to emerge at an early SOA of 0 ms, and the effect was observed at the SOA of 150ms in Experiment 2-(b). The performance in the Perception task, however, was greatly influenced by the decrease of cue luminance in both Experiment 2-(a) and 2-(b). Lower luminance cues elicited slower reaction times and a higher error rate, compared to high luminance cues, in the Perception task.

The orienting with low contrast cues was as rapid as that with high cue luminance in its speed, and as big as that with high cue luminance in magnitude. The result may suggest that the orienting was processed in the luminance-sensitive M cells in the LGN where low luminance information can be processed as efficiently as high luminance information (Shapley & Perry, 1986). The performance in the Perception task, on the other hand, was affected by lowering cue luminance. Lowering the cue luminance impaired the discrimination or identification of the cue letters, and the result in the Perception task seems to reflect the involvement of the P cell processing. The luminance sensitive M cells are suggested to process the visual features of visual stimuli rapidly but somewhat crudely, mostly by luminance increment (Shapley & Perry, 1986), as its processing needs to be rapid enough to enable an efficient reaction towards any upcoming stimuli (Bullier, 2001). In the present Attention task, therefore, the encoding of the visual features that distinguish the letter cue X from T may have been sufficient in eliciting an orienting. Vidyasagar (1999) proposed that the fast spatial processing of visual stimuli in the M pathway in the dorsal stream enables higher cortical areas to send a quick feedback so that the information, preattentively processed, receives a spotlight to be processed in the ventral stream (Laycock, et al., 2007). Studies have shown that higher cortical areas such as V5 receive the signals from the LGN and SC even before V1 (Buchner et al., 1997), enabling a rapid feedback onto V1 and V2, showing that top-down processing is fast enough to affect early cortical areas (Bullier, 2001).

The idea of the M and P cell involvement in orienting and perception is also in conformity with ‘separate visual systems for action and perception’ (Milner & Goodale, 2008; Goodale & Milner, 2006). Together with the M cells’ critical input to the parietal cortex for motion perception (Chapman, et al., 2004), the findings of the M cell involvement in visual orienting emphasizes the importance of the M cells in the dorsal stream. The result in the current study provides direct behavioural evidence that supports neurological studies which showed a close connection between the M cells and the parietal areas, and P cells and temporal areas, along the dorsal and ventral pathways respectively (Sclar, et al., 1990; Maunsell, Nealey, & Depriest, 1990).

Although there was a clear dissociation in cue processing between the Attention and Perception tasks in both Experiment 2 (a) and (b), an orienting effect appeared a little later in 2 (b) at the SOA of 150ms, in comparison with 2 (a) where it started to emerge at the SOA of 0ms. It is possible that the lowering of cue luminance was slowly taking its toll in orienting performance in Experiment 2 (b). Experiment 3 involved cue luminance that is even lower than that in Experiment 2 (b) to see if further lowering of the cue level brings any further deterioration in the performance to the Attention task.

Experiment 3

Introduction

Experiment 3 further investigated this orienting effect with low luminance cues observed in Experiment 2. Even though the luminance of the lowest luminance cue in Experiment 2 was fairly low, the cues were quite discriminable (the error rate in the Perception task was 11.2%). Lowering cue luminance from 16% to 10% in Experiment 2 (a) and (b) seemed to cause a delay in the emergence of orienting effect, from 0ms to 150ms. Experiment 3 employed a cue of even lower luminance (5.9%) in order to see if the lowered luminance of cue would affect the orienting. If further lowering cue luminance reduces the orienting effect as hypothesized in Experiment 2 (b), even lower luminance cues in Experiment 3 would elicit a weaker orienting effect or it may not elicit an effect at all. Experiment 3 involved only low luminance targets in order to better elicit orienting effects.

Methods

Participants Forty undergraduate students in the University of Auckland participated in the present experiment. All had normal or corrected-to-normal vision acuity.

Apparatus Same as in Experiment 1.

Display and stimuli Same as in Experiment 1 except that the luminance contrast of cue stimuli were 5.9%, 14.2%, and 40%, and target luminance contrast, 14.2%. Weber contrast was used for the calculation of the stimuli contrast.

Procedure Same as in Experiment 1 in the Attention task. In the Perception task, participants were asked to press '←' if the letter x was on the left side, and '→' if x was on the right side of the fixation.

Design Validity (valid/invalid), the luminance levels of cue (low, medium and high), three different SOAs (0ms, 150ms and 500ms) and target visual field (left and right) were varied randomly throughout valid and invalid trials.

Data analysis A 2×3×3×2 repeated design analyses of variance was performed on the data using Validity (valid and invalid), Cue luminance level (low, medium and high), SOA (0ms, 150ms and 500ms) and Target visual field (left and right) as the within-subjects variables.

Results

The results from three out of forty participants were discarded due to the excess of anticipation and catch trial errors. The average catch and anticipation errors were 2.7% and 1% respectively for the remaining 37 participants. Mean reaction time was recorded for the Attention task and the mean error rate was recorded for the Perception task.

Attention task Mean reaction time results from the Attention task are shown in Figure 10. There was a main effect of SOA (F (2, 72) =50.8, p<.001). Mean RT at the SOA of 0ms (M=433ms, S.E. =7.36) was slower than that of 150ms (M=400ms, S.E. =6.5) or 500ms (M=406ms, S.E. =7.47) (all p<.001). Mean RT between 150ms and 500ms did not differ (p=.42). There was a main effect of Cue luminance (F (2, 72) =31.63, p<.001). Mean RT for low luminance cue (M=427ms, S.E. =7.14) was slower than that for medium luminance cue (M=406ms, S.E. =7.12) or high luminance cue (M=406ms, S.E. =6.89) (all p<.001). Mean RT between medium and high luminance cues did not differ (p=.1). There was also a significant interaction between Cue luminance and SOA (F (4,144) =5.23, p=.001). The reaction times for medium and high luminance cues were significantly faster than that for low luminance cues at the SOA of 150 and 500ms (all p<.004).

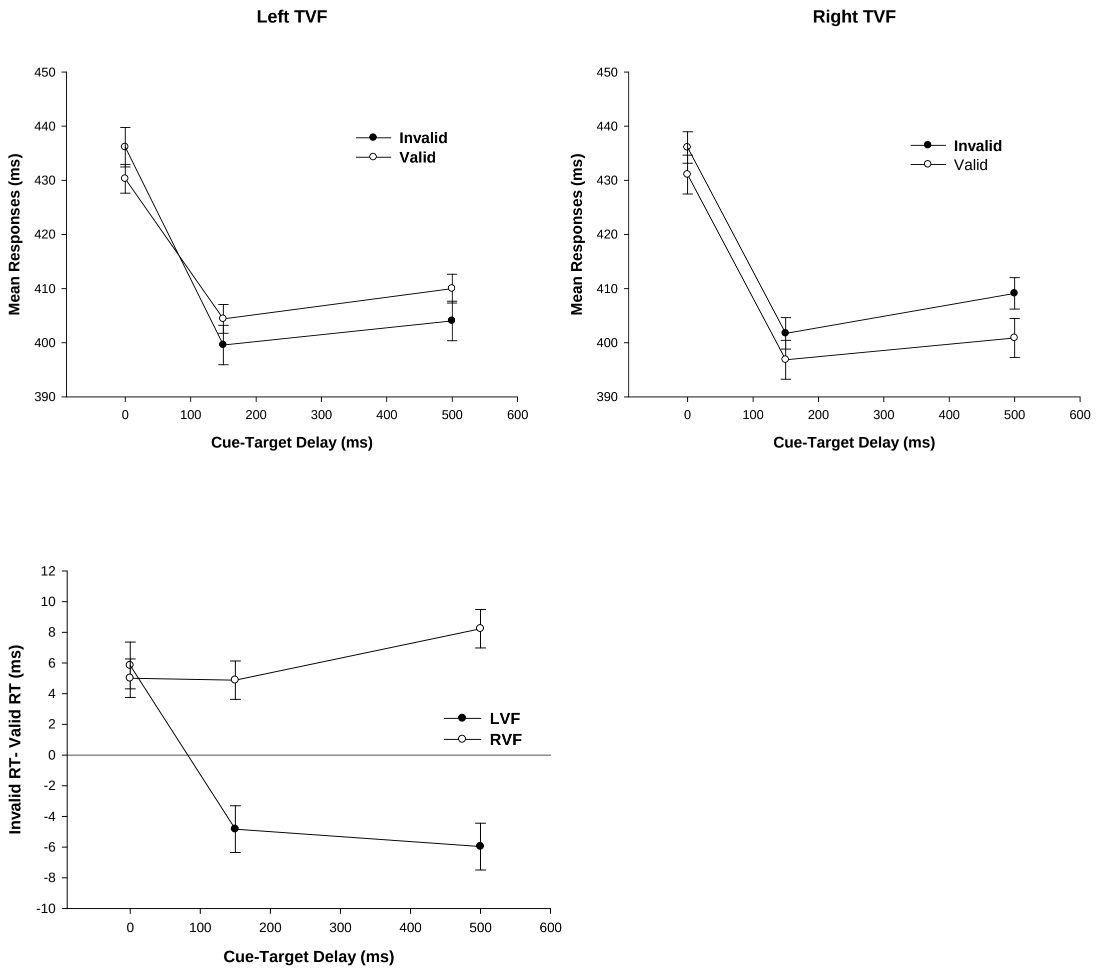


Figure 10. The difference in reaction time between invalid and valid trials for target visual field at the SOA of 0, 150 and 500ms (the error bars are the standard error of the means)

There was no main effect of validity or target visual field (all p>.1). As a post hoc analysis target visual field was added as a factor in the analysis to see whether there is a hemispheric benefit in orienting processing on either side of the visual field. There was an interaction between validity and target visual field (F (1, 36) =5.2, p=.029) (Fig.10.). Mean RT in valid trials (M= 410ms, S.E. =6.82) was faster than in invalid trials (M=416ms, S.E. =7.53) in the right visual field (p=.006). Mean RTs between valid and invalid trials at the left visual field did not differ (p=.53). A 2 (validity) × 3 (cue luminance) × 2 (target visual field) repeated ANOVA revealed no orienting effect at the SOA of 0ms (p=.17) and 150ms (p=1). But at the SOA of 500ms, there was an interaction between validity and target visual field (F (1, 36)

=6.98, p=.012) of which effect was 8ms in the right visual field compared to no effect in the left visual field.

Perception task Mean error rates for low and medium luminance cues are shown in Figure 11. The mean error rates for high luminance cues (40% luminance contrast) were excluded in the analysis because the error rates were expected to be less than that of 16% luminance cue (the error rate was 9%) in Experiment 2 (a). The error rate for the lowest luminance cue in the left visual field (M=27.9%, S.E.=3.8) did not significantly differ from those in the right visual field (M=23%, S.E.=2.6) (F(1,36)=1.54, p=.222), nor did the error rate for the medium luminance cue differ between the left visual field (M=4.4%, S.E.=1.2) and right visual field (M=4.5%, S.E.=1.7) (F(1,36)=.001, p=.981).

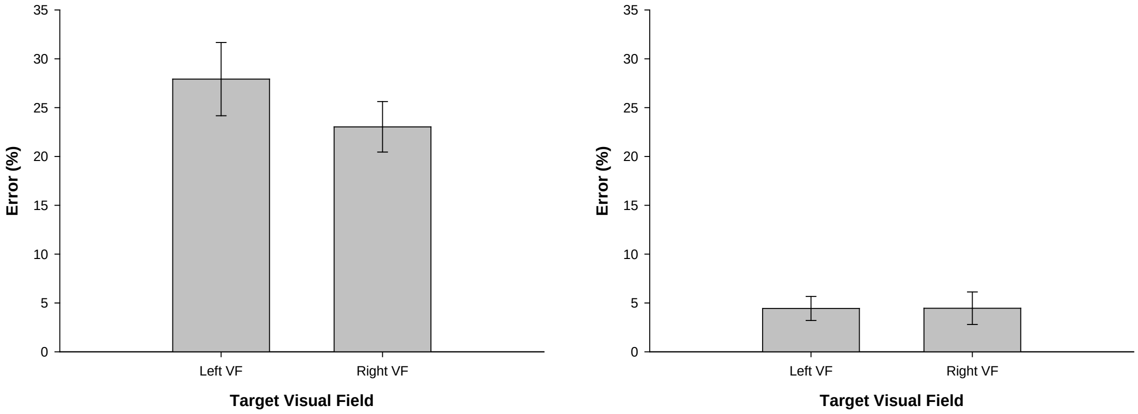


Figure 11. Effects of luminance contrast on performance for low (left panel) and medium (right panel) cues in the Perception task (the error bars are the standard error of the means).

Discussion

In contrast to the cue luminance contrast in Experiment 1 and 2, the cue contrast was lower in Experiment 3. Further lowering the cue luminance impaired the orienting performance in the left visual field (LVF) in the Attention task. A clear orienting was observed on the right visual field at the SOA of 500ms. The error rates on both left and right visual fields in the Perception task were greatly affected by lowering cue luminance. The error rates in the Perception task did not differ between the two visual fields. Other results were overall consistent with Experiment 1 and 2.

The impaired performance in the LVF with low cue luminance in the current experiment seems to suggest that, even though orienting is possible without a clear perception of cues, the performance eventually deteriorates with a very low luminance contrast (The error rate in the Perception task was 27.9%). The orienting effect was absent in the left visual field and the effect in the right visual field was observed at a later SOA of 500ms, which is much slower than 0ms in Experiment 1 and 2(a), and 150ms in Experiment 2 (b).

The right visual field benefit could be due to the fact that the left visual field is more vulnerable to impairment. Only the right hemisphere of the brain was shown to manage the attention in the left visual field opposed to the right visual field which receives attentional inputs from both left and right hemispheres (Mesulam, 1999; Corbetta, et al., 2002; Corbetta, et al., 2005). The hemispheric effect was observed only in the Attention task and not in Perception task, which supports the asymmetry in the visual attentional system.

The observed right visual field (RVF) benefit in the Attention task is consistent with Marzouki, Grainger and Theeuwes (2007). The study involved uninformative peripheral flash cues (left or right of fixation) which preceded peripherally presented letter priming (either letter or pseudo-letter on the left or right side of fixation). Letter W was always presented on the opposite side of a prime letter. After the prime letter, a target letter appeared. Participants were to indicate whether or not the centrally presented target letter was a letter or pseudo-letter. A strong repetition priming effect, a benefit in reaction time for related letter prime and letter target, was shown when the prime was preceded by a valid peripheral cue. Interestingly this priming effect with a valid peripheral cue was only significant in the RVF. The researchers explained the RVF benefit in terms of a bias towards the RVF for linguistic stimuli (Simola, Holmqvist, & Lindgren, 2009). The orienting effect in the RVF, in the current study, thus, may reflect the advantage the letter cues have in the visual field. The right visual field is also associated with fast parallel word recognition by the left ventral occipito-temporal pathway (Cohen, Dehaene, Vinckier, Jobert, & Montavont, 2008).

General discussion

The three experiments in the current chapter examined the effect of the luminance level of cues and targets on visual orienting. Experiment 1 included three cue luminance levels and two target luminance levels. The results showed that orienting was greatly affected by the target luminance contrast, and the effect was clearer for low contrast than high contrast targets. Lowering the luminance contrast of cues did not impair performance in the Attention task. Experiment 2 examined a distinction between the cue processing in orienting and perception. A fast orienting performance observed by lowered cue luminance in the Attention task was in stark contrast to the performance that was greatly affected by the lowered cue luminance in the Perception task. It was suggested that these two different kinds of processing involve different neurological mechanisms. Experiment 3 employed an even lower luminance contrast (in comparison with cue luminance levels in Experiment 1 and 2) in cue luminance levels. Lowering cue luminance did impair the orienting performance in the LVF with spared performance in the RVF. The performance in both hemispheres in the

Perception task was affected by the lowered cue luminance which was consistent with Experiment 2.

Although the orienting observed was relatively resilient to lowering the luminance of the cues, it did start to deteriorate as the luminance of the cues reached just above threshold. Orienting effect was elicited systematically at later SOAs as the lowest luminance of the cues was further lowered, in that an orienting was observed at the SOA of 0ms with the luminance cue of 14 % (Experiment 1), 150ms with the luminance cue of 16% and 10%, respectively (Experiment 2-a and b), and 500ms with the luminance cue of 5.9% (only in the right visual field, Experiment 3). The delayed orienting in Experiment 2 and 3, compared to Experiment 1, suggests that lowering cue luminance does have an effect in processing the cues in orienting when the luminance contrast is just above threshold.

The goal of participants in the Attention task was to consciously detect a target and respond to it. Hence, the luminance contrast of the target had a direct influence on reaction times and a lower luminance target elicited a slower reaction time. The slow perception of a low luminance target benefited by being cued which facilitated responding to low luminance targets (Reynolds & Chelazzi, 2004), leading to an orienting effect. Participants, however, did not consciously need to discriminate or detect the cues since they were to respond to the target only. This may explain why the cue luminance was not closely tied to the orienting effect compared to the target luminance (Experiment 1, 2). Nevertheless, the participants needed to process the cues to some extent in order to exhibit the orienting effects. The fact that low luminance cues were as efficient as high luminance cues in eliciting an orienting effect (Experiment 2 and 3) suggests that a clear discrimination of the cues was not necessary in cue processing, hence the processing is somewhat exogenous, unconscious and implicit. The orienting observed is not purely exogenous either as the cues were letters and informative. Experiment 2 and 3 showed that the mechanism involved in cue processing in the Attention task was shown to be different from the cue processing in the Perception task. In the Attention task, the cue was used as an orienting trigger for target perception, a secondary stimulus in the task; while, in the Perception task, the cue itself was the primary stimulus of the task. Depending on the role of the cue, the same visual stimulus seemed to be processed via different mechanisms, along the dorsal stream in the Attention task, and along the ventral stream in the Perception task.

Chapter 3

Experiment 4

Introduction

Experiment 3 demonstrated that lowering the luminance of cues had differential effects on the Attention and Perception tasks. Although the cueing effect for the stimulus in the left visual field was eliminated by lowering the cue luminance to near threshold, the cueing effect persisted on the right visual field. In contrast, perception performance was greatly affected by the lowering of cue luminance regardless of where the target was presented. It was suggested that the orienting was elicited via rapid processing in the luminance-sensitive M pathway, followed by target perception processing along the P pathway. The faster M cell processing along the dorsal stream to the parietal cortex enables a rapid endogenous intervention from the higher brain areas to the lower brain areas (Bullier, 2001). The top down processing was suggested to interact with bottom up processing and to facilitate object identification in the P cell pathway. The rapid processing of visual stimuli along the dorsal stream maps out spatial location, which is followed up by the processing of fine details of the stimuli in the P pathway along the ventral stream. The current study further examined the involvement of the M pathway in the processing of cues.

One of the behavioural methods in studying the M and P pathways involves over-stimulating the visual pathways in order to exhaust the attentional resource in the pathway. A prolonged exposure to a battery of luminance flickers with either a portion of a computer screen (Brigell, Strafella, Parmeggiani, Demarco, & Celesia, 1996), or the entire computer screen (Chapman, et al., 2004) at 10Hz, for approximately 2 minutes, has been shown to exclusively attenuate the processing in the M pathway as the M pathway is the most sensitive to the flicker stimuli at 10Hz.

Flicker procedures have also been much used in motion perception studies to examine the connection between the M cells and MT. Lesions in the M cells, in rhesus monkeys, produced a dramatic reduction in responses to flicker and moving dots whereas P cell lesions showed no deficit (Schiller, Logothetis, & Charles, 1990). In normal humans, an exposure to flickers of 10 Hz was shown to increase the threshold of the perception of moving signal dots among random moving dots (Chapman, et al., 2004). In the study, participants were to adapt to a battery of sinusoidal flickers with a frequency of 9.37 Hz for 2 min. After the flickers, there was a beep after which the participants were presented with a set of white moving dots and they were to indicate the direction in which most of the dots were moving. The results showed that the flicker adaptation elevated the coherence thresholds (i.e. the flickers impaired the ability to detect coherent motion) for the moving dots at the speed of 0.934deg/s by 37% and the coherence threshold for the moving dots at the speed of 8.0deg/s by 43%, confirming that the disturbance in the M cells by flicker adaptation causes impairment in motion processing in MT.

The current experiment examined if a disturbance in the M pathway by a flicker procedure impairs orienting performance as in the case of motion processing in Chapman et al (2004). If visual orienting is processed in the M pathway as previously suggested in Chapter 2, a disturbance in the M pathway should lead to impairment in orienting performance, as in motion perception studies (Chapman, et al., 2004). The finding would suggest a strong connection between visual orienting and motion processing, and the cortical visual pathway from the M pathway to MT as the main visual pathway for visually guided motor system (Goodale & Milner, 1992). The flicker adaptation procedure in Chapman et al. (2004) was incorporated in the cue-target paradigm in Chapter 2.

Methods

Participants Twenty four undergraduate students in the University of Auckland aged 18-30 years were recruited in the experiment. All had normal or corrected-to-normal vision acuity.

Apparatus Same as Experiment 2.

Display and stimuli Same as in Experiment 2 except for the following changes. Only the high cue luminance, 71%, was used in the experiment, so, a cue with a luminance contrast of 71% preceded a target with a luminance contrast of 16%. There was also a flicker adaptation procedure where a battery of full screen sinusoidal flickers similar to the flicker adaptation procedure used in Chapman, et al. (2004) was employed. The flicker modulated between 1.24 and 95.48cd/m^2 with a frequency of approximately 10 Hz. Due to participants' discomfort in being exposed to flashing lights, the durations of flicker adaptation and re-adaptation procedure were adjusted so that they were shorter than those of Chapman et al. (2004). The flicker adaptation initially lasted for 1.1 min at the start of a task, and reappeared for 1.5s at the start of each trial for re-adaptation.

Procedure The procedures in the Attention and Perception tasks were similar to Experiment 2 so as to elicit a consistent orienting effect observed in Experiment 2. There were two blocks of trials for each flicker and non flicker condition, for both Attention and Perception tasks. Flicker adaptation occurred at the start of the flicker blocks. The order of flicker and non flicker blocks was counterbalanced. Participants were instructed to focus on the middle of the screen during the flicker adaptation and re-adaptation phase. In the Attention task, there were 20 trials with targets and 6 catch trials in a block. As in Experiment 1 and 2, they were instructed to use the cue letter 'X' or 'T' for target perception. In the Perception task, there were 20 trials with targets in a block without any catch trials. As in

Experiment 2, participants were asked to press ‘z’ or ‘/’ depending on where the cue letter X or T appeared. The number of trials in a block was lower than the experiments in Chapter 2 as the duration of each trial in the experiment (re-adaptation + orienting/perception task) was longer than those in the previous chapter.

Design. Validity (valid/invalid) and two different SOAs (150ms, 500ms) were varied randomly throughout the valid and invalid trials.

Data analysis. Mean response times were analyzed with a 2 (Flicker: flicker vs. no flicker) × 2 (Validity: valid vs. invalid) × 2 (SOA: 150, 500ms) within groups ANOVA with Flicker, Validity and SOA as the within-subjects independent variables.

Results

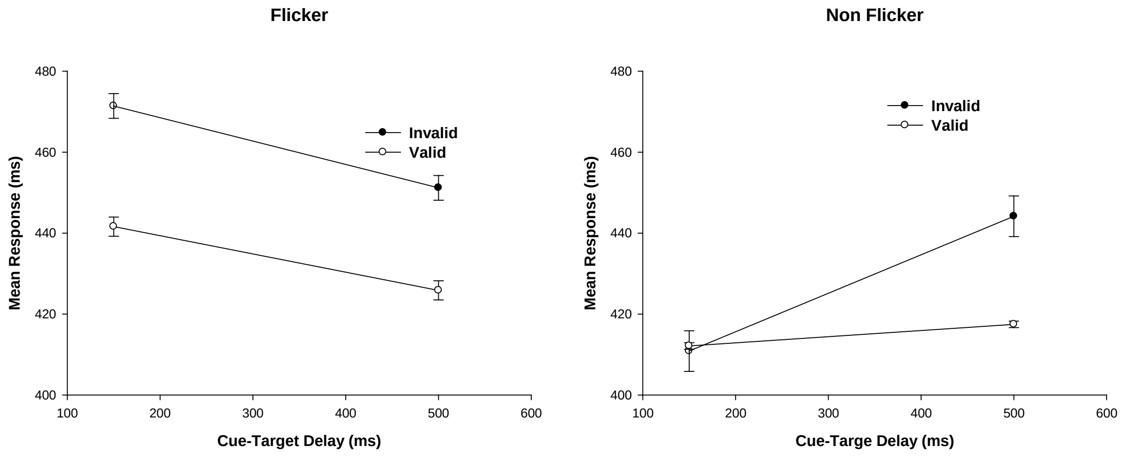
Attention Task The average rates of catch trial errors and anticipation errors were 1.5% and 0.5 % respectively. Mean response time results are illustrated in Figure 12. There was a main effect of flicker (F (1, 23) =11.44, p=.003). Mean response time was quicker in the non flicker condition (M=416ms, S.E. =11.5) than flicker condition (M=441ms, S.E. =15). There was an interaction between flicker and SOA (F (1, 23) =6.03, p=.022). Mean response was quicker in the non flicker condition than the flicker condition at the SOA of 150ms (p<.001). Participants responded faster at the SOA of 150ms than 500ms in the non flicker condition (p=.026). There was no main effect of SOA (p=1) in the omnibus analysis.

There was a main effect of validity (F (1, 23) =11.31, p=.003). The mean response time was quicker on valid trials (M=419ms, S.E. =13.12) than on invalid trials (M=438ms, S.E. =13.38). There was no interaction between validity and flicker (p=.29).

Further analysis on validity as a function of SOA The validity effect observed in the omnibus analysis was further analyzed to assess the effect at each SOA. At the SOA of

150ms, a validity effect was observed (F (1, 23) =4.29, p=.05) where a faster response was observed in valid trials (M=422ms, S.E. =13) than invalid trials (M=435ms, S.E. =15). There was also a significant validity and flicker interaction (F (1, 23) =5.53, p=.028) at the SOA of 150ms. Flicker condition elicited a faster response on valid trials (M=436, S.E. =16) than invalid trials (M=464ms, S.E. =20) (p=.019), whereas in the non-flicker condition the responses in valid and invalid trials did not differ (p=.88). At the SOA of 500ms, a validity effect was observed (F (1, 23) =7.24, p=.013) in which a faster response was shown in valid trials (M=416, S.E. =14) than invalid trials (M=442ms, S.E. =14). There was no interaction between validity and flicker at the SOA of 500ms (p= .79).

Further analysis on validity as a function of condition There was a validity effect (F (1, 23) =10.14, p=.004) in flicker condition in which a faster response was observed in valid trials (M=429, S.E. =15) than invalid trials (M=454ms, S.E. =16) (Fig. 12.). In non flicker condition, an interaction between validity and SOA was observed (F (1, 23) =4.27, p=.05). At the SOA of 150ms, the responses for valid and invalid trials did not differ. At the SOA of 500ms, however, a faster reaction time was observed on valid trials (M=411, S.E. =13) than invalid trials (M=439, S.E. =16) (p=.053). No other effect was significant.



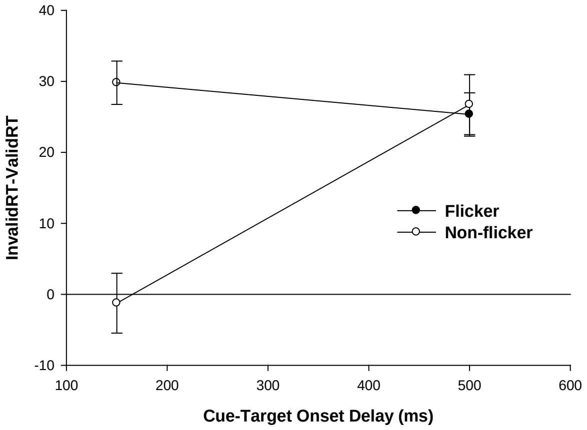


Figure 12. The difference between reaction times between valid and invalid trials in flicker and non-flicker blocks at the SOA of 150 and 500ms (the error bars are the standard error of the means)

Perception task Mean response times and error rates in the flicker and non-flicker condition are shown in Figure 13. Participants responded faster in the non-flicker (M=307ms, S.E. =10) than the flicker blocks (M=332ms, S.E. =15) (F (1, 23) =8.37, p=.008). The mean error rate for the flicker blocks (M=98%, S.E. =0.01) was lower than that for the non-flicker blocks (M=87%, S.E. =.03) (F (1, 23) =18.64, p<.001).

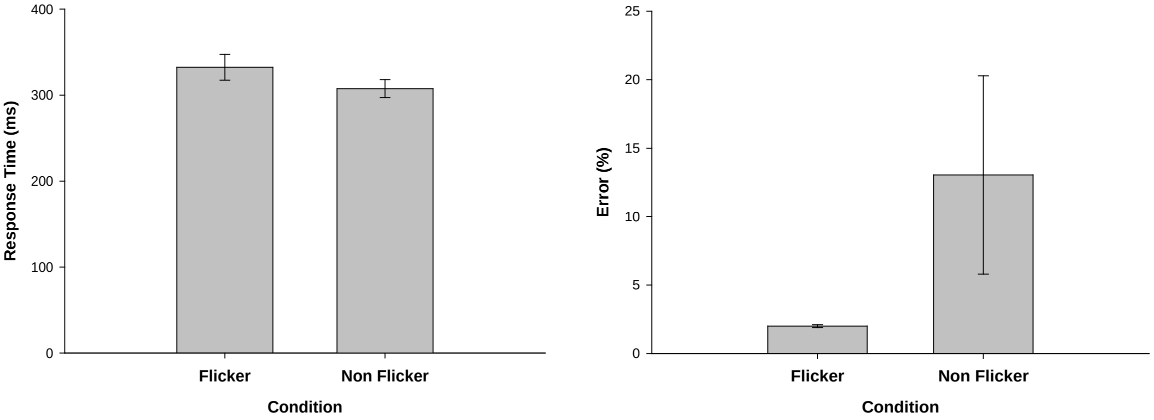


Figure 13. Effects of flicker on performance in the Perception Task (the error bars are the standard error of the means)

Discussion

The results of the current experiment were the exact opposite of the result expected. It was expected that the non-flicker condition would elicit a clear orienting effect and the effect was expected to attenuate in the flicker condition in the Attention task. The result showed an orienting effect in both flicker and non flicker conditions, and interestingly, the effect appeared earlier in the flicker condition at the SOA of 150ms. In the non flicker condition, the orienting effect was reliable only at a later SOA of 500ms. Mean response accuracy was also a little higher in the flicker condition than in the non flicker condition in the Perception task. In contrast, performances in both the Attention and Perception tasks showed that participants responded faster to targets in the non flicker condition than in the flicker condition.

The finding of a faster orienting effect in the flicker condition compared to the non-flicker condition was surprising. The current result of a cueing effect at an earlier SOA in the flicker opposed to the non flicker condition showed that having a battery of flickers before a cue did not attenuate but enhanced the cueing effect. The result seems to indicate that luminance flickers might actually have increased participants' alertness in the task. Participants were exposed to flickers for a longer duration of time in Chapman et al. (2004) (2 mins) than in the current study (1.1 mins), and it is possible that this shorter duration of exposure to the flickers sensitized rather than desensitized the cells in the LGN, which may explain the higher accuracy observed in the flicker condition. However, it is still puzzling why participants' responses were faster in the non flicker condition in comparison with the flicker condition if the flickers made the participants more alert.

Chapman, et al. (2004) has shown deterioration of motion perception after a flicker adaptation. If attention is initially processed in the M cells and most of M cell inputs are fed into MT for motion perception, a disturbance in the M cells should attenuate performances in both attention and motion perception. The difference in the results, in the two different studies, could be attributed to the difference in the intervals between the flicker presentation and the actual trial in the Attention and Perception tasks. In Chapman et al., participants were presented with a motion perception task immediately after the flicker presentation, as fixating participants' attention in the centre of the screen was not crucial for the motion perception. In the current study, however, there was an interval of approximately 2.1s for the fixation between the flicker and the Attention task to ensure that the focus of participants stayed in the centre, which is an essential procedure in covert orienting studies. However, this interval between the flicker adaptation and the Attention task may have given enough time for the participants to recover from the flicker, with somewhat more alertness, hence the contrasting results between Chapman et al. and the current study. A future study may include a fixation on which participants should focus during the flicker adaptation phase so that there is no need of an interval between the flicker adaption phase and the actual Attention task.

However, the difference between the results of the current study and Chapman et al. could also be more fundamental, in that there may be a difference between the effects of flickers on orienting and on motion perception. The results could imply that different mechanisms are involved in orienting and motion perception, and that orienting is resilient to the flicker administered in the M pathway and that motion perception is more easily disrupted by luminance flickers. It is possible that the orienting system recruits more than just the M cells in its processing. Moreover, this disruption in motion processing may be due to the flickers disrupting the processing in the areas other than the M pathway alone (Skottun & Skoyles, 2006). Studies have argued that the M cells do not directly process speed and direction of visual stimuli, that are critical elements of motion (Skottun, 2011). It is important to note that it is V1 where directional sensitivity first appears (Livingstone & Hubel, 1988). The inputs from the M cells to the motion area MT go via V1 in which the inputs from multiple areas such as the P, K cells and the inferior pulvinar are mixed, hence the input from the M cells to MT is not direct and could be influenced by the inputs from other areas such as the P (Maunsell, et al., 1990) and K cells (Sincich, Park, Wohlgemuth, & Horton, 2004). Furthermore, it was suggested that K cells bypass V1 going directly to MT, further weakening the integrity between the M cells and MT (Girard, Salin, & Bullier, 1992).

The current result showed that the flicker procedure has different effects on orienting and cue perception. In contrast to the enhancement in performance in orienting (i.e. a faster orienting) the flickers elicited impairment in cue perception (i.e. slower responses). The finding may suggest that an over-stimulation of the M cells influenced cue perception processing in the P pathway via the interconnection between the M and P cells through V1 and the parietal cortex (Bullier, 2001).

Chapter 4[3]

Introduction

The current chapter has developed further on the work of Lambert and Duddy (2002) and Lambert, et al. (2006) which provide evidence against a cue eccentricity based distinction between two processes of orienting. Both studies have suggested that spatial correspondence learning between the spatial features (e.g. asymmetry) of cues and the position of targets is an important factor that drives visual orienting, showing a bigger cueing effect for asymmetrical cues than symmetrical cues (refer to *spatial correspondence* in Chapter 1).

The present study attempted to investigate an interesting discrepancy observed in these studies, Lambert and Duddy (2002) and Lambert et al. (2006). Lambert and Duddy (2002) demonstrated a clear orienting effect at the SOA of 150ms by symmetrical bilateral letter cues, regardless of whether the letters were presented centrally (the cueing effect of 10ms) or peripherally (the cueing effect of 23ms). Although the effect was generally smaller than the effects elicited by centrally and peripherally presented asymmetrical bilateral letter cues (34.5ms for central cues, 30.3ms for peripheral cues, averaged across all SOA), it was statistically reliable. However, Lambert et al. (2006) showed a somewhat contradictory result that exhibited no evidence of a cueing effect with centrally presented symmetrical single letter cues, x or o. If cue symmetry was the *only* factor that directed the course of the visual orienting observed, no orienting effect should have been found for the centrally presented symmetric bilateral letter cues in Lambert and Duddy (2002). The discrepancy observed between the two studies, Lambert and Duddy (2002) and Lambert et al. (2006), was examined in Experiment 5, in an attempt to replicate the findings and further explore the effects of cue asymmetry (symmetric or asymmetric) and cue numerosity (single or double) in visual orienting.

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[3] The findings of this chapter was published in Shin et al. (2011)

The results of Experiment 5 replicated the findings of Lambert and Duddy (2002) in that an orienting effect was observed with bilateral letter cues both when centrally and peripherally presented, and the findings of Lambert et al. (2006) in that no orienting was observed with centrally presented single symmetric letter cues. Experiment 6 followed up the results of Experiment 5 and investigated other properties, apart from cue asymmetry, such as the size of cue, to see if the visual system favours a bigger visual presentation of centrally presented bilateral letter cues over a smaller presentation of centrally presented single letter cues. The results showed that although the spatial correspondence between cue and target was crucial, the mere size of cue was not.

Experiment 5

The aim of the present study was to undertake a direct comparison between the attention effects of symmetric central single cues (Lambert, et al., 2006) and centrally presented symmetric bilateral double cues (Lambert & Duddy, 2002).

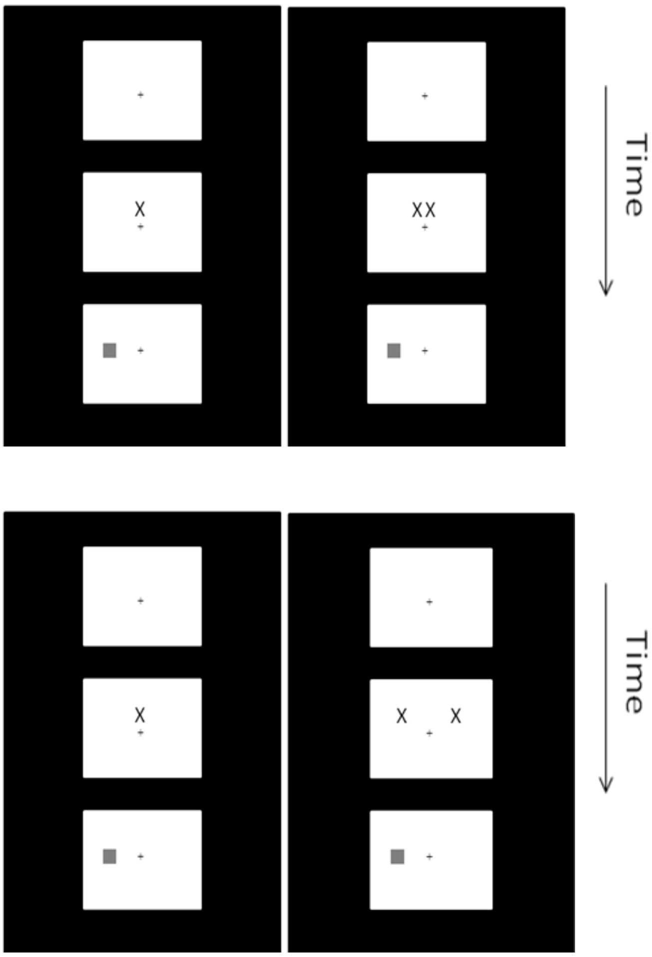

Figure 14. An example of single central and bilateral central cues (top) in central condition and single central and bilateral peripheral cues (bottom) in peripheral condition in valid trials.

In a central condition, symmetric central single letters (e.g. X) and symmetric central bilateral double letters (e.g. XX) were randomly presented as cues (top panel). The central condition would enable a close examination of the discrepancy observed between centrally presented cues in the studies of Lambert et al. (2006) and Lambert and Duddy (2002). In a peripheral condition, symmetric central single letters (e.g. X) and peripherally presented symmetric bilateral letters (e.g. X+X) were randomly presented as cues (bottom panel) as a peripheral counterpart of the central condition. The result of a clear validity effect elicited by bilateral double cues (in both central and peripheral condition), but not by single cues, as observed in Lambert and Duddy (2002) and Lambert et al. (2006) respectively, would suggest that there is a critical difference between single cues and bilateral double cues, when the cues are symmetric. If an orienting effect is only shown by peripherally presented bilateral cues, and not by centrally presented bilateral or single cues, it would indicate that the eccentricity of cues should be taken into account as well as spatial correspondence in visual orienting. The effect was expected at a longer SOA, at 150ms or 500 ms, as the lack of spatial correspondence in the symmetrical cues and targets would delay the processing of orienting (Lambert & Duddy, 2002).

Methods

Participants Twenty five and eighteen volunteers aged 18- 30 years were recruited for the ‘central’ and ‘peripheral’ conditions respectively in the experiment. They were undergraduate students in the University of Auckland and all had normal or corrected-to-normal vision acuity.

Apparatus This was the same as in Experiment 2 and 4.

Display and stimuli All stimuli were presented in black against a white background (Fig. 14). A fixation cross subtending 1.5° × 1.5° was presented in the centre of the screen. Cue stimuli were the letter X or T subtending 1° × 1.5°. The centre of the central cues was 1.4° above the centre of the fixation cross. This ensured that the letters were presented as centrally as possible, and did not overlap with the central fixation cross. The centre of the peripheral cues was also 1.4° above the centre of the fixation cross. Peripheral cues were presented on both side of the fixation cross (i.e. $X_{left} + X_{right}$). The centre of each letter of double cues in central and peripheral condition were presented 0.5° and 6° respectively from the fixation cross. The target stimulus was a black filled square subtending 0.4° × 0.4° presented either to the left or to the right of the fixation cross. The centre of each target was approximately 6° from the fixation cross.

Procedure The procedure was generally similar to the Attention tasks in Experiment 2 and 4. There were 288 trials in a block. The cue letters were followed by a target on 83% of the trials. For half of the participants, the targets usually appeared on the left if X appeared, and on the right if T appeared. For the other half of the participants, the contingency was reversed. The participants were told to use the cue letters, X and T, in order to predict the probable location of the target. On trials with a target, the stimulus onset asynchrony (SOA) of 0ms, 150ms or 500 ms was set[4].

Seventeen percent of the trials were catch trials on which cue letters were presented without a target. There was an interval of 0.5s to 1 s between the offset of the letter cues and the “blink” of the fixation cross.

Design. Of 83% of the trials in a block on which the cue letters were followed by a target, 75% were valid trials where the cue letters (X or T) validly indicated the probable location of the target. 25% were invalid trials where the cue letter invalidly informed the location of the target. The locations of the target, three different SOAs, the type of the cues (single or double) were varied randomly from trial to trial.

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[4] Even though we did not expect to see a validity effect at the SOA of 0ms and clearer effects at later SOAs since the cues were symmetrical, cues and targets were presented at a standard SOA of 0, 150 and 500ms to make the results compatible with our all other experiments.

Data analysis. A 2 (Validity: valid vs. invalid) × 3 (SOA: 0, 150, 500ms) × 2 (Cue number: single vs. double) × 2 (Cue location: central vs. peripheral) split-plot ANOVA with Cue location as the between-subject independent variable, and Validity, SOA and Cue number as the within-subjects independent variables.

Results

The average rates of anticipation error and catch trial error were 2.7% and 0% respectively. Mean response time results are shown in Figure 15. There was a main effect of SOA (F (2, 82) =143.02, p<.001). Mean reaction time at the SOA of 0ms was significantly slower than that at the SOA of 150ms or 500ms (all p<.001). There was a significant interaction between SOA and cue number (F (2, 82) = 8.85, p<.001). Mean response time with single and double cues at the SOA of 0ms was significantly slower than that at 150 and 500ms (all p<.001). The mean response time with single cues was slower than with double cues at the SOAs of 150ms (p=.016) and 500ms (p=.001). There was no significant main effect of cue location (p=.85).

There was also a main effect of validity (F (1, 41) =6.21, p=.02). To specifically investigate the orienting effect of cues, separate analyses were performed for double (both central and peripheral conditions) and single cues. When only double cues, in central and peripheral conditions, were analyzed, a significant effect of validity was observed (F (1, 41) = 6.18, p=.017) (Fig. 15. top panel). A follow up test showed that the mean RT on valid trials (M = 339ms, S.E. = 8.4) was faster than on invalid trials (M = 355ms, S.E. = 9.13) at the SOA 500ms (F (1, 41) = 7.60, p=.01). This effect did not vary as a function of whether the double cues were presented centrally or peripherally (F<1). The mean RTs between valid and invalid trials did not significantly differ at the SOA of 0ms or 150ms.

When only single cues were analyzed, the effect of validity was not significant (F (1, 42) =1.38, p=.25) (Fig. 15. bottom panel). Follow up tests failed to show a validity effect at the

SOA of 0 ms (F (1, 42) = .34, p=.57), 150ms (F (1, 42) = 1.62, p=.21), or 500ms (F (1, 42) = 1.03, p=.32).

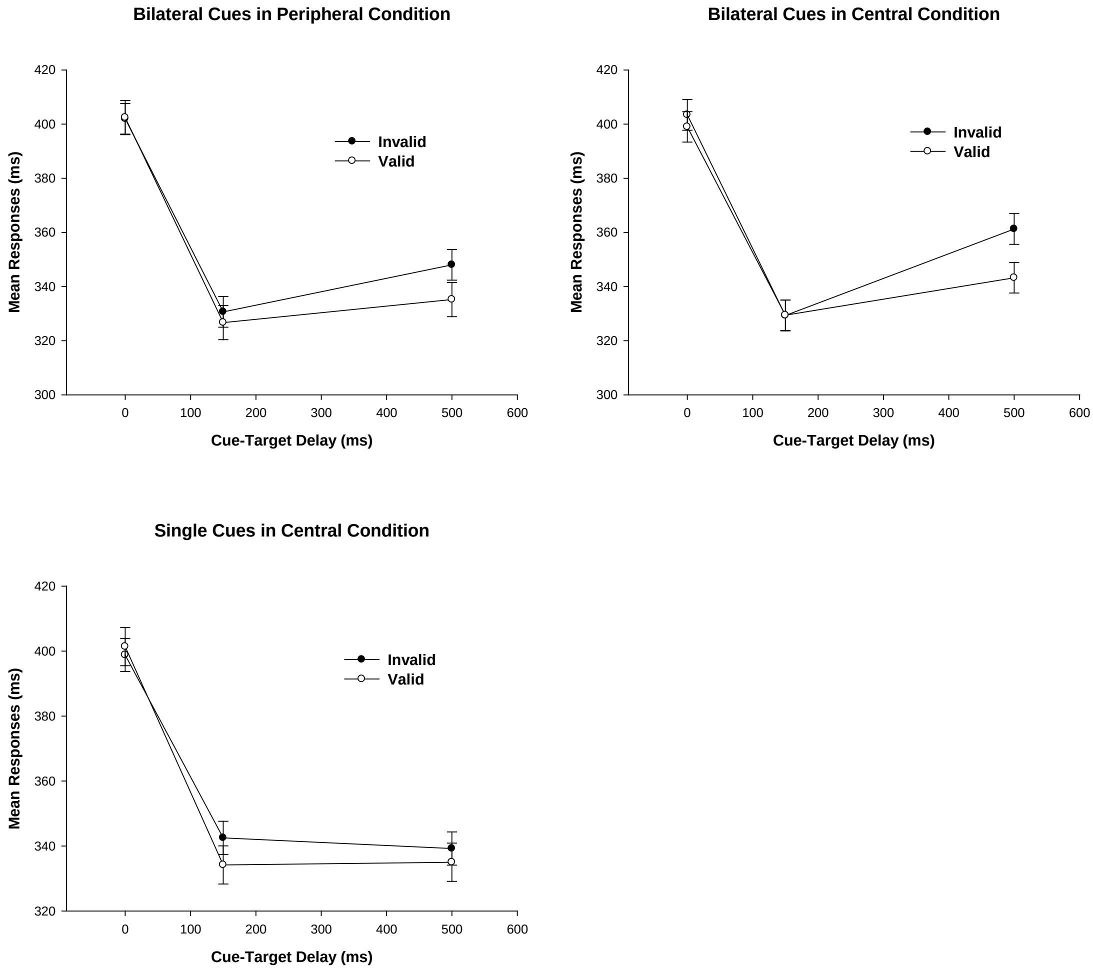

Figure 15. Mean reaction times for bilateral central and peripheral cues in valid and invalid trials at SOAs of 0, 150 and 500ms (the error bars are the standard error of the means)

Discussion

Bilateral double cues in both central and peripheral conditions elicited an orienting effect mainly at the SOA of 500ms. Mean reaction times between these cues in the central and peripheral conditions did not differ. Centrally presented single cues did not show any effect of orienting at any of the SOAs. The response times generally decreased dramatically from the SOA of 0ms to 150ms.

The effect observed at the SOA of 500ms by the symmetric bilateral double cues was remarkably slower than the rapid orienting (observed at SOA of 0ms) by spatially asymmetric cues (Lambert & Duddy, 2002; Lambert, et al., 2006) as the cues in the present study lacked the clear spatial correspondence of the asymmetric cues and targets used in these earlier studies. A clear orienting effect with the symmetric bilateral cues in both central and peripheral conditions is consistent with the spatial correspondence hypothesis (Lambert & Duddy, 2002) in that a target on the left could be spatially associated with one of the cues (e.g. X) and a target on the right would be associated with the other cue (e.g. T).

The similarity observed between the orienting by the bilateral double cues in central and peripheral conditions further supports Lambert and Duddy (2002), and Yantis and Jonides (1990) in that cue eccentricity up to 6° does not have a significant effect on visual orienting. The somewhat larger orienting effect by bilateral double cues in the peripheral condition opposed to the central condition in Lambert and Duddy (2002) should not be interpreted in terms of peripheral cues having an advantage over central cues as condition (i.e. eccentricity of cues) did not interact with validity.

Spatial information is particularly salient in cueing paradigms such as visual search (Theeuwes, Reimann, & Mortier, 2006) and the cued target perception task (Vecera & Farah, 1994; Posner & Cohen, 1984). Providing participants with the word “red” or “colour” as cues before the presentation of target did not improve their performance in finding the target within a red coloured circle among green circles in Theeuwes, et al. (2006), whereas spatial cues reliably elicited cueing effects in Theeuwes and Van der Burg (2007). In Theeuwes and Van der Burg (2007), there were six possible target positions around a fixation and a likely target position was cued by the numbers that corresponded to the hour indications in an analogue clock (e.g. “2” for top-right, “6” for bottom). Cueing the location of a probable target location by the numbers elicited a fast response. The result was in contrast to the effect of cueing with the word “colour” for a red colour singleton target circle among green circles, which did not elicit an orienting effect. The finding of the current study is consistent with space based attention (Vecera & Farah, 1994), where attention is allocated to the location of visual stimuli. The current result showed that it was easier to spatially link the cues with the target when double cues were presented bilaterally (regardless of eccentricity) than when single cues were presented centrally. The bilateral double cues could easily be divided into the left half and the right half and this lateralization may have facilitated orienting by spatially grouping the halved cues with the target on the left or right. When the cues are asymmetric, the grouping becomes much easier as the asymmetry of the cues anchors attention towards the target. Even when the cues are symmetrical, this spatial grouping is possible when the cues were bilaterally presented as the cues could be divided and grouped with the targets on the left or right[5].

The lateralization of cues could have been problematic, however, when the single cue was presented centrally and symmetrically, as it is harder to divide a symmetric single cue into two independent shapes (two objects) and link them with targets, and this makes the strategy of spatially dividing the cue and grouping them with targets inefficient. It would be relatively more efficient to process the single cue as an object with a meaning rather than lateralizing it. When forced to be halved, a central single cue loses much of its original shape (i.e. > on the left and < on the right for ‘X’, or ┐ on the left and ┌ on the right for ‘T’), and the single cue

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[5] Vertically presented bilateral symmetric cues (e.g. an ‘X’ above and below the fixation) showed no orienting effect in a related study in our lab.

loses its identity as a symbol. This makes it harder to relate the letter cues to the directional meaning initially assigned to the letters.

Hommel, et al. (2001) showed orienting effects in response to directional word cues where an over-learned behaviour was associated with the directional words. It was suggested that attention is pulled to the left or right somewhat exogenously after much practice of interpreting the symbolic meaning of the words (Galfano, et al., 2006, also see Tipples, 2008, on eye gazing cues or arrows being associated with certain directional behaviours). However, using the central single cue as an object with directional meaning to orient towards the target was unsuccessful in the current study. The relationship between letter cues and the direction they implied in the current experiments was entirely arbitrary, and the interpretation of the cues for orienting may need some time to develop. If practiced for a prolonged trial session, it may be possible to elicit a cueing effect that is comparable to that by eye gazing cues or arrows in the literature. An interesting future study may address this issue by placing a differing number of practice trial blocks before the Attention task to see how much practice is necessary to elicit an orienting effect that are similar to eye gazing cues or arrows (Dodd & Wilson, 2009).

Object based attention refers to attentional selection based on spatially invariant internal representations of visual stimuli (Vecera & Farah, 1994). The studies in object based attention suggest that detecting or reporting two dimensions is faster if they belong to the same object as opposed to two different objects (Duncan, 1984; Abrams & Law, 2000). Egly, Driver and Rafal (1994) presented participants with two oblong objects side by side and instructed them to report a target flash that appeared at one of the four ends of the two objects. A cue appeared at one of the four possible target locations before the presentation of the target. The perception of the target flash was slower when the target appeared at the opposite end of the cued object than when the target appeared at the cued end of the cued object. The cost in reaction time was greater when the target appeared at an uncued end of the uncued object even though the uncued end of the cued object and the uncued end of the uncued object were equidistant from the fixation.

It has been suggested that these location based and object based attentions are not mutually exclusive. Both location and object based attentions are available (Vecera & Farah, 1994; Matsukura & Vecera, 2011, 2009), in that, the former operates at an early processing stage such as V1(Ozgen, Payne, Sowden, & Schyns, 2006; Tootell, Silverman, Switkes, & Devalois, 1982) and the latter at a later processing stage such as the inferior temporal areas (Desimone & Duncan, 1995; Luck, et al., 1997).

The current finding of a clear orienting effect in response to bilateral double cues, in both the central and peripheral condition showed that the eccentricity of cues is not a crucial factor in visual orienting, as initially suggested by Jonides (1981). Rather, the orienting in response to central and peripheral cues in the current study can be explained in terms of a single mechanism, spatial correspondence learning (Lambert & Duddy, 2002) where the symmetry of the cues delays orienting in comparison with asymmetric cues. Orienting with symmetric cues, albeit weaker than that with asymmetric cues, was shown to be possible if the cues could be lateralized and spatially linked with target presentation, which was supported by an orienting effect with the bilateral double cues in central and peripheral conditions. An abrupt onset peripheral cue on either the left or right side of a fixation (Posner, et al., 1980) and asymmetric cues such as arrows or gazing to one side (Tipples, 2008) would attract attention easily as they are spatially correspondent with the target. The result is also consistent with the findings, in Experiment 1, 2 and 3, which suggest that mere encoding of the visual features that distinguish letter cue X from T is sufficient in eliciting an orienting. The current result implies the importance of the asymmetry of visual presentation in triggering a rapid orienting behaviour and the lateralization of visual stimuli in the visual field as a way of understanding the environment surrounding us.

Experiment 6

Results from Experiment 5 showed the importance of spatial correspondence learning in visual orienting, where the spatial presentation of cues could be lateralized and spatially grouped with targets. The current study attempted to further investigate the difference between centrally presented bilateral double cues and centrally presented single cues in their effect on visual orienting. Apart from the lateralization of the cues, these cues differed in two aspects. Firstly, bilateral double cues included, in their physical configuration, the repetition of the symbolic meaning of a letter (e.g. XX in the bilateral double cue, X in the single cue). The repeated presentation of the same cue both on the left and right side of the fixation in close proximity may have emphasized the importance of the cue, eliciting a clearer effect with the double cues in comparison with the single cues. However, the symbolic meaning of cues has been suggested to take a longer time to process in comparison with the spatial property of cues (Experiment 5, Lambert & Duddy, 2002; Lambert et al., 2006). Secondly, the double cues and single cues differed in their overall size in that the presentation of the bilateral central double cues was spatially larger than that of the central single cues. Previous studies have highlighted the importance of spatial features such as spatial correspondence and asymmetry of visual stimuli. Therefore, the size of cues, another spatial feature, may have contributed to the difference in orienting effect in Experiment 5. Experiment 6 was designed to see if the orienting effect observed with the bilateral central double cues was driven by the size of the cues. If orienting effect is influenced by the change of cue size it would further support the important role of spatial features, including spatial correspondence *and* the size of cues, as one of the main factors determining visual orienting.

Methods

Participants Twenty four undergraduate students in the University of Auckland participated in the present experiment. All had normal or corrected-to-normal vision acuity. They did not participate in Experiment 5.

Apparatus Same as in Experiment 5.

Display and stimuli Same as in Experiment 5 except for cue stimuli. The cues were single letters that were either big or small. The centers of big and small letters were presented 1.4° above the fixation subtending 2.6°×1.51° and 0.96°×1.51° respectively.

Procedure Same as in Experiment 5.

Data analysis. A 2 (Validity: valid vs. invalid) × 3 (SOA: 0, 150, 500ms) × 2 (Cue size: big vs. small) ANOVA with Validity, SOA and Cue size as the within-subjects independent variables.

Results

The average rates of anticipation and catch errors were 0.8% and 2.1% respectively. Mean response time results are illustrated in Figure 16. There was a main effect of SOA (F (2, 46) = 61.745, p<.001). Participants responded quicker for the target at the SOA of 150 and 500ms than at that of 0ms. There was no main effect of validity (F (1, 23) = 2.13, p=.16) or cue size (F (1, 23) =.53, p=.48). The reaction times in valid and invalid trials were not significantly different at any of the SOAs for either big or small letter cues (Fig. 16.; the difference between the reaction times on valid and invalid trials for small letters at the SOA of 500ms was not statistically significant). There was no interaction between cue size and validity (F (1, 23) = .284, p=.599).

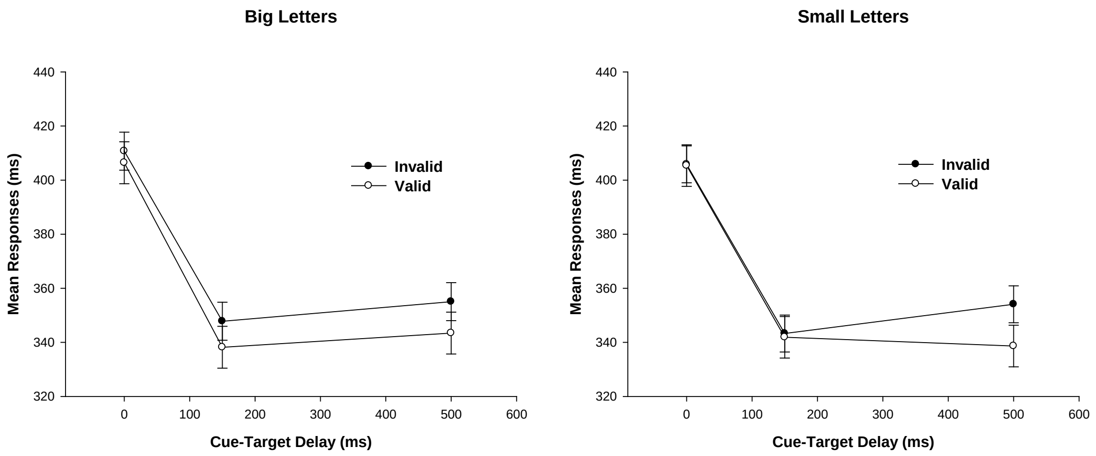

Figure 16. The difference in reaction time between valid and invalid trials for big and small letter cues at the cue-target delay of 0, 150 and 500ms (the error bars are the standard error of the means)

Discussion

Varying the size of single cues did not have an effect on the cue validity effect. The finding is consistent with the idea that cue eccentricity is not important in visual orienting. It seems that the closer proximity between cue and target by increasing the size of the cues does not have an effect on orienting. The result is also in line with previous studies where centrally presented cues of the similar size as the single cues, such as arrows (Posner & Cohen, 1984) and asymmetric letters (e.g. b or d, in Lambert et al., 2006) showed an orienting effect.

It was suggested, in Experiment 5, that orienting by the meaning of cue (when the cue-target relationship is arbitrary) develops more slowly than that by over-learnt cues such as arrows. Once over-learnt, the meaning of a letter could be as powerful as numbers as shown in Fischer et al. (2003). It would be interesting to see if the size of single cues does have an effect on orienting after an extensive training session. A word in a different font or size in a paragraph does attract attention because it is expected that the difference in fonts and sizes may mean an emphasis on the word.

After the relationship between letter cues and targets is well learnt, the repetition of cues (e.g. XX) may facilitate orienting, as well as an increase in size of cues or different font of the cues. Hence, it would also be interesting if the orienting effects of single asymmetric cues such as “d” and centrally presented double asymmetric cues such as “dd” could be compared so that the number of cues differs between two different conditions while maintaining the asymmetry of the cues constant.

Experiments 5 and 6 examined whether the eccentricity, number or size of cues has an effect on the cue validity effect. The findings of these two experiments showed that (i) the distinction between single and double cues was important, that (ii) the eccentricity of the double cues did not influence the validity effect, and that (iii) the size of the single cues did not influence the validity effect.

Chapter 5

General Discussion

1. Summaries of findings

Experiment 1, 2 and 3

The luminances of both cues and targets were varied in order to manipulate the degree of perceptual awareness of the visual stimuli. It was predicted that the levels of both cue and target luminance would influence orienting. Low luminance targets were hypothesized to elicit a larger orienting effect in comparison with high luminance targets as the slower processing time for low luminance targets should allow more time for a temporally prior cue to be processed. The result was consistent with the prediction showing that low luminance targets elicited a clear orienting effect, whereas high luminance targets did not. It was reasoned that the processing of the low luminance targets benefits more from being attended by cueing than high luminance targets which already reached the maximum processing speed (Reynolds & Chelazzi, 2004; Reynolds, et al., 2000; Carrasco, et al., 2004).

For cues, on the other hand, a high luminance cue was expected to facilitate orienting to a greater extent compared to a low luminance cue which would take a relatively longer time to be processed. The result, however, was different from the hypothesis. A clear orienting effect was elicited by low luminance cues as well as high luminance cues, and lowering the luminance of the cues did not reduce the magnitude or retard the time-course of the orienting effects observed in these experiments.

These results showed that orienting was more affected by a target luminance level rather than a cue luminance level. A clear perception of targets was essential in order to successfully perform the task and the perception of lower luminance targets was greatly benefited by being validly cued and attended. Although the processing of cues was necessary to elicit an orienting effect, processing the cues to the same level as the target (i.e. to the level of conscious identification of the cue letters) was not crucial in performing the Attention task because direct responses to the cues were not required in the task. Thus, manipulating the perceptual awareness of cues by lowering the luminance of the cues did not hinder orienting, and a clear orienting effect with both low and high luminance cues was observed. It was suggested that this processing of cues, that is fast and somewhat below-perception-level, is a feed-forward input via the M pathway prior to reentrant influences on slower P pathway processing. This hypothesis on orienting via the M pathway led to the next experimental question on the effect of over-stimulation of the M cells on visual cue processing.

Experiment 4

Whether the over-stimulation of the M cells disrupts cue processing and hence impedes orienting was examined in Experiment 4. It was reasoned that, if visual orienting is processed via a fast feed-forward processing in the M pathway, the over stimulation of M cells would lead to a disturbance of cue processing. Chapman et al. (2004) has suggested that disturbing processing in the M pathway by administering luminance flickers leads to impairment in motion perception, as a majority of the M pathway input is projected to MT which processes motion. In the previous experiments it was hypothesized that the M pathway is crucial in visual orienting, and it was predicted that a disturbance in the M pathway would elicit a similar effect in orienting as in motion perception. Hence, it was expected that a disturbance in the M pathway by administering a battery of flickers would hinder the processing of cues, leading to a poor performance in the Attention task.

Contrary to the hypothesis that flickers would impair the M cell processing and the orienting performance in the Attention task, the administration of luminance flickers facilitated orienting. It was suggested that the M cells could have recovered quickly from the flickers as the interval between the flickers and orienting trial was longer than in Chapman et al. (2004). The administration of the flickers could also have sensitized, rather than desensitized, the M cells since the duration of the flickers was relatively shorter than in Chapman et al. (2004). Chapman et al. explained that a flicker adaptation momentarily reduces the response rates of the M cells as the cells will be fatigued after being exposed to a battery of luminance flickers, and this reduction in the responses of the M cells affects the processing in MT. The flicker procedure, however, may have had a very different effect on the M cell responses in the current study, because the repeated presentation of a visual stimulus could reduce the amount of resources needed in its processing (Tipper & Cranston, 1985). Hence, it is possible that the flicker procedure reduced the attention load required for the cue luminance processing, facilitating the orienting.

Experiment 5 and 6

In contrast to Experiments 1-4 which examined the effect of luminance of cue and target stimuli (a non-spatial feature) on attention shifting, Experiments 5 and 6 investigated the effects of the spatial features of cues on orienting. The aim of these experiments was to examine the discrepancy between the study of Lambert and Duddy (2002) where centrally presented bilateral symmetric cues (e.g. XX) elicited a reliable orienting effect and the study of Lambert et al. (2006) in which centrally presented single symmetric cues (e.g. X) failed to elicit any orienting at all. Lambert and Duddy (2002) have suggested that spatial correspondence between cue and target is more important than the eccentricity of cues in visual orienting. It was, thus, hypothesized that (i) double cues in both peripheral and central cueing conditions would elicit an orienting effect, and (ii) that single cues in a central condition would not elicit orienting. As observed in Lambert and Duddy (2002), an orienting effect was observed by double cues in both peripheral and central conditions, at an SOA of

500ms. In contrast, when single visually symmetric cues were presented centrally, orienting effects were conspicuously absent. It was suggested that orienting was more likely to occur if the cue could be spatially lateralized to the left and right, to be linked with targets which appeared either to the left or right of the fixation, in association with one of the cue letters (X or T). Bilateral double cues in both peripheral and central conditions could be divided into separate objects in the left and right visual field, whereas this lateralized object segregation was difficult or impossible to achieve when the cues comprised a single, centrally presented letter. Moreover, in these experiments the central letter cues were visually symmetric, unlike letters such as b or d with which attention could be pulled by the asymmetry of the cues, together with the spatial correspondence learning. The results were interpreted in terms of spatial correspondence hypothesis in which the link between spatial features of cue and target stimuli in the visual field is crucial in determining orienting behaviour. The interpretation is consistent with the result, in Experiment 1, 2 and 3, which suggested that the encoding of the visual features of cue letters that differentiates X from T is sufficient in eliciting an orienting.

The hypothesis that the asymmetry, but not eccentricity, of cues is important in triggering orienting was further supported by the findings in Experiment 6. The difference between the orienting effects by centrally presented bilateral double cues and single cues in Experiment 5 was further investigated. In Experiment 6, the single cues were made bigger so that they were visually as big as the size of the bilateral double cues in Experiment 5. The closer proximity between cue and target by the increase of cue size did not contribute to eliciting an orienting effect, suggesting that the increase in size of the cues did not increase the utilization of the cues in orienting.

2. Rapid orienting

The speed of orienting observed in the current experiments is consistent with previous studies in the literature. Informative letter cues elicited an orienting effect at an early SOA of 0-150ms even when the cues were just above threshold (Experiment 1, 2-a and 2-b) or following flicker adaptation (Experiment 4), as long as the cue was presented asymmetrically or bilaterally. The rapid orienting in Experiments 1, 2 and 4 at the SOA of 0-150ms is comparable to the typical exogenous orienting at the SOA of 50ms in previous studies (Posner, 1980). An orienting effect at a later SOA of 500ms was observed when the luminance of these cues was at the lowest level (Experiment 3). The delayed orienting effect with the lowest luminance level may be because cues at very low levels of luminance require more processing time. A late orienting effect was also observed at the SOA of 500ms when the cues were symmetrical and bilaterally presented (Experiment 5). The slower orienting in Experiment 5, however, may reflect symbolic-meaning-based orienting hence showing more of an endogenous effect. The orienting is comparable to the endogenous orienting at the SOA of 150-500ms in previous studies (Posner, 1980; Shepherd and Muller, 1989).

3. Is the orienting strategy driven?

Since the cues comprised letters and were informative of target location, the orienting in the Attention task was initially expected to be strategy-driven and endogenous. The endogenous orienting observed in the current study was not the conventional one, however. Depending on the goal of a task, the visual system processed cues at different levels, to below perception level for orienting and to conscious perception level for detecting.

The key for a successful performance in the Attention task was a fast conscious perception of targets, and cues were available to facilitate this process. Although participants used the cues in order to better detect the target, processing the cues to a conscious perception level was not essential to target perception, which might unnecessarily burden the system and hinder target processing. The cues being presented in a high luminance contrast may not have been necessary as they would not be processed to a perception level anyway. Hence, lowering the luminance of the cues did not hinder orienting. The cue processing to below perception level was more rapid than the cue processing to the level of conscious perception (Experiment 1, 2) and was quick to recover from the exposure to luminance flickers (Experiment 4). Orienting effects were reduced only when the luminance of the cues was lowered to be very near threshold (Experiment 3).

In the Perception task, however, the conscious perception of the cues was the primary goal. A fast and somewhat unconscious processing of the cues was no longer sufficient for the task and a change of strategy was necessary in order to perform the task successfully. The processing of cues to a conscious level became essential and lowering the luminance of the cues evidently increased the stimulus processing load when the cues were processed to the level of conscious perception. This variation in strategy makes the visual system as efficient as possible, because it limits any excessive information and allows only necessary information for a given task, so that the system can maximize its resource to successfully perform the task. Orienting and perception have been suggested to utilize different sub-cortical pathways, the M and P pathways, respectively. Hence, it is plausible that, depending on the goal of a task, different parts of the visual system are activated.

The visual system also determines which of symbolic-meaning-based or space-based attention would be more suitable for a given task. Spatial information is always necessary in responding to a visual stimulus (Theeuwes, 2010), hence, participants may be disposed to use the spatial property of cues first, such as the asymmetry of cues in orienting. However, attention is allocated not only to space but also to objects, as perceiving different features of an object as parts of one thing is crucial in object identification. When the space based attention strategy is not effective anymore such as when the shape of cues is symmetric (e.g. 8 or M), or ambiguous in shape with the pointy or round ends facing both leftwards and rightwards (e.g. & or 4), perceiving the cues as objects and interpreting the meaning of the cue become more beneficial.

The results of Experiment 5 showed that bilaterally presented cues (e.g. XX) were perceived as two objects and were divided into two parts, one on the left and the other on the right, and one of the two lateralized objects was spatially associated with the target and pulled attention towards the target. Thus, the orienting effect was observed regardless of whether the cues were presented centrally or peripherally. A single central cue (e.g. X), however, was perceived as one object with a meaning and it was more effortful to divide it into separate left and right components. The lateralization of the central cue would break the cue to the level in which it loses its integrity as a letter and the meaning it entails. Hence, it would be impossible to perceive the cue as an integrated letter and simultaneously segregate it into distinct left and right components- in much the same way as it is impossible to segregate the Rubin face-vase figure into two separate faces, *and* simultaneously perceive it as a single integrated object-a vase. Centrally presented cues if asymmetric, such as letters d or b, or arrows, are still able to direct the attention towards probable target location with their asymmetric ends. If symmetric, however, this is an effortful process and the orienting is to be based on the meaning of the cue and its relationship with the target location rather than the spatial grouping of the cue and the target. Therefore, in Experiment 5, this symbolic meaning interpretation strategy with centrally presented symmetric cues hindered successful performance in the Attention task. This strategy, however, has been shown to elicit attentional orienting if extensive training was given (Dodd & Wilson, 2009). Participants showed an orienting effect by learning arbitrary associations between the colour of cues and target locations after 800 trials of training.

A cue directs attention either by its spatial features or by the meaning it conveys as an object. Words as cues could also elicit orienting as the visual system would perceive a word (e.g. nurse or doctor) as one object rather than a row of letters because the processing of words is greatly over learnt. When a symbol is greatly over learnt, the speed of the symbol processing becomes rapid, showing more of an exogenous effect. A clear orienting effect was observed in response to number cues (Fischer, et al., 2003) despite them being non informative. In contrast, symmetric letter cues (Lambert et al., 2006) failed to elicit orienting despite them being informative of target location. If both numbers and symmetric letters are processed as symbolic cues both cues should have elicited orienting. The discrepancy between the two kinds of cues could be because the mental number line is over learnt, whereas the relationship between the cue letters X/T and the targets on the left and right is arbitrary, and the relationship between the letters and target location needs more time to develop. Once established, however, the semantic cues are powerful in that an orienting is elicited even when their location is non-informative of target location (Fischer, et al., 2003; Dehaene, et al., 1993; Hubbard, et al., 2005; Ranzini, et al., 2009).

4. Is the orienting stimulus driven?

On the other hand, the findings of orienting effects in the current study also showed the characteristic of stimulus driven orienting. First of all, an orienting effect was observed at an early SOA of 0ms, which is comparable to that with exogenous cues such as flashes. The finding that lowering the luminance of the cues did not hinder orienting in Experiment 1 and 2 has been interpreted in terms of the processing of the cues below-perception level, which is in line with exogenous, stimulus driven orienting. Although the meaning of the cue could have been interpreted and used in target perception, the process is an effortful one, compared to more exogenous orienting based on the spatial features of cues. The asymmetry of cues has been shown to be powerful enough to trigger a rapid orienting even when the luminance of cues was just above threshold (Experiment 1 and 2). Orienting by the spatial features of cues appears to be more stimulus-driven than strategy-driven as the processing does not seem to involve a great deal of top down control. This idea that the orienting observed was mostly stimulus driven by bottom up control is further supported by the findings of Shin, Marrett, & Lambert (2011) (Experiment 3) in which an orienting effect was elicited in the absence of knowledge of the cue-target contingency. Using a similar paradigm to the current experiments, participants oriented to the cues even when they were unaware of the association between letter cue and target location (refer to *Implicit learning in General Introduction in Chapter 1*).

Another experimental condition that may have contributed to the exogenous effect observed in the results is the abrupt onset presentation of cue and target, which may have led to attracting attention more exogenously (as discussed in the *General Introduction*). Moreover, they were presented for a brief duration of 67ms. The fact that the cues were presented for a short period of time may have sped up orienting by freeing attention from the cue earlier compared to when cues were presented for a longer period of time (e.g. for 300ms as in Fischer et al., 2003). Furthermore, both cues and targets being presented via luminance increments may also have helped the learning of the cue-target contingency in the Attention task (Folk, et al., 1992), and an administration of luminance flickers, in Experiment 4, may actually have strengthened the relationship between the cue and targets both marked by the repetitive presentation of visual stimuli by luminance increment, which is supported by the enhancement in orienting effect observed after an administration of flickers for 1.1mins.

5. Is it implicit learning?

The results showed that participants have processed the cues to two different levels in these studies, somewhat below conscious level in the Attention task and above conscious perception level in the Perception task. The orienting observed in these studies was not purely stimulus driven, as different strategies (i.e. space or symbolic meaning based orienting) were adopted depending on the goal of a task. However, it was not purely strategy driven either as the orienting observed in the Attention task was qualitatively different from the processing observed in the Perception task. The results of the current study blurs the boundary between exogenous and endogenous, or stimulus driven and strategy driven orienting, as the orienting observed shares much in common with the characteristics of both exogenous and endogenous orienting. In a way the orienting observed in the study was somewhere between exogenous and endogenous orienting in that it was shown to be rapid and was unaffected by lowering the luminance of the cues (i.e. the cue was processed to somewhat below perception level), but also influenced by top down control as the cue could be processed either as a spatial cue with its asymmetric edge, or a symbolic object to be interpreted for probable target location.

This utilization of knowledge about the relationships between cue and target stimuli in orienting is consistent with the findings of contextual cueing in which a cue embedded around a target in an obscure context improves target perception in that the orienting in these studies are neither exogenous nor endogenous (Chun & Jiang, 2003). There has been a difference in these two studies, however, in that, participants were perceptually aware of the visual stimuli but were unaware of the contextual cue –target contingency in Chun and Jiang (2003), whereas participants were explicitly informed of cue target contingency in the current study. Despite the difference in the experimental designs, the orienting effect observed in these two studies is qualitatively different from a process that is consciously executed by endogenous top down control. Although participants were explicitly informed of the cue target contingency, in the current study, they oriented based on the spatial information of the cues in most of the Attention tasks rather than using the cues as symbols (i.e. symbolic meaning based orienting) as in the Perception task. Rather, the knowledge of the cue-target contingency seemed to be somewhat subconsciously stored in memory as the orienting observed showed an exogenous effect. The letter cues were initially processed spatially (e.g. based on the cue symmetry) as the cue-target relationships in these two studies were arbitrary. As the spatial features of cues tend to be processed at an earlier stage in visual processing than the symbolic meaning of cues, this orienting based on the spatial features of the cues may have helped eliciting an exogenous effect in these studies.

The results of the current study are also consistent with the proportion valid effect (Risko & Stolz, 2010) in that the visual system selects the optimal strategy for successful performance in a task and this process is qualitatively different from conscious endogenous control. Risko and Stolz (2010) have suggested that participants unconsciously understood the varying validity of cues in predicting target location and this implicit understanding affected the performance in the attention task. The current results showed that the visual system varied the extent to which cues would be processed depending on what the goal of the given task was. The system has also been suggested to select either space or symbolic meaning based strategy depending on the suitability of the strategy in a task in allocating attention and distributed attention. This flexibility and efficiency in processing visual cues in the Attention and Perception task, in the current study, has also been shown when the validity of cues varied from experimental block to experimental block in Risko and Stolz (2010). As in the study of Risko and Stolz, the processing of cues in the Attention task in the current study may not have involved conscious awareness, since the cue processing has been shown to activate the dorsal visual stream which is differentiated from the ventral visual stream in which conscious perception takes place (Marrett et al., 2011). Further support for the idea that the orienting in the current study may not involve conscious awareness comes from the study of Marrett et al. (2011) in which DF, who has shown impairments in form perception from bilateral damage to the ventral stream, successfully performed an orienting task by using the shape of the letter cues, in contrast to her impaired performance in an cue perception task.

As discussed in the Introduction, the findings of contextual cueing and the proportion valid effect provide evidence of implicit learning on the cue-target relationship, which does not quite fit into the dichotomy model of exogenous and endogenous attention. The results of the current study share much in common with these studies on implicit learning, in that the orienting effect was neither purely exogenous as informative letter cues were used, nor purely endogenous as orienting was possible without being able to consciously identify the cue. Together with contextual cueing and the proportion valid effect, the findings of the current study advocate an attention model that embraces evidence of implicit learning and better explains the findings that are mixtures of exogenous and endogenous effects.

6. Was the orienting covert or overt?

One may argue that the orienting observed in the current study may not have been covert since eye movements were not monitored in the current study. However, it has been shown that eye movement does not interact with cue validity in a cueing paradigm similar to the present study (Greenwood, 2011). There was no significant difference in response times between participants who moved their eyes and who did not, which suggests that eye movement does not benefit the orienting process. If anything, eye movements somewhat increased reaction times, which is contradictory to the finding of the current study which showed shorter reaction times for longer SOAs.

7. Attentional selection at multiple levels

The findings of the current study support the proposal that attentional selection occurs at multiple levels (Lavie, 1995). The visual system determined whether it was sufficient to process cues to below or above perception level, and allocated attentional resources accordingly. The minimal processing of cues in the attention task enabled a faster feed forward input along the dorsal stream (if only for orienting), which then, facilitated the identification of the target (if only for perception). The results are consistent with Bullier (2001) which suggested that the interaction between fast feed-forward and later feedback inputs between the lower and higher areas are crucial for efficient visual processing. When the spatial features of visual stimuli (e.g. asymmetry) can be used to elicit a shift of attention, the attentional selection is likely to be based on the spatial features of cues because a more primitive feature would takes up less attentional resource and also could be processed at an earlier stage of visual processing. This is supported by a faster orienting with asymmetric letters compared with symmetric letter cues (Lambert & Duddy, 2002). When it was not easy to use the spatial features of the cues (i.e. if the cue display is symmetric), the selection was based on the cue as an object, necessitating processing at a later stage, which was supported by an orienting effect at the late SOA of 500ms with symmetric bilateral cues (Experiment 5). The processing of an arbitrary relationship between the meaning of letter cues and target location is more effortful than the processing of the over-learnt relationship between arrows and target location, hence the former elicits more endogenous effects than the latter. The optimization of the attentional mechanism is consistent with Lavie (1995) who suggested that the perceptual load of visual information decides whether the attentional selection will take place early or at a later stage in visual processing in order to avoid information overload in the system.

8. Neurological correlates of the orienting

The current results are also consistent with previous neurological studies on spatial orienting. The current result suggests the M pathway to be the area where the spatial cues are processed in orienting as the cues were processed faster and to a somewhat more crude level in orienting than in cue perception (Bullier, 2001). Single cell studies have suggested that the M pathway is faster and more sensitive to luminance than the P pathway which was shown to be slower and colour sensitive (Shapley & Perry, 1986). It seems that the spatial information and luminance of the cues were initially processed via the M pathway. The input from the M pathway is initially fed into the dorsal stream in DAN where general distribution of attention is managed by goal driven control (i.e. a fast feed forward input) (Corbetta, et al., 2000; Bullier, 2001). Attention is more predisposed to be based on space (via the M cells) rather than object identity (via the P cells) because spatial information is faster to process and is more crucial in visual processing (Theeuwes, 2010). This input from the M pathway may also have been fed into the ventral stream, and into VAN where salient features of visual stimuli are processed such as the asymmetry of cues by stimulus driven control (Corbetta, et al., 2000). Only the spatial features of the letter cues were processed at this initial feed forward stage as the letter cues are less biologically salient than flashes and their relationship with space is less ‘over-learnt’ than arrows or numbers (Dehaene, et al., 1993 1993; Fischer, et al., 2003). Some of the M pathway input may have gone via the SC which then may be fed into DAN for the preparation of a saccade if necessary (Goldberg & Wurtz, 1972).

After the initial input from the M pathway, the DAN sends a quick feedback signal to the V1, where the inputs from the M, P and K cells are integrated (Bullier, 2001). The extent to which a cue should be processed or the optimal strategy (either space or symbolic meaning based) for the distribution of attention in the task for a successful performance is decided in DAN. Depending on the goal of the given task, more information from either M, P or K cells may be required (Bullier, 2001) for further processing. Identifying the cues is necessary in cue perception and this would need more information from the P cells (Goodale & Milner, 1992). There is much interaction between feed forward and feedback inputs, and also between the lower and higher areas in processing the cues and targets at this stage (Marois, Chun, & Gore, 2004; Bullier, 2001). DAN distributes attention based on spatial property (e.g. the asymmetry) or symbolic meaning of a cue for target perception, facilitating attentional resources in valid locations and inhibiting invalid locations. DAN also depresses activation in VAN so that any irrelevant distracter does not attract attention (Corbetta, et al., 2000) although there was no need of this suppression as there was no distracter in the current study. When the target appears, VAN is activated, and more so for targets in unexpected location, as the network is stimulus driven (Corbetta, et al., 2000). When explicitly informed the cue-target contingency would be strengthened, and when not informed cue-target contingency may be formed either implicitly or explicitly in DAN after a few trials (Nissen & Bullemer, 1987). As more of this sequence is repeated the responses in DAN and VAN for the cue-target contingency becomes more exogenous and may have become relatively more unconscious.

Previous studies have much emphasized the difference between DAN and VAN suggesting spatial information and object identification are processed via two distinct dorsal and ventral networks (Corbetta, et al., 2000). The general control of DAN in the orienting process includes getting the initial feed-forward input from the M cells and sending feedback to various areas. It also suppresses and activates the VAN. These multiple roles of DAN suggest that DAN and VAN are not equal in terms of controlling attention. Rather DAN monitors the whole system in order to get a coherent picture of the various incoming information of visual stimuli and elicit appropriate responses. Moreover, many brain areas suggested in DAN and VAN have been shown to overlap considerably. Marois, Leung and Gore (2000) showed that location and identity of visual stimuli activated both M and P pathways, supporting the large overlap between the two networks. Both identity and location of visual stimuli activated the areas in both ventral and dorsal streams, including the lateral occipital cortex, the temporal cortex and the intra-parietal cortex. Furthermore, EEG recordings that showed enhancements in both P1 and N1 by either exogenous or endogenous cues (Brignani, et al., 2009; Hopfinger & West, 2006) may reflect the rapid interactions between DAN and VAN. More closely related to the current study is the work of Peelen et al. (2004) in which brain activation was recorded during the processing of non-informative peripheral and central cues. The same brain areas, a fronto-parietal network, were activated for both peripheral and central cues, consistent with the findings of much overlap between DAN and VAN.

9. A possible attentional model

The literature often classifies visual orienting as either exogenous or endogenous (Posner, 1980; Jonides, 1981). Some researchers suggest that there are two separate forms of attention - exogenous and endogenous attentions. Other researchers argue that there is one attentional mechanism, with two different modes, exogenous and endogenous, sharing one limited capacity attentional resource (Posner, et al., 1980; Jonides, 1981; Santangelo, et al., 2008). Műller and Rabbitt (1989) emphasized the qualitative difference between the two attentional mechanisms with a mutual interference between the two types of attention (Muller & Humphreys, 1991). These two modes can be interactive (Folk & Remington, 2008), overridden or interrupted by each other (Yantis & Jonides, 1990; Theeuwes, 1991a).

Behaviourally, much research on visual orienting has shown effects that are mixtures of exogenous and endogenous effects (such as orienting by arrows, words and letters). Moreover, it was shown that cue-target contingency could be implicitly learnt (Chun & Jiang, 2003; Risko & Stolz, 2010). The processing of cues below perception level was suggested to be sufficient to elicit orienting. Detecting, in contrast, required full perception level processing in the current study. These findings suggest that two distinct attentional systems or one system with two distinct modes is too rigid a mechanism to encompass these findings and that the change from exogenous to endogenous effects may be gradual.

Neurologically, the initial fast feed forward input from the M cells to higher areas in the dorsal stream enables the higher areas to manage the whole attentional system, combining information from features of visual stimuli at appropriate stages in the course of processing and regulating the amount of information so that the processing does not over-burden the system. It has been suggested that the intra-parietal and the superior parietal cortex in the dorsal stream manages general control of attention rather than only being involved in spatial perception (Marois, et al., 2000). These behavioural and neurological findings together may suggest that there is one attentional system that is controlled by DAN that regulates endogenous and exogenous effects on a continuum with an extreme exogenous end in one side and an extreme endogenous end the other, rather than two qualitatively different attentional systems or modes. If a cue is informative and also asymmetric the orienting would show the characteristics of a mid point on this exogenous-endogenous continuum as the effect would be a combination of endogenous effect by the informativeness of the cue and exogenous effect by the asymmetric feature of the cue.

10. Future studies

An interesting future study may further investigate the effect of a disturbance in the M pathway in orienting as discussed in Experiment 4 in Chapter 3. Administering luminance flickers for a longer period of time in the initial flicker adaptation or re-adaptation procedures may in the end remove the orienting effect observed in the flicker condition in Experiment 4. Shorter intervals between the flicker phase and the actual Attention/Perception task by having a fixation and instructing participants fixate on the fixation throughout flicker adaptation or re-adaptation phase may eliminate the possibility of recovery from the prior flicker phase before orienting.

Another possibility for future research is to further examine cue processing via the M and P pathways. It was suggested that orienting is initially based on spatial features but when it is difficult to do so such as when the cue is symmetric, attentional resources are allocated to decode the cue and process it as an object. A future study may employ a set of cues that are symmetric and could be perceived as one or two objects, such as a circle with two breaks at the top and the bottom, to directly examine this hypothesis. Participants may be asked whether they perceived the cue as one or two objects.

Another future study could investigate the possibility of the P pathway involvement in orienting process. The study could employ a symmetric cue that is the same as the letter cues (e.g. X or T) used in the current study but with the left and right part of the cue in different isoluminant colours (e.g. blue for targets on the left and green for targets on the right). Petersen and Gibson (2011) argued that it is difficult to learn the relationship between colour as a cue (e.g. a green circle for the left side and a red circle for the right side) and probable target location. This further confirms that spatial information is special in shifting attention and that the M pathway that codes spatial information is the best candidate for a rapid orienting process. An experiment with symmetric letter cues with different isoluminant colours on each side may encourage participants to learn the link between colour information (cue) and spatial information (probable target location) than when they are presented with circles in uniform colour for either targets on the left or right. A comparison of the magnitude and speed of orienting effects between the current study with luminance cues and the suggested future study with isoluminant colour cues would enable us to determine whether the initial cue processing in the Attention task was exclusively carried out in the M pathway alone or in the M and P pathways concurrently.

11. Conclusion

Dissociation in cue processing between orienting and cue perception was revealed as perceptual awareness of the cues decreased in the Attention and Perception task. The involvement of the M pathway in attentional orienting was supported by the finding that the over-stimulation of the pathway had an effect on orienting. Both space and symbolic meaning based attention strategies were suggested to be at disposal in orienting. However, a space based attention strategy was shown to be preferable to a symbolic meaning based attention strategy in processing visual cues in orienting, and when forced to use a symbolic meaning based strategy the effect was suggested to take a longer time to develop (see Dodd & Wilson, 2009).

The results in the present study provide evidence for the distinction between orienting and detecting (Posner, 1980), by showing the differential effects decreasing the perceptual awareness of cues has on orienting and cue perception. The orienting and perception were suggested to be processed in the segregated M and P pathways in the dorsal and ventral streams respectively, which is consistent with the two stream visual processing model of Goodale and Milner (1992). Utilizing the dorsal stream for processing both orienting and visually guided movements would maximize the efficiency of the visual system.

The current study showed that asymmetric cues elicited faster orienting responses compared to symmetric cues. The result adds evidence to the spatial correspondence hypothesis showing the asymmetry of cues was one of the crucial factors in determining optimal attentional strategy in an orienting task. Cues were processed either by space or symbolic meaning based attention strategy depending on which strategy was more efficient given the spatial property of the visual cue, supporting Vecera and Farah (1994), which suggested that both space and symbolic meaning based attentional strategy are at disposal when processing visual cues and these strategies may work together in order to efficiently process the stimuli. The flexibility and efficiency of the visual system were emphasized further when it was shown the visual system also decides whether a visual cue is to be processed to below or above perception level. It was suggested that the top down control of DAN, which manages general attentional distribution, enables the flexibility of the system in cue processing, receiving feed-forward and feedback inputs from various areas, including lower areas such as the SC and V1, and higher areas such as TPJ and SMG in VAN, consistent with Corbetta, Patel and Shulman (2008). This flexibility in adopting different strategies in processing a visual cue stimulus in such a short time (at the SOA of 0 or 150ms) is possible only because of the fast feed-forward input from the M cells in the LGN via V1 to the areas in DAN, consistent with the re-entrant theory by Bullier (2001).

The present study adds to the current literature in that it provides behavioural evidence for dissociation of orienting and perception in the visual system using a cue-target orienting paradigm. It also suggests the involvement of the M pathway in visual orienting. Further behavioural or neurological studies of the attentional system using EEG, fMRI or TMS could be built upon the current findings to investigate further the feed forward and feedback connections between the M and P pathways, and the dorsal and ventral fronto-parietal networks in the visual attentional system.

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Appendix

Target level	Cue level	SOA (ms)	Mean Difference (Valid-Invalid trials) (ms)	S.E.	Significance	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
Low	Low	0	12.429	6.122	.052	-.133	24.990
		150	-7.500	6.107	.230	-20.030	5.030
		500	-9.321	5.509	.102	-20.625	1.982
	Medium	0	-7.000	7.759	.375	-22.920	8.920
		150	-.464	5.479	.933	-11.706	10.777
		500	4.571	5.373	.402	-6.453	15.596
	High	0	-2.679	6.272	.673	-15.548	10.191
		150	-8.786	7.343	.242	-23.851	6.280
		500	-12.036	6.348	.069	-25.062	.990
High	Low	0	-21.929*	7.193	.005*	-36.687	-7.170
		150	-4.607	5.351	.397	-15.587	6.373
		500	-6.750	5.864	.260	-18.782	5.282
	Medium	0	-10.071	6.743	.147	-23.908	3.765
		150	-2.786	7.471	.712	-18.115	12.543
		500	-11.607	5.978	.063	-23.873	.659
	High	0	-6.750	7.495	.376	-22.129	8.629
		150	-17.714*	5.710	.004*	-29.430	-5.999
		500	-18.714*	8.378	.034*	-35.904	-1.525