RETHINKING HUMAN ATTENTION AND ITS COMPONENTS

by

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B. A., The University of British Columbia, 2000
M. A., The University of British Columbia, 2003

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE STUDIES

(Psychology)

THE UNIVERSITY OF BRITISH COLUMBIA

November 2006

Abstract

People attend to where others are looking. In three sections, spanning six studies and 11 experiments, the present thesis examines whether this social orienting effect is reflexive (Section I), if it should be considered a unique form of attentional orienting (Section II), and how it relates to traditional forms of reflexive and volitional spatial orienting (Section III). The results from Sections I and II indicate that social attention can be conceptualized as a strongly reflexive effect that is unique to eye gaze direction. However, other directional cues, like arrows, trigger similar spatial attention effects although their effects do not appear to be as strongly reflexive as the effects produced by eye gaze. The results from Section III demonstrate that reflexive orienting elicited by an attentional cue positioned at fixation, such as gaze or an arrow, can occur independently of the orienting effects produced by cues that have typically been used to study reflexive and volitional orienting, i.e., nonpredictive peripheral onsets and predictive central cues, respectively. Taken together these results carry important implications for understanding social attention specifically, and the conceptualization and experimental examination of human spatial attention in general.

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Acknowledgements

First, I would like to express sincere gratitude to my supervisor Alan Kingstone for giving me exceptional guidance and support during my graduate studies. I am truly privileged to have had you as an advisor. I would also like to acknowledge my colleagues and collaborators, especially Chris Friesen, for inspiring me through thought-provoking conversations and debates. Finally, the work presented here would not have been completed without the unconditional love, support, and encouragement that I have received from my parents Sonja and Pavle and especially from my husband Sasa.

Co-Authorship Statement

I am the primary author on all the work presented in this PhD Dissertation, save for the study presented in Chapter 5, to which I have contributed equally as the first author. This study was included in the dissertation because its results are directly relevant to the main theme of the thesis.

CHAPTER 1

General Introduction

In one of the earliest conceptualizations of human attention, William James (1890) proposed that attention might be conceived as being either reflexive or volitional in nature. According to James, reflexive attention reflected passive activation by sensory events, whereas volitional attention reflected conscious effort to actively attend to sensory events. This distinction between reflexive and voluntary attention has persisted into modern experimental psychology and helped to form one of the most influential behavioral tasks for studying human attention -- the Posner cuing paradigm (e.g., Posner, 1978; Posner, 1980; Posner, Snyder, Davidson, 1980). In this cuing paradigm, an abrupt peripheral onset stimulus, that <u>does not predict spatially</u> where a response target is likely to appear, is used to engage reflexive attention; and a central directional stimulus, usually an arrow, that <u>does predict spatially</u> where a response target is likely to appear, is used to engage volitional attention (e.g., Jonides, 1981).

Importantly, this clear cut distinction between nonpredictive peripheral cues that isolate reflexive attention and predictive directional central cues that isolate volitional attention, has recently been brought into question. Specifically, there is now a substantial body of evidence suggesting that a picture of a face with the eyes directed toward a peripheral location will trigger a shift of attention to the cued (gazed-at) location even when the eyes are spatially nonpredictive (e.g., Friesen & Kingstone, 1998; Driver et al., 1999; Langton & Bruce, 1999). In other words, nonpredictive central directional cues would appear to trigger reflexive attention.

This PhD dissertation investigates the properties of the attentional shift elicited by eye direction and the implications of this result for attention research. In Section I the evidence that eyes as an attentional cue trigger a special form of reflexive social orienting is considered. In Section II this social orienting effect for gaze direction is

considered relative to another familiar directional cue, the arrow. Finally, in Section III a comparison between reflexive orienting elicited by peripheral cues and reflexive orienting elicited by central cues is considered. Collectively, these data converge on the conclusion that central cues activate reflexive orienting. The behavioral signature of this reflexive effect is similar for eye direction and arrow direction, although as suggested by studies in Section I, and confirmed by studies in Section II, eyes are more strongly reflexive than arrows thus making gaze direction unique. The general discussion considers the implications of these results for understanding both reflexive and volitional spatial orienting.

Modes of Attention Orienting

It is commonly conceived by researchers in the field of human attention that spatial orienting can be allocated in two qualitatively different ways: reflexively, sometimes called exogenous orienting; and volitionally, sometimes called endogenous orienting. Reflexive shifts of attention are understood to occur when stimuli in the environment capture attention independent of one's goals and expectations. Volitional shifts of attention, on the other hand, are understood to occur when attention is allocated in accordance with one's internal goals and expectations. Both reflexive and volitional attention can be allocated either in conjunction with eye movements, called overt orienting, or independently of any change in eye position, called covert orienting (Klein, Kingstone & Pontefract, 1992; Klein & Shore, 2000; Klein, 2005). The experiments presented in this dissertation have been designed to measure covert attentional orienting, that is, orienting of attention across space that occurs when participants maintain central fixation and do not make eye movements.

This division of human spatial attention in terms of reflexive and volitional processes is reflected in the prominent experimental cuing paradigm that is often referred to as the Posner cuing paradigm (e.g., Posner, 1980; Posner, Snyder & Davidson, 1980). This paradigm assumes that attention is a limited-capacity resource which benefits the processing efficiency of information arriving at an attended location, resulting in lower response time (RT) and/or response errors. Because human attention displays a capacity limitation, however, enhanced processing efficiency at an attended location is accompanied by poorer processing efficiency at unattended locations, resulting in higher RT and/or response errors. Two distinct versions of the Posner cuing task have been developed, each specific to the mode of attentional orienting to be measured. A peripheral cuing task (Posner, Snyder, Davidson, 1980; Posner, 1980) was designed to measure reflexive attentional orienting, and a central arrow cuing task (Posner, Snyder & Davidson, 1980; Jonides, 1981) was designed to measure volitional attentional orienting.

Reflexive Attention

Reflexive attention has traditionally been conceptualized as arising from the sensory pathway activation irrespective of an observer's current goals and expectations. To maximize the observed benefits of reflexive spatial attention a suprathreshold stimulus, such as an abrupt luminance change, normally serves as the attentional cue (e.g., Posner, 1980). In the peripheral cuing task, the fundamental reflexive characteristics of attentional orienting are considered to be revealed by requiring subjects to detect a target light at a peripheral location that was or was not preceded by an abrupt peripheral event, called the cue. Importantly, this peripheral cue does not predict where the target stimulus will appear. As a result, any spatial effects of the cue on target detection are attributed to the reflexive orienting of attention toward the cued

location. The standard behavioral result is that RT to detect a target, typically measured by a simple button-press response, is facilitated when a target appears at the cued location 300 ms or less after the cue was first presented. Beyond 300 ms, and lasting for up to a second or more, a target is detected more slowly at the cued location relative to a noncued location. This effect is called Inhibition of Return (IOR; Posner & Cohen, 1984). The typical stimuli and sequence of events occurring in the peripheral cuing task are illustrated in Figure 1.1A.

Voluntary Attention

In contrast to reflexive attention, voluntary orienting is conceptualized as arising from conscious allocation of attentional resources by an observer towards an expected or current sensory event. To maximize the benefits of endogenous spatial attention, attentional cues manipulating voluntary orienting typically require development and maintenance of a spatial expectancy. In the central arrow cuing task, the fundamental volitional characteristics of attentional orienting are thought to be revealed by requiring subjects to detect a target light at a peripheral location that was, or was not, pointed at by a central arrow. Importantly, the central arrow does predict where a target stimulus is likely to appear. Because spatial effects of the central arrow are assumed to occur only when the arrow is spatially predictive, the observed attention effects are attributed to volitional orienting of spatial attention (Jonides, 1981). The standard result is that RT to the target at the cued location is facilitated for all cue-target intervals exceeding 300ms with no evidence of IOR (e.g., Klein, Kingstone & Pontefract, 1992). The typical stimuli and sequence of events occurring in the central arrow cuing task are illustrated in Figure 1.1B.

<u>Spatially Nonpredictive Central Cues</u>

In contrast to the classic conceptualization of peripheral/reflexive and central/volitional cuing described above, recent studies have reported a novel behavioral result suggesting that spatially nonpredictive cues presented at central fixation will trigger reflexive shifts of covert spatial attention. In this modified Posner cuing task, subjects are required to detect a target light appearing at a location indicated by a <u>central cue</u> that <u>does not predict</u> where a target is going to appear. The typical results indicate that RT to respond to a target at the cued location is facilitated 100 ms after cue onset and this facilitation effect persists for cue-target delays of 700-1000ms with no evidence of IOR emerging (e.g., Friesen & Kingstone, 1998; Driver et al, 1999; Langton & Bruce, 1999). Because the attentional effect in this paradigm is triggered by a directional cue that carries no reliable spatial information as to where the target is likely to appear, and because the behavioral effects of the cue emerge very rapidly, the observed orienting effect has been interpreted as reflecting a reflexive shift of attention to the cued location (e.g., Friesen & Kingstone, 1998; Langton & Bruce, 1999; Driver et al. 1999). Figure 1.1C illustrates stimuli and a typical sequence of events used in the central nonpredictive cuing task.

In one of the first studies to employ spatially nonpredictive central cues, Friesen and Kingstone (1998) presented a schematic face (the cue) on a computer screen that gazed to the left or right. Importantly, gaze direction did not predict where the target would appear. Friesen and Kingstone reported that within 100 ms of cue presentation, participants were faster to detect, localize, and identify targets appearing at a gazed-at target location compared to a not gazed-at target location. Driver et al. (1999) and Langton and Bruce (1999) reported similar results using central uninformative eye direction cues (Driver et al, 1999) and eye and head orientation cues (Langton and

Bruce, 1999) that were derived from photographs of real faces. Driver et al. (1999) examined the influence of pupil deviation on a letter discrimination task and found that identification responses were always faster for targets appearing at a gazed-at location. Similarly, Langton and Bruce (1999) examined the influence of pupil deviation and head orientation on target detection responses. Extending Friesen and Kingstone's (1998) and Driver et al's (1999) data, their results indicated that head orientation also triggered reflexive shifts of spatial attention. Importantly, and in agreement with Friesen and Kingstone's (1998) results, the attentional effects obtained with pictures of real faces emerged early, 100-300 ms after the cue was presented, and persisted for approximately a second.

Although the interpretation that central nonpredictive cues trigger reflexive orienting of attention is consistent with the reported data, in their original study Friesen and Kingstone (1998) noted that in addition to displaying properties of reflexive orienting, the orienting effect shared two important properties with traditionally defined volitional orienting. Namely, consistent with a typical arrow cuing task, the orienting effect was triggered by a cue presented at central fixation (Jonides, 1981; Müller & Findlay, 1988; Müller & Rabbitt, 1989) and, the IOR effect, which is typically absent when observers orient attention voluntarily (e.g., Taylor & Klein, 1998), was also absent when central spatially nonpredictive cues were used. Because attentional orienting triggered by central eye gaze possesses both reflexive and volitional characteristics, it has sometimes been conceptualized as representing a "hybrid form of covert orienting" (Klein & Shore, 2000, p. 203) with "ambiguous" underlying control mechanisms (Klein, 2005) or more extremely, it has been speculated that orienting to central eye gaze is just an instance of top-down volitional orienting (e.g., Vecera & Rizzo, 2004; Vecera & Rizzo, in press).

Dissertation Overview

This PhD dissertation, which follows a manuscript based format, is comprised of eleven experiments that make up six studies. These studies are divided into three sections. In Section I, two studies explore the proposed reflexive nature of the spatial attention effect triggered by central eye direction cues (Chapter 2 and 3). In Section II, three studies investigate the supposed uniqueness of reflexive orienting to eye gaze relative to the familiar central arrow cue (Chapters 4-6). In Section III, a novel cuing study compares reflexive orienting elicited by central and peripheral cues (Chapter 7). In the General Discussion (Chapter 8) the implications of the collective data for past and present conceptualizations of reflexive and volitional attention are discussed.

Figure1.1
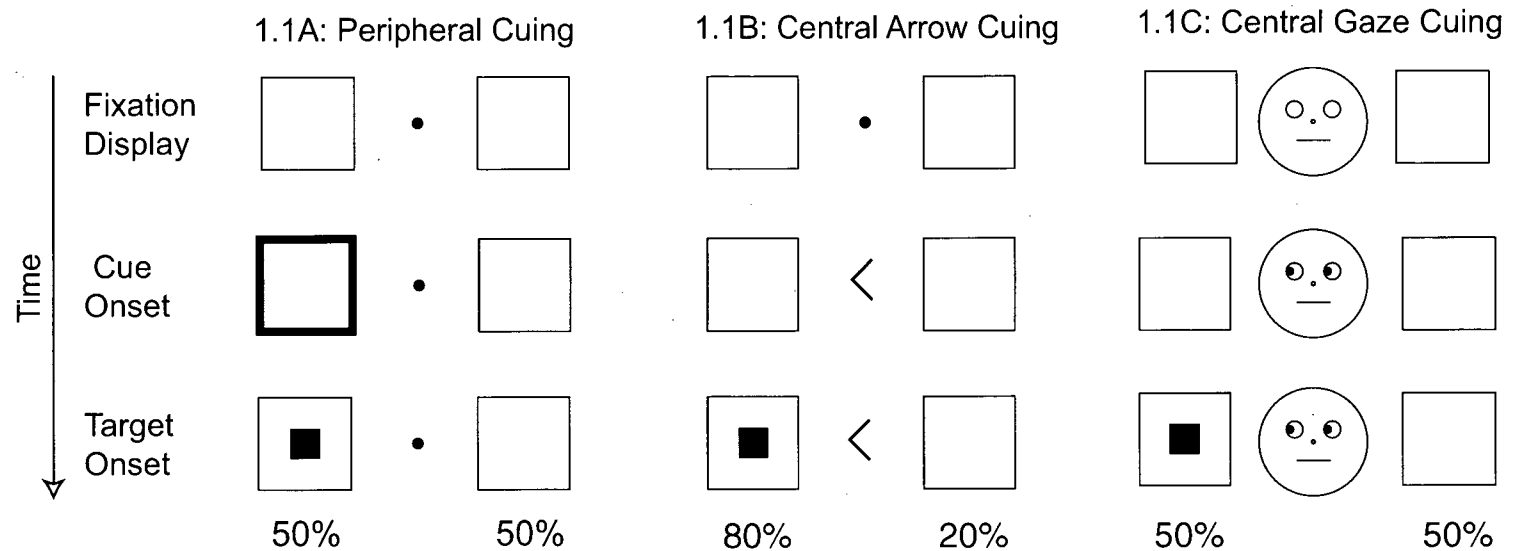
Figure 1.1. An Illustration of the Posner Cuing Task. Each row presents three stages (Fixation Display, Cue Onset, and Target Onset) that are standard to the paradigm. **1.1A: Peripheral Cuing Task.** At the start of each trial a central fixation dot is flanked by two squares. The left or right box is cued by brightening a box briefly (illustrated by the thick black line), and then a target is presented in either cued or uncued box. The task is to press a key as quickly as possible when the target is detected. The target appears in the cued box 50% of the time and in the uncued box 50% of the time. Thus, the cue does not predict where the target will appear. **1.1B: Central Arrow Cuing Task.** The left or right box is cued by a central arrow pointing towards a box, and then a target is presented in either cued or uncued box. The task is to press a key as quickly as possible when the target is detected. The target appears in the cued box 80% of the time and in the uncued box 20% of the time. Thus, the cue predicts where the target will appear. **1.1C: Central Gaze Cuing Task.** The left or right box is cued by eyes looking towards a box, and then a target is presented. The target appears in the cued box 50% of the time and in the uncued box 50% of the time. Thus, the cue does not predict where the target will appear.

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SECTION I: SOCIAL REFLEXIVE ATTENTION

Introduction

In the first laboratory study to measure reflexive orienting to eye direction, Friesen and Kingstone (1998) asked participants to detect, localize, or identify a peripheral target preceded by a central face that gazed left or right. Despite the fact that gaze direction and target location varied randomly from trial to trial, RT was shorter if a target appeared at a gazed-at versus a nongazed-at location. Because this effect emerged early and occurred even though participants knew that gaze direction was irrelevant both to the task and location of the target, Friesen and Kingstone (1998) concluded that gaze direction had triggered a reflexive shift in attention to the gazed-at location, possibly mediated by gaze-specific cells within the superior temporal sulcus (STS). A similar position was advanced by Driver et al. (1999) and Langton and Bruce (1999).

The first chapter of this thesis (Chapter 2) considers whether the reflexive gaze effect is sensitive to top-down cognitive control. To get at this issue, participants are shown an ambiguous stimulus cue that, depending on the top-down perceptual set adopted by participants, can be perceived either as a "car" or as containing "eyes". Consistent with a minor role for top-down cognitive control, the data indicate that a gaze orienting effect emerges when participants are instructed to see the stimulus as having eyes. Importantly however, this reflexive orienting effect, once activated, cannot be abolished by a change in the top-down perceptual set. Thus it appears that activation of the STS may be sensitive to top-down cortical input, but that once activated it cannot be inhibited easily (see Dolan et al., 1997; Bentin et al., 2002 for similar conclusions from neuroimaging data).

These first two experiments help to answer how attention comes to be oriented at a gazed-at location, but they do not answer why it is oriented there. This issue is considered in the final study of Section I (Chapter 3). The existing literature suggests

two main explanations for why attention is shifted to a gazed-at location. One account, the "social reading hypothesis" is that attentional orienting occurs because eye direction is normally understood to be a meaningful social cue, for instance, communicating information between people about their internal states, e.g., sexual attraction or disinterest (Baron-Cohen, 1995). The other explanation, the "feature correspondence hypothesis" is that people are sensitive to the fact that features of the eyes are often pointed toward important events in the environment (Langton & Bruce, 1999). Chapter 3, reports an investigation that dissociates these often entangled accounts by examining social orienting for individuals with high functioning autism (HFA) and typically developing (TD) individuals. The data reveal that orienting to a gazed-at location normally occurs because of the social meaning that is read into the gaze direction of another individual.

Together the results of these investigations indicate that orienting to where someone else is looking is a powerful, reflexive social phenomenon. Section II considers whether this means that no other directional cue can have a similar effect, and if other cues can have a similar effect what this means for studies of reflexive orienting to gaze direction.

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CHAPTER 2

Taking Control of Reflexive Social Attention

Recent behavioral studies indicate that humans will attend to where someone is looking (e.g., Friesen & Kingstone, 1998; Langton & Bruce, 1999). In the typical laboratory demonstration, a picture of a face looking left or right is projected onto a screen and observers are required to respond as quickly as possible to a target that appears beside the face. The standard finding is that response time (RT) to the target is shorter when the face is looking at the target rather than away from it, indicating that attention has been shifted to where the eyes are looking.

Several reasons have been put forward for why this social orienting effect is reflexive in nature. First, it occurs rapidly, within a few hundred milliseconds after a gazing face is presented (e.g., Friesen & Kingstone, 1998). Second, it occurs even if eye direction is negatively correlated with where a target might to appear (e.g., Driver et al, 1999; Friesen, Ristic & Kingstone, 2004). Third, cells in the right inferior temporal (IT) cortex are dedicated to processing gaze direction in an obligatory fashion, which dovetails with the finding that attention is shifted rapidly to where someone else is looking (Langton, Watt & Bruce, 2000).

Whether this social orienting effect is <u>purely</u> reflexive or not, however, has been the focus of considerable speculation. Some investigators have suggested, either explicitly or implicitly, that the effect is driven in a purely "bottom-up" fashion by cells in IT (e.g., Friesen & Kingstone, 1998; Kingstone, Friesen & Gazzaniga, 2000). For instance, in an early study of the social orienting phenomenon (Driver et al, 1999) observers were shown gazing faces and informed that on most trials a target would appear at the location opposite to where the eyes were looking (e.g., eyes looking left predicted that a target was likely to appear on the right). Even though the eyes were counterpredictive, observers first shifted attention to the gazed-at location (where the

target was unlikely to appear), suggesting that the initial attention shift triggered by gaze direction operates independent of top-down executive control processes that are sensitive to the predictive nature of a stimulus.

There are, however, also reasons to think that the social orienting effect depends at least in part on top-down processes that interpret the trigger stimulus. For instance, Dolan et al (1997) observed that ambiguous pictures activated face-processing cells in IT <u>only</u> when observers recognized the pictures as depicting faces. Similarly, Bentin and colleagues (2002) have recently demonstrated that neutral stimuli, such as a pair of dots, will trigger a face-specific brain potential <u>only</u> when the neutral stimuli are first represented as depicting the eyes of a face.

Importantly, each of these lines of evidence also has its shortcomings. For example, in the Driver et al. (1999) study observers never actually oriented attention to the predicted target location, raising the possibility that top-down control processes were never even engaged. Conversely, the studies by Dolan et al (1997) and Bentin et al (2002) lack behavioral data against which to compare the neural imaging results. Thus whether or not the social orienting effect, measured as a behavioral facilitation for targets appearing at the gazed-at location, is driven purely by bottom-up processes remains very much an open question. The aim of the present study was to address this issue directly.

Experiment 1

The present study used ambiguous displays to assess whether top-down processes have a behavioral effect on attentional orienting to gaze direction. Participants were tested in one of three conditions. In the FACE condition (based on the original work of Friesen & Kingstone, 1998), participants were presented with a

schematic face that gazed to the left or right of center. Target onset occurred 100 – 1000 ms after the face stimulus and was uncorrelated with gaze direction. In the other two conditions participants were presented with an ambiguous stimulus (see Figure 2.1). In the EYES condition participants were instructed that the stimulus was a picture of a hat pulled down to the eyes of a face. In the CAR condition participants were instructed that the stimulus depicted an automobile.

Our predictions were as follows. In the baseline FACE condition we expected to replicate the results of Friesen and Kingstone (1998), and many others (e.g. Langton & Bruce, 1999; Ristic, Friesen & Kingstone, 2003) with shorter RT at the gazed-at (valid) location versus the nongazed-at (invalid) location. A similar result was expected to emerge in the EYES condition, where the central stimulus would again be represented as gazing left or right. Two possible outcomes were plausible in the CAR condition. If face processing mechanisms in IT proceed in a purely modular bottom-up manner independent of top-down processing mechanisms, then performance in the CAR condition should replicate the EYES condition. That is, the cells in IT will analyze the stimulus as having the geometric shape of eyes, and trigger an attentional shift – a prediction well articulated by Pinker "... If objects other than faces (animals, facial expressions, or even cars) have some of these geometric features, the module will have no choice but to analyze them" (p 273). Alternatively, it is possible that top-down processing of the stimulus as depicting a gazing face is necessary for the social orienting effect to occur. If this is the case then in the CAR condition, and only in the car condition, a social orienting effect will be absent.

Method

Participants

All 45 participants were naive to the purpose of the experiment and assigned randomly to one of the three groups (N=15/group). Each completed 10 practice trials followed by 10 blocks of 60 trials for a total of 600 experimental trials. Catch trials, in which a target was not presented, varied randomly across trials and ranged from 6 – 10% in a given block.

In the FACE condition, participants were informed that the central stimulus depicted a face, and that eye direction did not predict target position. The instructions for the EYES and CAR conditions were carefully scripted so that the only difference between the two was the information regarding the identity of the central stimulus, i.e., a hat pulled down to the eyes or a car. Participants were informed that any changes in the central stimulus (e.g., eyes or car) did not predict target position.

Results

Key press errors, false alarms, anticipations (RT< 100 ms), and slow RTs (RT> 1000 ms) were classified as errors and excluded from analysis. For all conditions, false alarms occurred on less than 4.33% on catch trials. Additionally, less than 2.6% of all target present trials in each cue condition were trimmed because of errors. Mean RT, standard deviations, and error rates for each condition are presented in Table 2.1. Mean RTs were calculated for correct target trials for each condition as a function of validity and SOA across all participants. The means are illustrated in Figure 2. 2 and show that for both the FACE and EYES conditions RT was shorter when a target appeared at a gazed-at (valid) versus a nongazed-at (invalid) location, i.e., the social attention effect. In contrast, there was no reliable effect of validity in the CAR condition.

These observations were supported by a 3 x 2 x 4 analysis of variance (ANOVA) with condition (FACE, EYES, CAR) as a between subject factor and validity (valid, invalid) and SOA (100, 300, 600, and 1000 ms) as within subject factors. There were main effects for validity [$F(1,42)=19.97, p<.0001$] reflecting the overall facilitative effect of attention being allocated to a valid location; and SOA [$F(3,126)=91.69, p<.0001$] reflecting the general decline in RT that occurs as participants prepare to respond to a target (called a foreperiod effect; Bertelson, 1967). SOA also interacted with condition [$F(6,126)=2.48, p<0.05$], and validity, [$F(3,126)=6.43, p<0.001$] reflecting that the foreperiod effect was most pronounced in the FACE and EYES condition, and when the target was at the valid location. Most importantly, there was a significant condition x validity interaction [$F(2,42)=3.41, p<0.05$] consistent with attention being allocated to the valid location in the FACE and EYES conditions but not in the CAR condition. In agreement with this interpretation, when each condition is analyzed individually, there is a significant main effect of validity for the FACE and EYES conditions [both $Fs>9.4, ps<.01$] but not for the CAR condition [$F<1$; the only significant effect being SOA [$F(3,42)=19.98, p<.0001$].

Discussion

The results of Experiment 1 were clear cut. Attention was shifted reflexively by stimuli that were represented as eyes in the FACE and EYES conditions. However, the very same ambiguous stimulus used in the EYES condition failed to trigger reflexive orienting in the CAR condition. As noted in the introduction to Experiment 1, this data pattern agrees with the position that bottom-up orienting mechanisms triggered by perceived gaze direction are modulated by top-down processes. We return to this issue in the general discussion.

The reason why we chose to assign different participants to different conditions in Experiment 1 was because there is recent neuroimaging evidence suggesting that once people perceive an ambiguous stimulus as representing a face, they have difficulty representing it as another type of object (Bentin & Golland, 2002). In Experiment 2 we turned this bias toward face representation to our advantage. All the participants in Experiment 2 received both the EYES condition and the CAR condition, with half receiving the EYES condition first and half receiving the CAR condition first.

<div align="center">Experiment 2</div>

Manipulating the EYES and CAR conditions within the same participants is crucial for two reasons. First, a between group comparison of performance after the first half of testing provides a direct replication of the EYES versus CAR comparison in Experiment 1. Here we expected that if the difference we observed previously between these conditions is real and replicable we should find again that attention is shifted only in the EYES condition.

Second, and most importantly, a different prediction is made for the second half of testing. Here we expected that the participants who had first received the CAR condition would now show evidence of reflexive orienting in the EYES condition because the central stimulus would now be perceived as a face. This prediction stands in contrast to the outcome expected for the participants who had received the EYES condition first. Because of the asymmetry noted above, where a stimulus persists in being perceived as a face once it is seen as a face, we expected that participants who received the CAR condition second – that is, after receiving the EYES condition -- would continue to show a validity effect in that condition.

Method

All 36 participants were naive to the purpose of the experiment and to the condition change that occurred halfway through testing. The apparatus and the ambiguous fixation stimuli were the same as in Experiment 1. Design and procedure were also the same with the following exceptions. Half the participants received the EYES condition before the CAR condition; the remaining participants received the reverse order of conditions. Each condition was preceded by 10 practice trials followed by 8 blocks of 60 trials, for a total of 960 test trials. Instructions for these conditions were as before.

Results

False alarms occurred on less than 2.5% of the catch trials, and less than 0.5% of all target present trials were in error. Mean RTs, standard deviations, and their associated error rates are presented in Table 2. Mean RTs for correct target trials were calculated for each participant. Interparticipant means across SOA and validity conditions for both conditions are shown in Figure 2. 3.

To test whether the effects observed in Experiment 1 were replicated in the present study, we conducted a 2 (condition) x 2 (validity) x 4 (SOA) ANOVA with EYES [first] versus CAR [first] as a between subject factor and validity and SOA as within subjects factors. The results replicated Experiment 1, with significant main effects of validity [$F(1,34)=16.57, p<.0005$] and SOA [$F(3,102)=85.24, p<.0001$] as well as the crucial interaction between condition and validity [$F(1,34)=4.26, p<.05$] reflecting again the presence of a validity effect in the EYES condition and the absence of one in the CAR condition. No other effects were significant.

We had predicted that both the EYES [second] and CAR [second] conditions would reveal a significant effect of validity. A 2 (condition) x 2 (validity) x 4 (SOA) ANOVA confirmed this prediction. The main effects of validity [$F_{(1,34)}=18.9, p<.0001$] and SOA [$F_{(3,102)}=68.98, p<.0001$] were highly significant with no significant interactions (all $Fs<1.8$, $ps>.14$). In particular, there was no condition x validity interaction ($F<1$), demonstrating that there was a significant, and equivalent, effect of validity for both the EYES and CAR conditions[1].

Together these data converge on the conclusion that the validity effect varied as a function of condition only for those participants that received the CAR condition first. This was confirmed by two separate within-group 2 (condition) x 2 (validity) x 4 (SOA) ANOVAs. For the CAR [first] – EYES [second] group, main effects of validity [$F_{(1,17)}=9.28, p<. 01$] and SOA [$F_{(3,51)}=55.54, p<.0001$] were highly significant, as was the condition x validity interaction [$F_{(1,17)}=4.61, p<.05$]. No other effects were reliable [all $Fs<2.1$, all $ps>.1$]. In contrast, for the EYES [first] – CAR [second] group, the main

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[1] Note that, as in Experiment 1, when CAR [first] was analyzed using a separate 2 (validity) x 4 (SOA) within-subjects ANOVA, only a main effect of SOA was significant [$F_{(3,52)}=35.71, p<. 0001$]. The lack of a significant validity effect ($p>.12$) or validity x SOA interaction ($p>.19$) indicates there was no social attention effect in this condition.

[2] We were concerned that the validity effect emerged in the CAR [first] – EYES [second] group because of practice effects rather than because of the perception of the ambiguous stimulus as possessing eyes. A close examination of the data eliminated this concern. For Experiment 2 we compared the last two blocks (blocks 7 and 8) of the first condition with the first two blocks (blocks 9 and 10) of the second condition. As before, in the CAR [first] – EYES [second] group there was a significant condition x validity interaction [$F_{(1,17)}=4.6, p<. 05$] reflecting the emergence of a validity effect when the condition was switched from CAR to EYES. In contrast, in the EYES [first] – CAR [second] group a significant validity effect was observed [$F_{(1,17)}=6. 55, p<. 05$] which persisted across conditions [condition x validity interaction, $F<1$]. Critically, when the CAR condition in Experiment 1 was examined in an identical manner (blocks 7 and 8 vs. blocks 9 and 10), there were no significant effects involving validity (all $Fs<1$). Together these data demonstrate conclusively that the validity effect emerged in the CAR [first] – EYES [second] group, and persisted in the EYES [first] – CAR [second] group, because of the perception of the ambiguous stimulus as possessing eyes.

effects of validity [F (1,17)=23.52,p<. 001] and SOA [F (3,51)=46.62,p<. 0001] but importantly there was no interaction involving validity (all ps >.17) [2].

Discussion

The results of Experiment 2 extended the results reported in Experiment 1 in two important ways. One, we found again that attention was shifted reflexively when the ambiguous stimulus was first perceived as EYES but not when it was initially seen as a CAR. Importantly when these participants in the CAR condition were presented with the EYES condition, they began to shift attention reflexively.

Two, we found that the participants who received the EYES condition first continued to shift attention reflexively when presented with the CAR condition. This new result converges with, and provides behavioral support, for the Bentin and Golland (2002) finding that once an ambiguous stimulus is perceived as a face it will persist in being perceived as such.

General Discussion

Attention is shifted reflexively to where someone else is looking. A wealth of evidence implicates face processing mechanisms specific to inferior temporal (IT) cortex as being crucial to this social attention effect (e.g., Kanwisher, 2000; Hoffman & Haxby, 2000). In the present study we asked whether this social attention effect is driven by neurons in IT in a purely bottom-up manner independent of top-down control processes responsible for stimulus interpretation. The answer is no. The reflexive social attention effect is modulated by top-down control processes. Two lines of evidence in the present study converge on this conclusion.

First, in Experiment 1, we showed that whether the same stimulus triggers a reflexive shift in attention depends on how it is perceived by the observer. That the

absence or presence of the reflexive social attention effect can be triggered by a slight change in stimulus interpretation demonstrates that this attention effect is sensitive to top-down control.

Second, in Experiment 2, we found an asymmetry in the ability to manipulate the attention shift triggered by the ambiguous stimulus. Specifically, when first informed that the stimulus was a CAR and then later informed that it contained EYES, an attention shift was observed only in the EYES condition. However, when first informed that the stimulus possessed EYES, and then that it was a CAR, the attention shift in the EYES condition persisted into the CAR condition. This provides strong and convergent behavioral evidence that once top-down processes lead to the perception of a stimulus as a face, it is extremely difficult to avoid seeing that stimulus as a face. Together the data go a long way toward reconciling a point of contention within the field – whether or not the reflexive social attention effect is sensitive or not to top-down control. On the one hand our study shows clearly that the social attention effect is sensitive to top-down control insofar as determining whether a stimulus is at first perceived as possessing facial features or not. On the other hand, the social attention effect is not sensitive to top-down control insofar as a stimulus will persist in being seen as having face features once it has been perceived that way. This latter finding highlights why the social attention effect must ultimately be considered as reflexive in nature, for once a stimulus activates IT and is perceived as having features such as eyes, the attentional effect of this stimulus appears to be insensitive to top-down modulation. This complex interplay between reflexive and volitional attention, and how the activation of bottom-up processes may rely on executive top-down processes, dovetails with a growing recognition that reflexive attention may depend ultimately on

the meaning that individuals attach to stimuli (see Rauschenberger, 2003 for a recent

review on this issue).

Table 2.1.

Condition	FACE			EYES			CAR		
	M	SD	%E	M	SD	%E	M	SD	%E
100 ms SOA									
Valid	341	49	.5	353	55	.2	350	36	0
Invalid	342	50	.8	354	57	.8	349	36	.3
300 ms SOA									
Valid	318	38	2.3	322	53	1.6	322	42	1.3
Invalid	329	43	2.3	337	53	2.2	328	43	1.3
600 ms SOA									
Valid	297	38	.8	305	44	.4	312	37	.5
Invalid	309	42	.7	318	46	.4	314	37	.6
1000 ms SOA									
Valid	309	46	.6	314	39	.7	332	41	.9
Invalid	313	41	.6	321	47	.3	329	37	.5

Table 2.1. Mean RTs, standard deviations, and error rates for Experiment 1.

Table 2.2.

Condition	GROUP											
	CAR-EYES						EYES-CAR					
	CAR			EYES			EYES			CAR		
	M	SD	%E	M	SD	%E	M	SD	%E	M	SD	%E
100 ms SOA												
Valid	336	33	.1	335	36	.3	330	35	.3	323	39	.9
Invalid	339	33	.1	341	43	.1	337	34	.2	325	42	.2
300 ms SOA												
Valid	307	29	2	305	34	2.1	304	33	.7	305	43	.9
Invalid	315	33	1.5	315	42	1.4	313	30	.8	308	38	1.5
600 ms SOA												
Valid	306	35	.2	302	38	.3	288	29	.3	287	33	.7
Invalid	305	27	.8	307	36	.5	298	28	.4	296	37	1.0
1000 ms SOA												
Valid	317	34	.2	311	36	.4	305	31	.3	299	37	.6
Invalid	315	32	.2	314	32	.3	307	31	.7	301	30	.2

Table 2.2. Mean RT, standard deviations, and error rates for Experiment 2.

Figure 2.1

FACE   EYES OR CAR

Fixation Display
675 ms

Cue Onset

Time

Target Onset
until response or 2700 ms
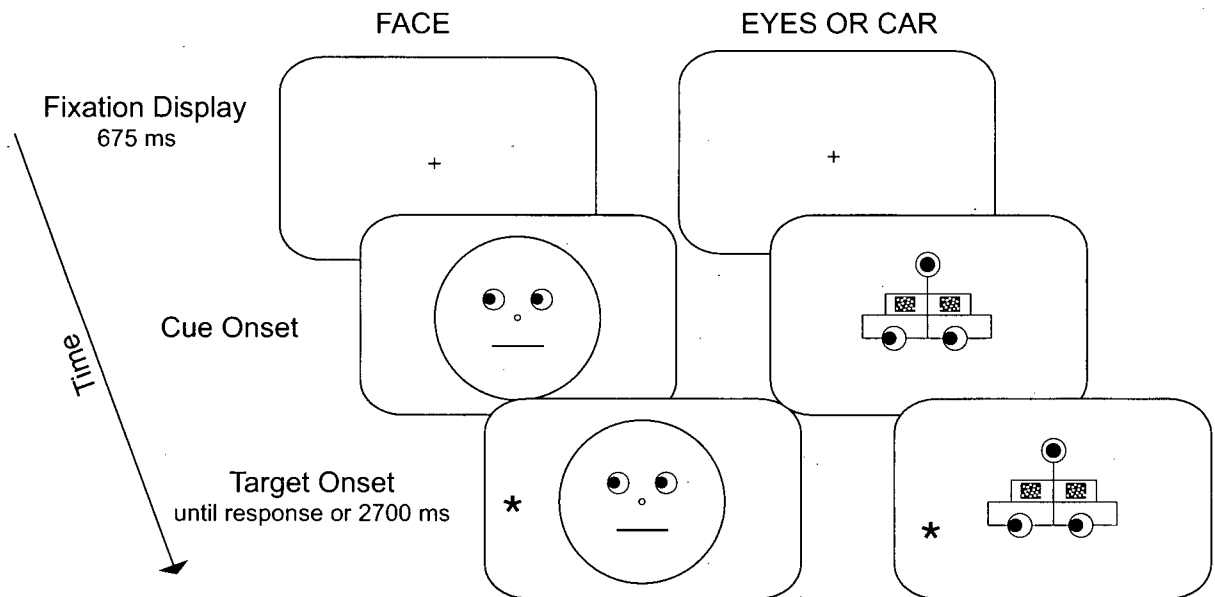
Figure 2.1. Illustration of stimuli (not to scale) and sample sequence of events. Every trial began with a 675 ms presentation of a fixation point (subtending 1°) followed by a central stimulus cue (FACE, EYES, or CAR). The stimulus onset asynchrony (SOA) separating the presentation of the central cue and the target was 100, 300, 600, or 1000 ms. Cue direction (e.g., eyes left or right), target position, and SOA were varied randomly. Participants were instructed to maintain central fixation and press the spacebar on a computer keyboard as quickly as they could when the target was detected. Both the central stimulus and the target remained present until a response was made or the trial timed-out after 2700 ms. Response time (RT) was measured from the onset of the target. The intertrial interval was 680 ms. The central stimulus condition was manipulated between participants. All computer stimuli were black drawings shown on a white background. The FACE stimulus was comprised of a circle outline (8.2° long and 7.2° wide) with two inner upper circles representing eyes, middle small circle representing the nose (0.2°) and the straight line representing the mouth (2.5° in length). The circle outline of eyes subtended 1 and filled-in circles representing pupils measured 0.6°. The pupils were positioned so that they were either touching the left or right circle outline. The central stimulus was identical for the EYES and CAR conditions. This stimulus was a symmetrical black and white line drawing. It measured 5° in width and 4° in height. The line drawings of three circles subtended 1° and black filled in circles measured 0.6°. The target was a black asterisk appearing on either left or right side of the central cue with an eccentricity of 7° of visual angle. The asterisk was 1° high and 0.9° wide.

Figure 2.2
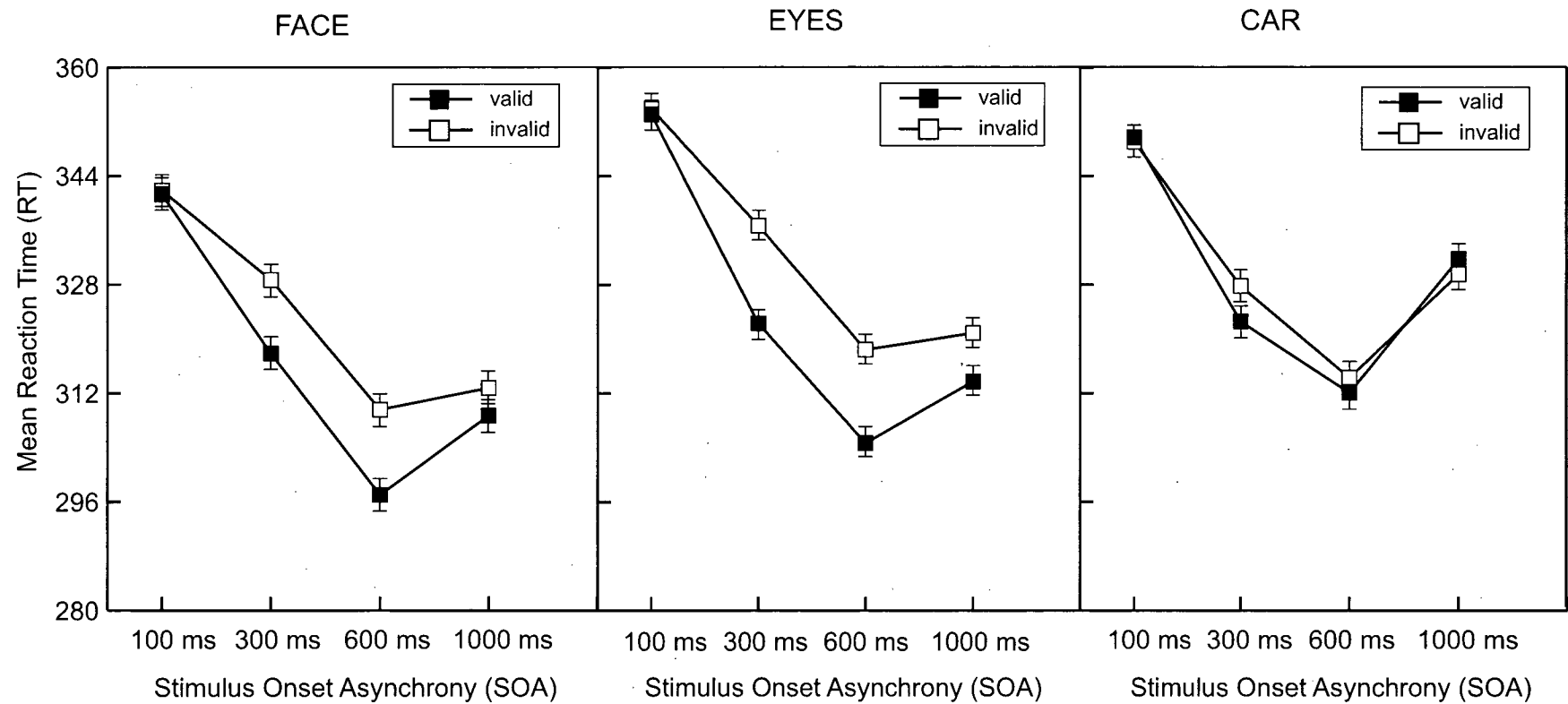
Figure 2. 2. Experiment 1 results. Figure 2.2 shows mean RTs in milliseconds as a function of SOA and validity for the three stimulus cue conditions (FACE, EYES, CAR) manipulated in Experiment 1. Error bars depict standard error of the difference of the means.

Figure 2.3
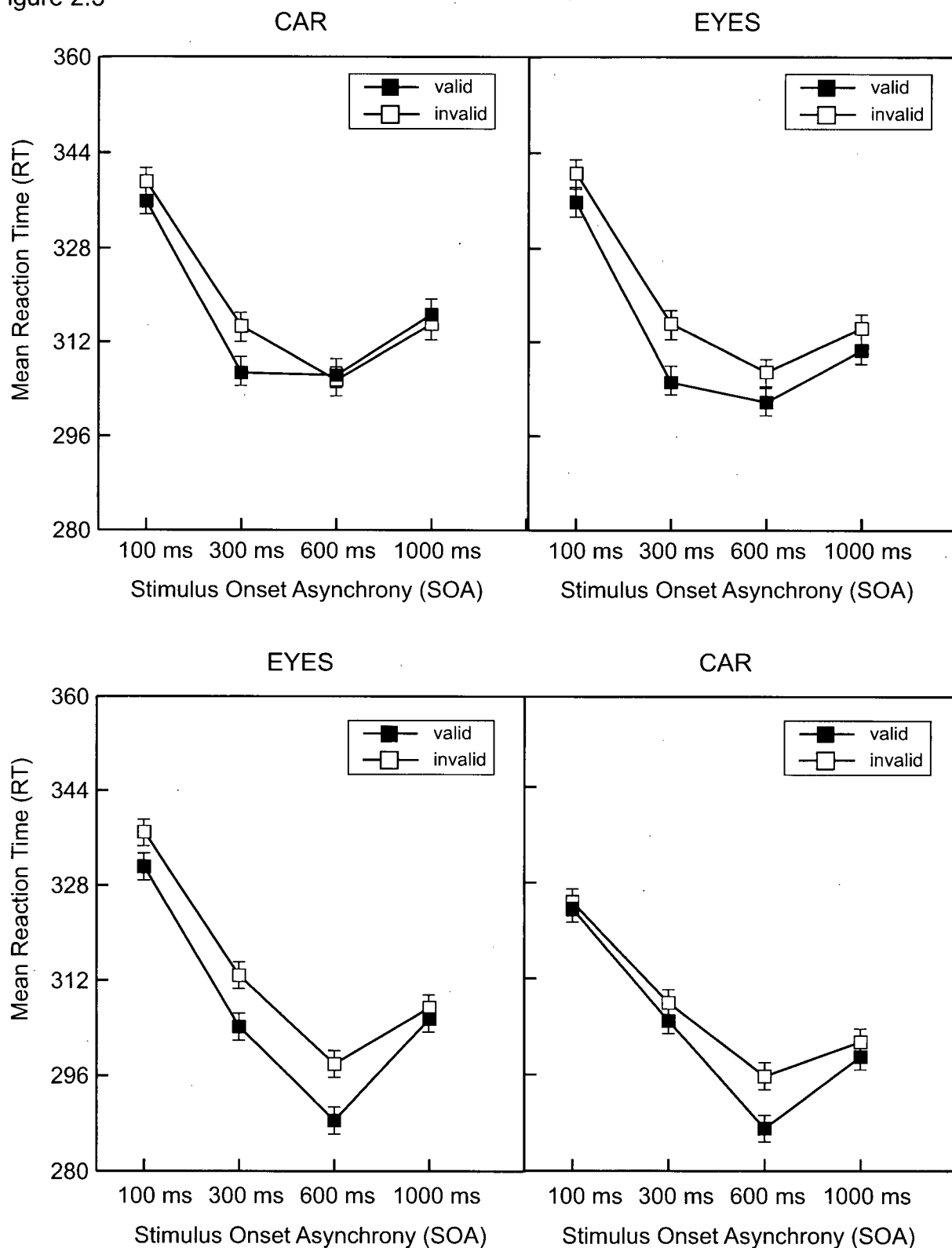
Figure 2.3. Experiment 2 results. Figure 2.3 illustrates mean RTs in milliseconds as a function of stimulus onset asynchrony (SOA) and stimulus cue validity in Experiment 2. The top row illustrates results for the CAR [first]-EYES [second] group and the bottom row shows the results for the EYES [first]-CAR [second] group. Error bars depict standard error of the difference of the means.

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CHAPTER 3

Eyes are Special but not for Everyone: The Case of Autism

Why do we have a tendency to shift our attention to where other people are looking? Investigations suggest that there are two possible explanations. One is that eye direction conveys key social information, such as status, personal interest, and attentional engagement (Baron-Cohen, 1995). We call this the social reading hypothesis. The other is that people are sensitive to changes in the basic stimulus features that are associated with shifts in gaze direction, in particular, the correspondence between the location of an interesting event in the environment and the position of the pupils/irises in the eyes that are directed towards that location (Langton & Bruce, 1999; Friesen & Kingstone, 1998). We call this the feature correspondence hypothesis.

In the past, these two conceptualizations were tied so closely to one another that they were often discussed as though they were synonymous, as it is difficult to imagine a natural situation in which the social meaning associated with gaze direction and the perceptual features associated with gaze direction could be disentangled (Driver et al, 1999). In the present study, we show that the two indeed can be dissociated, a finding that carries substantial implications for the understanding of human social cognition.

<div align="center">Method</div>

We examined the performance of a total of 47 participants (see Table 3.1), who viewed static displays of left- and right-deviated gaze on a computer screen. The participants were asked to make a speeded keypress response when they detected a target occurring to the left or right of the face following one of four gaze cue - target delay intervals (see Figure 3.1). Both high functioning individuals with autism (HFA) and typically developing peers (TD) were assigned randomly to either the nonpredictive gaze condition or the predictive gaze condition. In the nonpredictive condition, a target appeared at the gazed-at location 50% of the time and at the not-gazed-at location 50%

of the time. In the predictive condition, a target appeared at the gazed-at location 80% of the time and at the not-gazed-at location 20% of the time.

Results

When eye direction was spatially predictive, as illustrated in Figures 3.2A & 3.2C, both HFAs and TDs were faster to detect targets occurring at the gazed-at location. This indicates that both groups could perceive and use gaze direction as an attentional cue when the correspondence information was known to be a reliable aid to the task at hand. The key question, however, is whether attending to a gazed-at location is driven by the stimulus features (high correspondence between the cue and the target) or by social relevance of perceived gaze direction.

Figures 3.1B and 3.1D show that, consistent with previous findings (Friesen & Kingstone, 1998) TDs shifted their attention in response to perceived eye direction when it was spatially nonpredictive (that is, when the correspondence between eye direction and target location was at chance). In contrast, HFAs did not shift their attention in response to nonpredictive eye direction. This difference in performance supports the social reading hypothesis as TDs, who can respond to the social power of eyes, orient automatically in response to gaze direction even when it conveys no predictive information about environmental events. In contrast, HFAs do not attend to eye direction when it is spatially nonpredictive. This is consistent with the notion that HFAs are not sensitive to eyes as displaying socially relevant information (Grelotti, Gauthier & Schultz, 2002; Klin et al, 2002; Shultz et al, 2000) but are exquisitely sensitive to changes in event probability in their environment (Klinger & Dawson, 2001). Thus, our experiment supports the feature correspondence hypothesis with regard to HFAs. It also highlights the outcome that HFAs essentially outperform the TDs in the nonpredictive condition insofar as HFAs were not "fooled" by a nonpredictive gaze cue.

Discussion

The results of the present study suggest that efforts to train individuals with autism to use eye direction as a probabilistic feature correspondence cue fail to capture the key and fundamental component that gaze direction is normally used as a cue that is prioritized by the human attention system because of its social relevance. At best, individuals with autism appear to learn to orient attention to features that are usually confounded with eye direction, such as abrupt transients and stimulus motion (Swettenham et al, 2003; Chawarska, Klin & Volkmar, 2003; Kylliäinen & Hietanen, 2004; Senju et al, 2004). This failure to appreciate the social power of human eyes appears to be grounded in fundamental differences in brain function between individuals with autism and the general population. For example, functional neuroimaging evidence indicates that the superior temporal sulcus' typical specialization for processing faces and eyes (Allison, Puce & McCarthy, 2000; Hoffman & Haxby, 2000; Deaner & Platt, 2003) is not evident consistently in individuals with autism (Klin et al, 2002; Schultz et al, 2000).

Our study provides evidence that perceived social relevance, and not feature correspondence, drives automatic attentional orienting in response to gaze direction for typically developing individuals, but that feature correspondence, and not social relevance, mediates attention to gaze effects in individuals with autism. As such, the present study provides the first dissociation of these two often-confounded explanations, carrying with it important implications for understanding the development of social attention in both healthy and atypical populations.

Table 3.1.

Condition	Group	N	Mean IQ	Mean CA
Predictive Gaze	HFA	12 (11 males)	106.1	17.1
	TD	11 (7 males)	100.1	15.0
Nonpredictive Gaze	HFA	12 (12 males)	110.8	20.5
	TD	12 (12 males)	114.8	21.8

Table 3.1. Detailed participant information. All individuals included in High Functioning Autism (HFA) group met the diagnostic criteria for HFA or Asperger Syndrome according to the Autism Diagnostic and Observational Schedule-Generic (Lord et al, 2000) and the Autism Diagnostic Interview-Revised (Lord et al, 1994). Participants included in the typically developing (TD) group were screened for history of psychiatric disorders. Groups were matched for mean IQ and chronological years of age (CA). Four participants (not shown) were excluded due to failures to perform the speeded aspect of the task.

Figure 3.1.

Fixation Display
675 ms

Gaze Cue Onset
105, 300, 600,
or 1005 ms

Target Onset
until response,
or 2700 ms
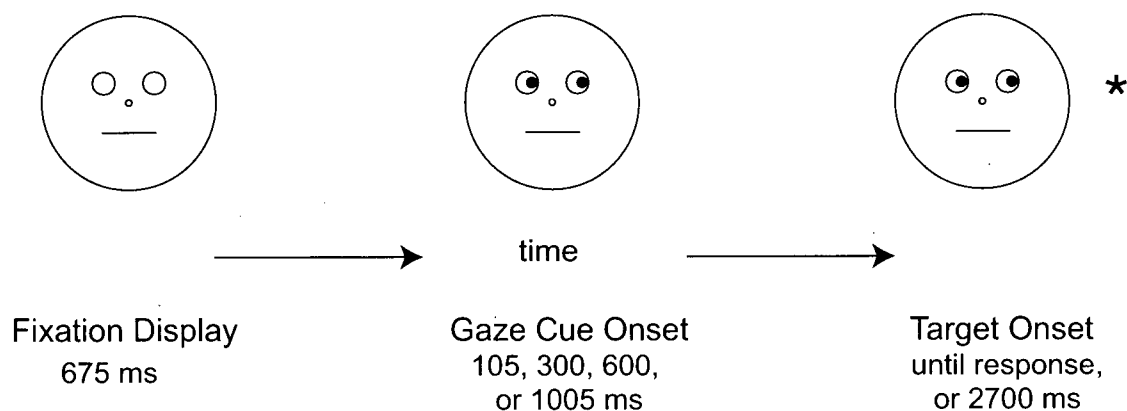
Figure 3.1. Illustration (not to scale) of stimuli and sample sequence of events. The start of each trial was signaled by the presentation of a schematic face with blank eyes. The pupils, looking left or right, appeared 675 ms later. A target presented at an eccentricity of 3.55° of visual angle was shown on the left or the right side of the fixation stimulus 105, 300, 600, or 1,005 ms after appearance of the pupils (the attentional cue). Both the central face and the target remained on the screen until a response was made or 2, 700 ms had elapsed, whichever came first. Speeded response time was measured from the onset of the target. Participants were instructed to maintain central fixation and were informally monitored as it is well established that eye movements do not occur when suprathreshold targets such as those used here must be detected. In the nonpredictive cue condition each participant received a total of 336 experimental trials, divided equally over 8 testing blocks while in the predictive cue condition each participant received 672 trials, divided equally over 16 testing blocks.

Figure 3.2

High Functioning Autism   **Typically Developing**

Figure 2A: Predictive Gaze — Figure 2C: Predictive Gaze — Figure 2B: Nonpredictive Gaze — Figure 2D: Nonpredictive Gaze
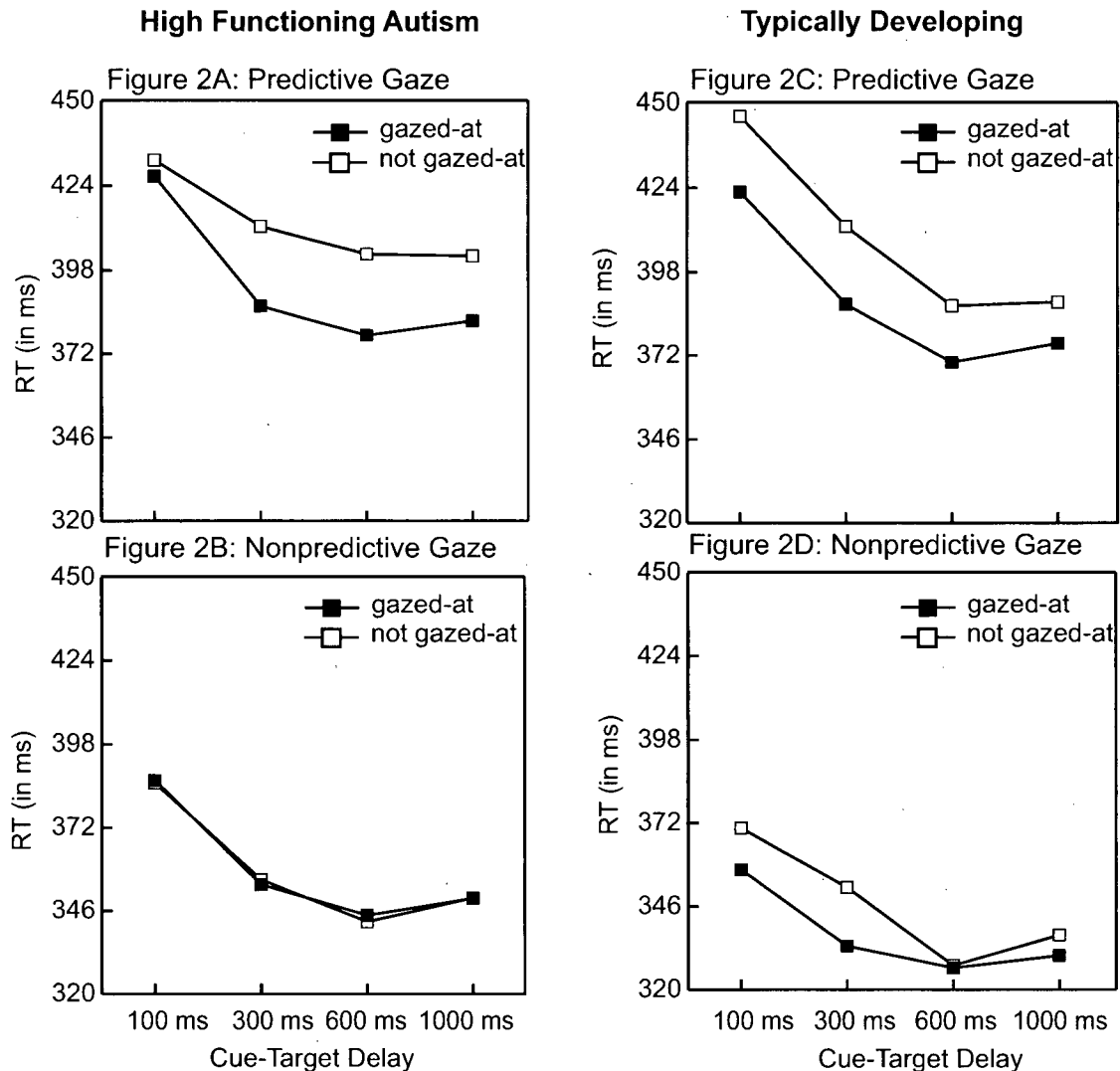
Figure 3.2. Mean response time (RT) in milliseconds (ms) for high functioning individuals with autism (HFA) and typically developing (TD) individuals as a function of gaze cue - target delay when the target appeared at a location that was or was not gazed-at. The column on the left shows HFA performance when gaze direction was predictive (top figure) and when it was nonpredictive (bottom figure) of target location. The column on the right shows TD performance when gaze was predictive (top figure) and when it was nonpredictive (bottom figure) of target location. Mean response error never exceeded 3.6% and averaged .9%. An analysis of variance (ANOVA) of HFA RT performance in the predictive condition, with gaze-target stimulus onset asynchrony (SOA) and gaze-target validity as factors, revealed significant main effects for both SOA and gaze validity [both $Fs>8.5$, $p's<. 005$] with the validity effect growing as a function of SOA [$F (3,33)=4.52, p<. 01$]. In the nonpredictive condition there was no effect for gaze direction and no interaction between gaze and SOA [both $Fs<1$] although there was a main effect of SOA [$F>35$, $p<. 01$]. A between-subjects ANOVA comparing the two conditions confirmed that there was a significant gaze x predictiveness interaction [$F (1,22)=11.23$, $p<. 01$]. The same set of analyses conducted on the TD data revealed that for the predictive condition, and for the nonpredictive condition, all main effects were significant [all $Fs>10.4$ $p<. 01$] as were the gaze x SOA interactions [both $Fs>2.93, p<. 01$]. A between-subjects ANOVA comparing the two conditions revealed that the gaze x predictiveness interaction was not significant [$F(1,21)=1.0, p>. 3$].

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SECTION II: THE UNIQUENESS OF SOCIAL REFLEXIVE ATTENTION

Introduction

Friesen and Kingstone (1998) argued that reflexive orienting triggered by eye gaze direction is reflexive, that it represents an attentional process that is unique to biologically relevant stimuli, and that it may be subserved by brain regions specific to the processing of eyes, i.e., the STS. The two studies presented in Section I support the notion that orienting to gaze direction represents a reflexive social attention phenomenon. Specifically, it was shown that orienting to gaze occurs because of the perceived social relevance conveyed by eye direction (Chapter 3) and that once activated the social attention effect is resistant to cognitive top-down modulation (Chapter 2).

Is eye direction the only central attentional cue that produces reflexive orienting? And if not, is there a distinction to be drawn between the effects elicited by different central cues? In the three studies presented next in Section II (Chapters 4-6) the attentional effects elicited by eye direction are compared to the attentional effects elicited by arrow cues.

Chapter 4 reports an investigation that directly compares the orienting effect produced by nonpredictive central gaze cues to the orienting effect produced by nonpredictive central arrow cues in three distinct populations: adult respondents, preschool children, and a split-brain patient. Surprisingly, eye direction and arrow direction produce behaviorally indistinguishable effects in adults and preschool children. However, the attentional effects for the two cues dissociate for the split-brain patient, with only the face-processing hemisphere orienting attention reflexively to gaze direction but both hemispheres orienting reflexively to arrow direction.

Chapter 5 and Chapter 6 investigate the strength of the reflexive attention effect for gaze and arrow cues. The attentional literature indicates that reflexive attentional

effects are marked both by an ability to interrupt ongoing cognitive activity (e.g., Müller & Rabbit, 1989) and by a resistance to modulation by changes in attentional set (e.g., Folk et al, 1992).

In Chapter 5, central eye gaze and arrow cues were counterpredictive with regard to a target's likely location (e.g., a face looking to the left or an arrow pointing to the left predicted a target was likely to appear on the right). The results indicate that participants cannot help but attend initially toward where the eyes are looking. In contrast, any evidence of reflexive orienting to arrow direction is abolished. These data suggest that the attention effect triggered by eye direction is more strongly reflexive than the effect engaged by arrow direction.

Chapter 6 examined whether the attentional effects of both central cues are influenced by changes in attentional set. A recent study by Pratt and Hommel (2003) found that attentional effects elicited by arrows cues are influenced by the attentional set created by a color congruency between the arrow cue and the target stimulus. Does a similar effect occur for eye gaze? In two experiments, participants were presented with spatially nonpredictive central arrow or gaze cues that either matched or mismatched a target's color (e.g., a central black arrow cue was followed by either a black or a white target). The results indicate a clear dissociation between the orienting effects produced by arrow and gaze direction. Attentional orienting triggered by arrow direction is influenced by cue-target color congruency such that larger attentional effects emerge for congruent cue-target relations. In contrast, the orienting effect for gaze spans equally across congruent and incongruent cue-target color relations.

Considered together the results of the three studies presented in Section II indicate that central spatially nonpredictive eye gaze cues are not unique in their ability to shift reflexive attention -- central arrow cues also trigger reflexive orienting. However,

unlike the attention effects produced by central arrow cues the orienting elicited by eye direction appears to be more strongly reflexive such that it can co-occur with volitional orienting (Chapter 5) and its effects are resistant to changes in attentional set (Chapter 6).

Thus, central eye gaze direction and arrow direction both can trigger reflexive orienting, although these two effects may be subserved by a different underlying neural architecture (Chapter 4) and orienting to gaze direction appears to be more strongly reflexive than orienting to arrows (Chapters 5 and 6).

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CHAPTER 4

Are Eyes Special? It Depends on how you Look at it.

In attentional cuing experiments shorter reaction time (RT) to a target at a cued location versus a noncued location indicates that people have shifted their attention to the cued location. By varying the time interval between the cue and the target a temporal profile of the attentional effect can be established (cf. Posner, 1980). Using modified versions of this standard paradigm, several recent studies have reported that spatially nonpredictive gaze direction facilitates RT to a target appearing at the gazed-at location (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999). Specifically, RT for a target at the cued (gazed-at) location is shorter than RT for a target at the noncued location 100 - 300 ms after onset of the gaze cue, and this effect disappears by 1000 ms (Friesen & Kingstone, 1998).

Friesen and Kingstone (1998) proposed that this reflexive orienting to gaze direction may represent an attentional process that is unique to biologically relevant stimuli, and that as such, it may be subserved by brain regions specific to the processing of faces and eyes. In support of this hypothesis, Kingstone, Friesen and Gazzaniga (2000) found that when individuals who have had their cerebral hemispheres surgically disconnected (split-brain patients) were presented with nonpredictive gaze stimuli, only the hemisphere specialized for face processing directed attention reflexively to the gazed-at location.

Remarkably, however, there is no published report directly comparing attentional orienting to spatially nonpredictive gaze cues (biologically relevant) with attentional orienting to spatially nonpredictive symbolic cues, such as arrows (biologically irrelevant). Such a comparison represents a crucial test of the "eyes are special" position. It is possible that this test has not been performed because the conventional wisdom in the field is that spatially nonpredictive central arrow cues will not produce reflexive orienting (cf. Langton et al., 2000, p. 55). This view stems largely from a

classic study by Jonides (1981, Experiment 2) that required subjects to search a briefly presented array of letters for the target L or R. Before the array appeared, a central arrow cue was flashed momentarily at fixation. The arrow pointed randomly at one of the letter locations. Results indicated that if subjects were told to ignore the arrow then orienting to the cued location was absent. This suggests that a nonpredictive arrow cue does not trigger reflexive attention. However, we will show that this finding does not hold when the task is target detection and the arrow cue remains present (seeTipples, in press for a similar result). Thus, it is an open question as to how reflexive orienting to gaze and arrow cues compare.

We addressed this issue in three ways. First, we tested the same adult observers with nonpredictive gaze and arrow cues across a range of cue-target intervals to compare the strength, and the temporal profile, of orienting to biologically relevant and irrelevant directional cues. Second, we tested 4- and 5-year-old children with these same conditions. Given that infants are predisposed to attend to faces and eyes (e.g., Maurer, 1985) and begin to follow gaze direction within the first year (e.g., D'Entremont, Hains, & Muir, 1997), we expected that nonpredictive gaze would produce reflexive orienting in young children. In contrast, given children's more limited experience with arrow stimuli, we expected that nonpredictive arrow cues would produce smaller orienting effects or none at all. Finally, we tested split-brain patient J. W. with nonpredictive arrow cues. Would the lateralization found for nonpredictive gaze cues (Kingstone et al., 2000) also occur for nonpredictive arrow cues? If not, the implication is that the cortical brain mechanisms subserving reflexive orienting to biologically irrelevant stimuli are distinct from those subserving reflexive orienting to gaze stimuli.

Experiment 1

The Friesen and Kingstone (1998) paradigm was modified to compare the attentional effects of nonpredictive gaze and arrow cues. Because we planned to apply precisely the same paradigm to preschool children in Experiment 2, the targets were pictures of a snowman and a cat.

Method

Participants

Nineteen psychology undergraduate students from the University of British Columbia participated for course credit.

Apparatus

A 3200c Macintosh Power Book presented stimuli on a 12-inch black and white monitor. Participants were seated approximately 57 cm from the monitor. Target detection RT was measured as the time interval between target onset and pressing the spacebar (marked with red tape).

Stimuli

Stimuli and trial sequences are illustrated in Figure 4.1. All stimuli were black drawings on a white background. For gaze cues, the central fixation stimulus was a line drawing of a happy face subtending 6°. The face contained two 0.8° circles representing eyes, a 0.2° circle centered within the face outline representing a nose, and a curved 2.6° long line representing a smiling mouth. Black filled-in circles representing pupils appeared in the eyes. The pupils were centered vertically in the eyes, and just touched the left or right eye outline. The pupils measured 0.5°, and the distance between the eyes was 1° when measured from the center of each eye. For arrow cues, the fixation stimulus was a horizontal line centered on the screen, 1.9° in length. An arrow head and an arrow tail appeared at the ends of the central line, both

pointing left or both pointing right. Each of the two lines comprising an arrow head or tail measured 0.5°, and the length of an arrow, from the tip of the arrow head to the ends of the tail, was 2.5°. The two target stimuli were drawings of a snowman and cat. The cat was 2.5° wide x 3° high; the snowman was 2.5° x 4°. Targets appeared 5° to the left or right as measured from the center of the face or arrow to the center of the target.

Design

A trial began by presenting a face with blank eyes or a straight line for 936 ms. Then pupils or an arrow appeared. A target appeared on the left or right side of the screen 195, 600, or 1005 ms after cue onset. Stimuli remained on the screen until a response was made or 3800 ms had elapsed, whichever came first. The intertrial interval was 808 ms. On cued trials the target appeared at the location towards which the cue was directed, and on uncued trials the target appeared at the other location.

Participants completed four blocks of 42 trials, two consecutive blocks with gaze cues and two consecutive blocks with arrow cues. Cue order was counterbalanced across participants (10 received gaze cues first). Cue direction, target location, target identity, and cue-target stimulus onset asynchrony (SOA) were selected randomly and equally. Four catch trials, in which no target was presented, occurred randomly in each block.

Procedure

Participants first received a description of the trial sequence and completed several practice trials. They were told that gaze and arrow direction did not predict target location or identity. Finally, participants were instructed to press the spacebar quickly and accurately when the target appeared, and to maintain central fixated during each block.

Results

Median RTs were calculated for each participant. The interparticipant means of these median RTs are illustrated in Figure 4. 2.

Figure 4.2 shows that for both gaze and arrow cues RT was shorter at the cued than at the uncued location at the 195 ms SOA by approximately the same amount (21 ms and 22 ms, respectively). As SOA lengthened the RT difference between cued and uncued locations decreased and RT became shorter overall (with a slight RT increase at the 1005 ms SOA — a classic cue-target foreperiod effect (Bertelson, 1967; Mowrer, 1940).

These observations were confirmed by a three-way analysis of variance (ANOVA) with cue type (gaze, arrow), cue validity (cued, uncued), and SOA (195 ms, 600 ms, 1005 ms) as within-subject factors. There were significant main effects for validity [$F (1, 18) = 39.54$ $p < .0001$] and SOA [$F (2, 18) = 40.58$ $p < .0001$], reflecting that RT was shorter at cued vs. uncued locations, and shorter overall at the longer SOAs. There was also a significant validity and SOA interaction [$F (2, 18) = 5.19$, $p < .02$], representing that the difference between cued and uncued locations decreased as SOA lengthened. Planned contrasts revealed that the cuing effect was signficant at all SOAs [all $Fs > 5$, all $ps < .05$]. Finally, the interaction between cue type and SOA was significant [$F (2, 18) = 13.93$, $p < .0001$], reflecting that RT was initially longer for an arrow cue than a gaze cue. No other effects approached significance. In particular, there was no significant main effect for cue type [$F(1,18) = 1.36$, $p > .25$], or interaction involving cue type and validity (cue x validity, [$F (1,18) = 1.79$, $p = .20$]; cue x SOA x validity, [$F < 1$]).

There were no incorrect key presses on target-present trials. False alarms were classified as errors and were excluded from the analysis. The false alarm rate on catch

trials was 2.4% in the gaze condition and 3.2% in the arrow condition. There was no significant effect of cue type [F <1].

Discussion

There were two key findings in Experiment 1. First, the basic pattern reported by Friesen and Kingstone (1998) and others (Driver et al., 1999; Langton & Bruce, 1999) was replicated. That is, nonpredictive gaze direction triggered a rapid shift of attention to the gazed-at location. The result was RT facilitation at the gazed-at location 195 ms after onset of the social cue, with the facilitatory effect declining as the cue-target SOA approached 1000 ms.

Second, this effect was also observed for nonpredictive arrow cues. In other words, the reflexive attentional effect is not unique to biologically relevant gaze cues. On this point the data are absolutely unequivocal. Nonpredictive arrows trigger a reflexive shift of attention to the cued location in a manner that is effectively indistinguishable from gazed-triggered orienting. Indeed, the only difference between the two cues was that initially RT was longer for arrows than eyes, reflecting perhaps the fact that gaze is more alerting than an arrow.

Finally, note that Tipples (in press) reported reflexive orienting to peripheral nonpredictive arrow cues. However, as he noted, this effect might be an artifact of the arrow cues being presented peripherally, and/or bilaterally. The present data rule out these possibilities and as such, to our knowledge, they represent the first clear demonstration that a nonpredictive central arrow cue will trigger reflexive orienting to a cued peripheral location.

Experiment 2

In Experiment 2 we tested 3- 5-year-old preschool children with exactly the same stimulus conditions as the ones that were applied to the adults in Experiment 1.

As noted in the introduction of this paper there is a tremendous amount of evidence indicating that infants are predisposed to preferentially process faces and eyes, and that within their first year they direct their attention to where others are looking (e.g., D'Entremont, Hains, & Muir, 1997; Maurer, 1985). This suggested to us that nonpredictive gaze cues would have greater attentional saliency for children than biologically irrelevant symbolic stimuli such as arrows, with which children have less experience. Thus we predicted that nonpredictive gaze cues would produce orienting effects in preschool children, and that nonpredictive arrow cues would produce either smaller orienting effects than nonpredictive gaze cues, or no orienting effects at all.

It is also worth noting that a comparison of the adults' and children's results would provide a novel way to test the extent to which attentional orienting to nonpredictive gaze and arrow cues is reflexive in nature. Specifically, there have been recent suggestions that reflexive orienting to gaze cues in adults may be a learned volitional process (Vecera, 2000, unpublished ms). Because children younger than 8 years demonstrate adult-like reflexive attention effects, but muted volitional attention effects in peripheral cuing experiments (Brodeur, Trick, & Enns, 1997), we reasoned that if orienting to biologically relevant (or irrelevant) stimuli was a volitional process, then the orienting effects should be smaller for the preschoolers than for the adults.

Method

Participants

Twenty-eight preschool children were recruited from two Vancouver daycare facilities, and parental permission was obtained for each child. Nine children failed to complete the experiment. Ages ranged from 3 years, 9 months to 5 years, 10 months (mean age 4 years, 8 months).

Apparatus, design, and procedure

As in Experiment 1, with two exceptions: (1) each cue condition was composed of one block of 42 trials, and (2) two experimenters were present when the experiment was conducted. One experimenter ensured that central fixation was maintained and the other that the correct response key was pressed. Extra care was taken in explaining that the direction of the eyes and arrows did not predict where the target would appear or what target would appear.

Results

Figure 4.2 shows that for both gaze and arrow cues RT was shorter at the cued than at the uncued location at the 195 ms SOA, and that this effect persisted across all SOAs (although disappearing temporarily at the 600 ms SOA for gaze cues). As SOA lengthened RT became shorter overall (the cue-target foreperiod effect).

Mirroring the adult data in Experiment 1, a three-way ANOVA revealed significant main effects for cue validity [$F_{(1, 18)}$ = 18.88 $p < .0005$] and SOA [$F_{(2, 18)}$ = 4.24 $p < .03$]. There was no significant main effect for cue type [$F < .01$], and no significant interactions [all $Fs < 1.2$, all $ps > .31$].

Incorrect key presses on target-present trials were 0.3 % for the gaze condition and 0.8% for the arrow condition, and these did not vary as a function of validity or SOA [all $Fs<1$]. The false alarm rate on catch trials was 41.5% for the gaze condition and 40% for the arrow condition (with a nonsignificant difference between cue conditions, [$F<1$]). These rates are obviously very high; however, it is important to note that they do not compromise the effects observed on target present trials. That is because false alarm responses normally occurred long after the gaze and arrow cues were presented (mean RT of 1841 ms and 1731 ms, respectively), with these long RTs falling well outside the latencies observed on target present trials. Thus the high false alarm rates

merely reflect the fact that the children had difficulty inhibiting a key press response for the full duration of a catch trial, i.e., they were not target anticipations.

Finally, we performed a four-way ANOVA to compare the adults' and children's RT data. Cue type, cue validity, and SOA were included as within-subject variables, and age group (adults vs. children) was included as a between-subjects variable. Consistent with previous findings (e.g., Enns & Akhtar, 1989), adults' RT was shorter overall [$F_{(1, 36)} = 192.68$, $p < .0001$]. The main effect for cue type was not significant [$F_{(1, 36)} = .050$, $p > .82$], and the main effects for SOA [$F_{(2, 36)} = 11.50$, $p < .0001$] and validity [$F_{(1, 36)} = 31.44$, $p < .0001$] were highly significant. The validity x age group interaction was also significant [$F_{(1, 36)} = 8.3$, $p < .007$], indicating that the children showed a larger cuing effect than adults. Of course whether children would show a larger cuing effect if they were not significantly slower than adults must still be determined. No other interaction was significant [all $Fs < 1.6$, all $ps > .20$].

Discussion

The results from Experiment 2 are clear-cut. Consistent with our expected finding, children oriented attention reflexively to the location cued by a nonpredictive gaze stimulus. Unexpectedly, however, children also oriented attention reflexively to the location cued by a nonpredictive arrow stimulus, and this effect was statistically indistinguishable from the gaze effect. These data replicate for children what we observed for adults in Experiment 1, and again bring into question the notion that the effects of a nonpredictive gaze stimulus are unique to biologically relevant stimuli.

Experiment 3

The results of the first two experiments strongly indicate that reflexive orienting to a biologically relevant nonpredictive gaze cue has a behavioral effect that is

indistinguishable from reflexive orienting to a biologically irrelevant nonpredictive arrow cue. Does this mean that the two types of cue activate the same brain pathways?

A recent study by Kingstone et al. (2000) revealed that split-brain patients shift their attention reflexively to a gazed-at location only when the gaze cue projects to the hemisphere that is specialized for the processing of face stimuli. This suggests that reflexive attention to gaze direction reflects an interaction between neurons in the temporal cortex of the hemisphere specialized for processing faces and eyes, and neurons in the parietal cortex responsible for orienting spatial attention (Harries & Perrett, 1991; Hoffman & Haxby, 2000; Puce et al. 1998; Wicker et al., 1998).

Would a split-brain patient show a similar lateralization of function for nonpredictive arrows? If the neural mechanisms that are responsible for orienting attention to nonpredictive arrow cues are the same as the neural mechanisms responsible for orienting attention reflexively to nonpredictive gaze cues, then J.W. should demonstrate reflexive orienting in the right hemisphere but not the left hemisphere.

Method

Participant

Callosotomy patient J.W. is a 46-year-old male who suffered from intractable epilepsy beginning in 1972. Both hemispheres comprehend language, although verbal and written language output is lateralized to the left hemisphere. This patient has participated in numerous behavioral investigations and is well known for holding central fixation on instruction. See Gazzaniga, Nass, Reeves, and Roberts (1984) for a detailed description of this patient.

Stimuli

Stimuli were controlled by an Apple Macintosh PowerBook 180c computer connected to a 14-inch monitor. The stimuli, illustrated in Figure 4.3, were black and the background was white. The arrow stimuli were the same as in Experiments 1 and 2, and were positioned 2.4° to the left and right of fixation. The target was an asterisk that subtended 0.7°, and always appeared 4.2° away from the central fixation cross (which subtended 0.3°).

Procedure

J.W. was centered with respect to the screen and keyboard, and central fixation was held without difficulty throughout each block of trials. Twenty (20) practice trials preceded two sets of 10 blocks of 64 test trials, for a total of 1280 test trials. J.W. was informed repeatedly, and understood, that arrow direction did not predict where the target would appear. He was strongly encouraged to respond as quickly and as accurately as he could, by pressing a left-hand key ("Z") when the target was presented to the left visual field (LVF; right hemisphere), and a right-hand key ("/") when the target was presented to the right visual field (RVF; left hemisphere).

Figure 4.3 presents an example sequence of events for a trial. Two vertical lines were presented concurrently to the left and right of fixation. 675 ms later arrow heads and tails appeared, creating arrows that pointed up or down. After 105 ms or 600 ms, a target appeared above or below one of the arrows. Arrow direction, target location, and cue-target SOA were selected randomly and equally within each block. Stimuli remained on the screen until a response was made or 2700 ms had elapsed, whichever came first. The intertrial interval was 675 ms. Note that this procedure duplicated Kingstone et al. (2000) except that arrow cues replaced gaze cues.

Results

Figure 4.3 shows that for both LVF (right hemisphere) and RVF (left hemisphere) targets, RT was shorter at the cued than the uncued location at 105 and 600 ms SOAs. Additionally, as SOA increased RT became shorter overall (the cue-target foreperiod effect), with this effect being greater for LVF than RVF targets. These arrow cue data contrast dramatically with the Kingstone et al. (2000) finding that gaze direction triggered reflexive orienting only for LVF (right hemisphere) targets.

RT and accuracy data were subjected to an ANOVA with cue validity, SOA, and target field as factors. RT analysis revealed that all main effects were significant [all Fs > 8.93, all ps < .01]. There was also a significant interaction between SOA and target field [F (1, 1251) = 5.38, p <.02] reflecting the greater foreperiod effect for LVF than RVF targets. Importantly, there were no other significant interactions [all Fs <1.5, all ps > 20]. Error analysis produced no significant effects [all Fs < 1.2, all ps >.35].

Discussion

The finding that nonpredictive arrow direction produces a cuing effect in both hemispheres of split-brain patient J.W., at both SOAs, contrasts with Kingstone et al. (2000) finding that nonpredictive gaze direction produces a rapid, and short-lived attention effect that is lateralized to J.W.'s face/gaze processing right hemisphere. Together these two findings strongly suggest that the neural mechanisms that subserve a reflexive shift of attention in response to nonpredictive gaze direction are fundamentally different from the mechanisms that subserve reflexive orienting in response to nonpredictive arrows. This agrees with current work indicating that there exists a distinct brain region that is specialized for processing biologically relevant directional face and gaze information, which is not activated by inanimate biologically

irrelevant directional information, such as arrows (see Kanwisher, Downing, Epstein, &

Kourtzi, 2001 for a review).

General Discussion

Three experiments were conducted to examine whether attentional orienting

triggered by spatially nonpredictive and biologically relevant gaze cues differs from

attentional orienting triggered by spatially nonpredictive and biologically irrelevant cues,

such as arrows. The results were unambiguous.

Our first two experiments found that the behavioral effects of nonpredictive gaze

cues and arrow cues were significant and equivalent across adults and children. At first

pass these data would appear to compromise the "eyes are special" position put

forward by Friesen and Kingstone (1998), Langton and Bruce (1999) and Driver et al.

(1999). That is, the position that the reflexive attentional orienting observed for gaze

cues reflects an attentional network that is qualitatively distinct from attentional orienting

triggered by biologically irrelevant stimuli.

In support of this position, Kingstone et al. (2000) found that when nonpredictive

gaze cues are presented to split-brain patient J. W., only the right (face/gaze

processing) hemisphere attends reflexively to the gazed-at location. While it is tempting

to conclude that this effect is specific to the processing of biologically relevant face

stimuli, an alternative possibility is that any directional stimulus, biologically relevant or

not, will trigger a lateralized reflexive shift of attention (see Hommell, Pratt, Colzato &

Godijn, 2001 for a similar consideration with regard to nonpredictive arrows and words).

Indeed, the behavioral equivalence of gaze and arrows observed in Experiments 1 and

2 supports this alternative. It is therefore new and significant to discover in Experiment 3

that nonpredictive arrows produce reflexive orienting in both hemispheres of split-brain

patient J.W., in contrast to the lateralized effect obtained with nonpredictive gaze. In this very important sense biologically relevant gaze cues are special.

Note that the split-brain data do not indicate simply that any index of attentional orienting to gaze direction will be lateralized to the hemisphere that is preferentially biased to processing face and gaze information. Rather, the key is whether the attentional orienting is reflexive (triggered by a nonpredictive gaze cue) or volitional (triggered by a predictive cue; see Danziger & Kingstone, 2000, for a recent review of exogenous vs. endogenous orienting). To demonstrate this point Kingstone et al. (2000) conducted a control study wherein they repeated the procedure used in the present Experiment 3 but with gaze stimuli that predicted where the target stimulus was likely to appear, i.e., in either visual field the target appeared at a gazed-at location on 75% of the trials and at a non-gazed-at location on 25% of the trials. Here both hemispheres attended volitionally to the predicted gazed-at location. Thus the lateralization of reflexive attention to nonpredictive gaze direction reflects an interaction between gaze processing and the predictive (attentional) value of the gaze cue.

In sum, our results with J.W. (present study; Kingstone et al., 2000) indicate that reflexive orienting to nonpredictive gaze is subserved by a neural system that is qualitatively unique both from the system that supports reflexive attention to biologically irrelevant stimuli and from the system that supports volitional orienting to predictive gaze direction. In this important way, reflexive orienting to eye direction is special. Moreover, a recent study with healthy adult observers indicates that reflexive and volitional orienting to gaze direction are behaviourally separable. Friesen, Ristic, and Kingstone (submitted) discovered that if eye direction predicts that a target will appear at a nongazed-at location, attention is committed reflexively to the gazed-at location concurrent with volitonal orienting to the predicted location. Counterpredictive arrows on

the other hand appear to produce only reflexive or volitional effects. Thus we find that even in healthy observers behavioural differences between eyes and arrows may emerge, consistent with the finding of the present study that eyes are indeed special.

Figure 4.1.
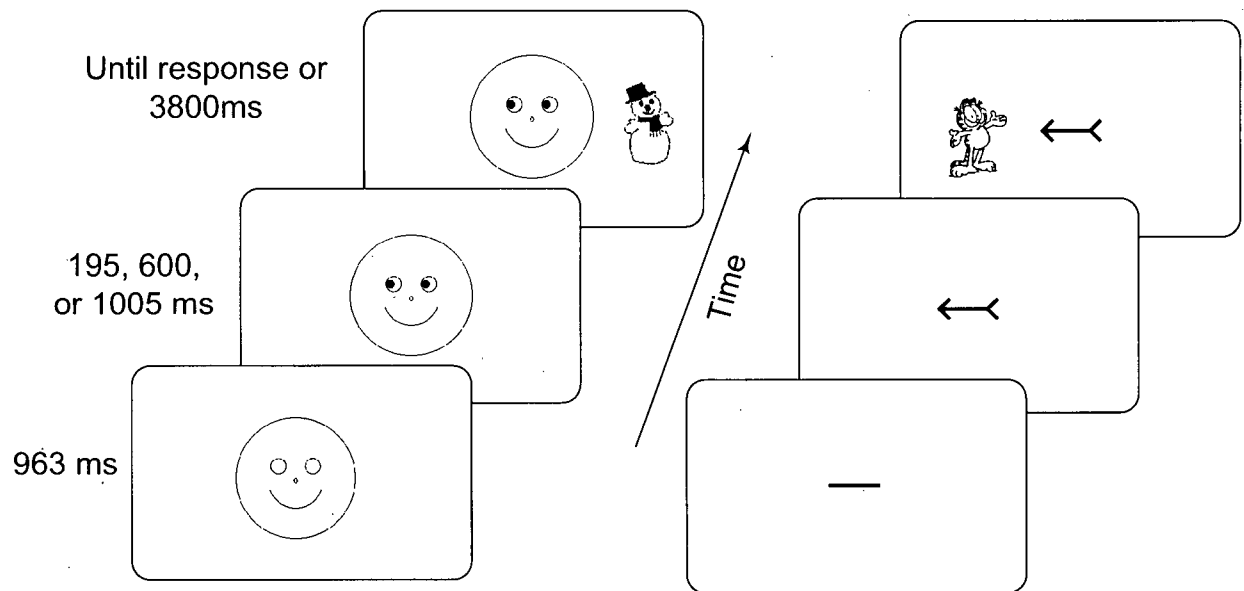
Figure 4.1. Illustration (not to scale) of stimuli and sample sequence of events for Experiment 1 and Experiment 2. For both experiments, the start of each trial was signaled by the presentation of either a face with blank eyes or a straight line. 936 ms later the pupils (looking left or right) or an arrow (pointing left or right) appeared. A target (snowman or cat) was presented on the left or right side of the fixation stimulus, 195, 600, or 1005 ms after cue onset. Both the central cue and the target remained on the screen until a response was made or 3800 ms had elapsed, whichever came first. Response time (RT) was measured from the onset of the target.

Figure 4.2.
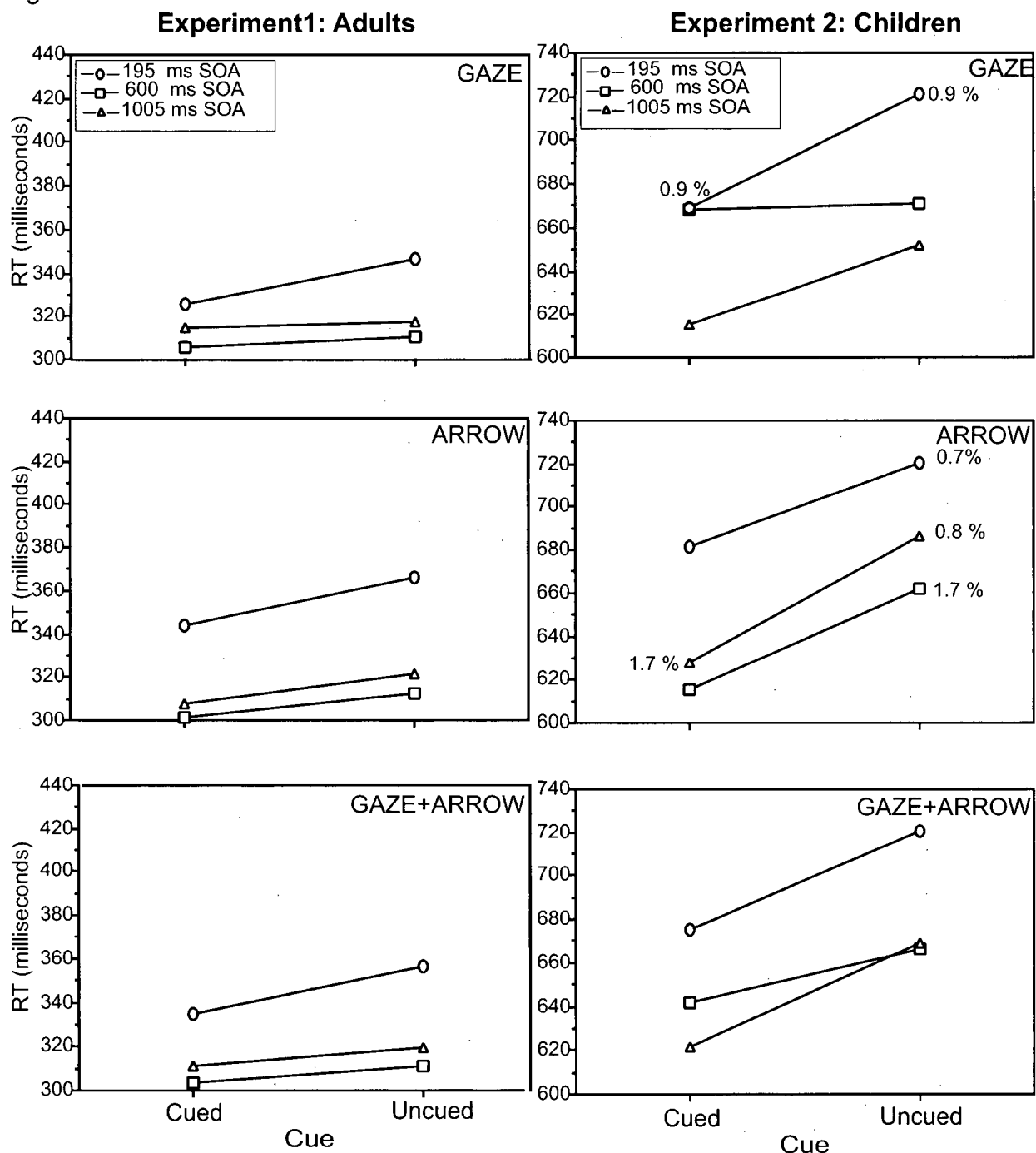
Figure 4.2. Mean response time (RT) in milliseconds (ms) for Experiment 1 (adult participants) and Experiment 2 (child participants), as a function of cue-target stimulus onset asynchrony (SOA) and cue validity. The top row shows performance for gaze cues, the middle row shows performance for arrow cues, and the bottom row shows performance collapsed across gaze and arrow cue conditions. Error rates (%) that are not zero are shown.

Figure 4.3.

Left Visual Field (Right Hemisphere)

Right Visual Field (Left Hemisphere)
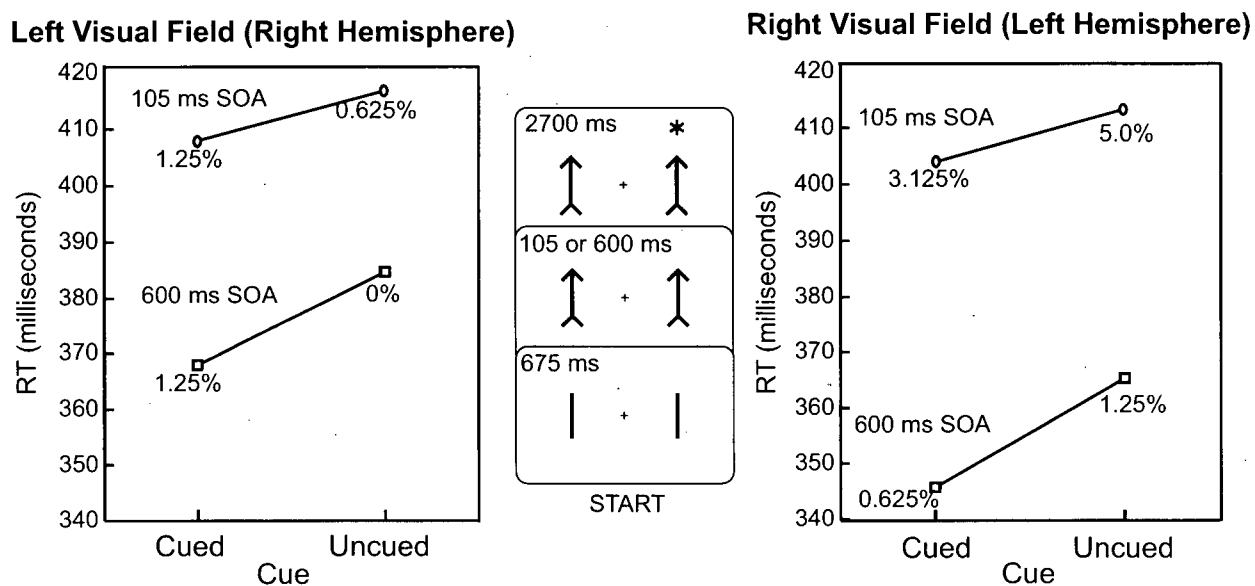
Figure 4.3. Illustration (not to scale) of stimuli, sample sequence of events, and mean response time (RT) for Experiment 3 (split-brain participant J.W.), as a function of cue-target SOA, cue validity, and visual field. The error rates (%) for all conditions are shown. See text for procedural details.

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CHAPTER 5

Attentional Effects of Counterpredictive Gaze and Arrow Cues

Behavioral studies with healthy adults have indicated that the tendency to move attention to where someone else is looking is so fundamental that people will attend automatically to a location gazed at by a face on a computer screen, even when gaze direction does not predict where a target item may appear (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999). More recently, a study by Kingstone, Friesen and Gazzaniga (2000) revealed that this effect is lateralized to the hemisphere specialized for processing face and gaze information. These findings, coupled with the observation that gaze direction can convey a broad range of important social signals, have led to the suggestion that orienting to gaze direction may represent a special form of attention (Langton, Watt, & Bruce, 2000; Kingstone, Smilek, Ristic, Friesen & Eastwood, 2003). The present study investigated this hypothesis by examining attentional orienting in response to directional stimuli that were either gaze cues or arrow cues.

In their original gaze study with adults, Friesen and Kingstone (1998) reported that when a schematic face was presented in the center of a computer screen and the gaze direction of the face was known to be spatially nonpredictive, adults were nevertheless faster to detect, localize, and identify a target stimulus if it appeared at the location that the face was looking at rather than at a nongazed-at location. An equally interesting result was that this facilitatory effect of gaze direction emerged soon after the schematic eyes were presented — at a cue-target stimulus onset asynchrony (SOA) of 105 milliseconds (ms) — and then persisted across SOAs of 300 and 600 ms before disappearing by a 1005 ms SOA. Both the rapid onset of the facilitation effect, and the fact that it occurred in response to a nonpredictive stimulus, are hallmarks of reflexive attentional orienting (Cheal & Lyon, 1991; Müller & Rabbitt, 1989; Jonides, 1981). This

suggested to Friesen and Kingstone that they were measuring a reflexive attentional phenomenon.

However, they also noted that orienting to gaze direction did not exhibit all the characteristics normally associated with reflexive shifts of attention. For instance, in their study the attentional shift to a peripheral location was triggered by a spatially nonpredictive stimulus (the eyes) presented at central fixation. In contrast, reflexive orienting is normally produced by presenting a spatially nonpredictive transient event, such as the brightening of a box, at a peripheral location where a target might appear (e.g., Posner & Cohen, 1984; Posner, Cohen, & Rafal, 1982). Another difference was that Friesen and Kingstone found that orienting to gaze direction persisted well beyond a cue-target SOA of 500 ms. The reflexive orienting effect produced by nonpredictive peripheral cues disappears when the cue-target SOA exceeds approximately 300 ms (Klein, Kingstone & Pontefract, 1998). A final difference was that when the facilitory effect of gaze direction disappeared, it was never replaced by the inhibition of return (IOR) effect, i.e., an increase in response time (RT) for targets appearing at the cued location. This contrasts with spatially nonpredictive peripheral cues, in which the short-lived early facilitation effect at the cued location is typically replaced by an IOR effect at longer SOAs (Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughan, 1985; for a review, see Klein 2000). Considered together, these differences suggested to Friesen and Kingstone that attention to gaze direction might represent a new, and different, type of reflexive orienting.

Similar findings, and conclusions, were put forward by Langton and Bruce (1999) and Driver et al. (1999). In addition, each of these two studies examined volitional orienting to gaze direction by testing performance when gaze direction predicted where a target stimulus was likely to appear. Langton and Bruce (1999; Experiment 3)

examined volitional orienting by presenting an image of a real face in the center of the computer screen. The face could be turned either to the left, to the right, up, or down. Subjects were informed that the target stimulus would appear 75% of the time at the location that the head and eyes were directed toward (the cued location), and 25% of the time at one of the other three uncued target locations. Results indicated that RT was facilitated for targets appearing at the cued location both when the cue-target SOA was short (100 ms) and when it was long (1000 ms). Langton and Bruce suggested that the facilitation observed at the short SOA reflected a reflexive shift of attention to the gazed-at location (because this effect was also observed at the short SOA in their first two experiments with nonpredictive gaze), and that the facilitation effect observed at the long SOA reflected voluntary orienting to the gazed-at location (because the attentional effect had disappeared at this long SOA in their nonpredictive gaze experiments). This account is both reasonable and consistent with the data. However, because Langton and Bruce only sampled performance at two temporal extremes — a short 100 ms SOA at which gaze-triggered reflexive orienting is often observed, and a longer 1000 ms SOA at which gaze-triggered reflexive orienting is often absent — their results do not indicate when voluntary orienting in response to the predictive cue emerged, or more specifically, whether this voluntary orienting effect replaces reflexive orienting.

Driver et al. (1999, Experiment 3) tested the reflexivity of orienting to gaze direction by making the gaze cue counterpredictive with respect to where a target was likely to appear. Observers were presented with an image of a real face pointed straight ahead but with eyes gazing to the left or right. They were informed that when the eyes looked to the left, the target would appear on the right 80% of the time, and vice versa. RT performance was sampled at 100, 300, and 700 ms cue-target SOAs. No effects of gaze direction were observed at the shortest SOA of 100 ms; however, at the 300 ms

SOA, RT was shorter at the location that the eyes were directed toward (where the target was <u>unlikely</u> to appear), and at the 700 ms SOA there was a nonsignificant trend for RT to be shorter at the location opposite to where the eyes were directed (where the target was <u>likely</u> to appear). In keeping with Langton and Bruce (1999), Driver et al. suggested that at the shorter 300 ms SOA, attention was reflexively committed to where the eyes were looking; whereas at the longer 700 ms SOA, attention was voluntarily shifted to the location where the target was likely to appear (in this case, the opposite location). Although this is a plausible interpretation of the data, the fact remains that performance was never significantly faster at the nongazed-at (but likely) target location, and therefore the evidence does not provide strong support for the view that the reflexive orienting observed at 300 ms SOA was replaced by volitional orienting at 700 ms SOA. One alternative interpretation is that with counterpredictive gaze cues, the conflict between the attentional effects of gaze direction and the task requirement to shift attention in the opposite direction somehow diminishes or delays volitional orienting (which usually emerges at cue-target SOAs of about 500 ms or less (Danziger & Kingstone, 1999; Müller & Rabbitt, 1989)). A second alternative is that reflexive orienting to gaze direction and voluntary orienting to the likely target location were both occurring at the 700 ms SOA. If this were the case, the overall result might be to facilitate RT performance both at the gazed-at location (because of reflexive orienting) and at the likely location (because of volitional orienting), thereby reducing or eliminating any significant differences between these two locations. Note that this alternative interpretation is reasonable because both Driver et al. (1999, Experiments 1 and 2) and Friesen and Kingstone (1998) demonstrated originally with nonpredictive gaze cues that reflexive orienting can be observed with cue-target SOAs as long as 600 - 700 ms.

Considering the data from these studies as a whole, it becomes clear that they do not provide a clear picture of reflexive and voluntary orienting in response to central gaze direction cues. The results of Langton and Bruce (1999) indicate that participants can orient attention both reflexively and volitionally in response to predictive face/gaze directional cues. But they do not reveal whether volitional orienting replaces, or overlaps with, reflexive orienting. Similarly, the findings of Driver et al. (1999) with counterpredictive gaze cues indicate that at a short SOA of 300 ms, attention is oriented reflexively to the gazed-at location even when participants have an incentive to shift their attention in the direction opposite to where the eyes are looking, suggesting that orienting to gaze direction may be strongly reflexive. And the trend towards a response time advantage for targets appearing at the predicted location at the longer 700 ms SOA suggests that some volitional orienting might have been occurring at this longer SOA. However, for the reasons just discussed, it is equivocal whether the nonsignificant benefit for predicted (but not gazed-at) targets at 700 ms SOA simply reflects weak or delayed volitional orienting, or whether reflexive orienting and volitional orienting were co-occurring at this longer SOA.

In Experiment 1 of the present study we used counterpredictive gaze cues in an improved design that allowed us to isolate reflexive orienting to a gazed-at location from voluntary orienting to a predicted location, and to examine the timecourse of orienting to counterpredictive gaze direction across a wide range of SOAs. In Experiment 2 we examined the attentional effects of counterpredictive arrows, in order to investigate whether the effects obtained with gaze cues in Experiment 1 are also observed with another common directional cue, i.e., an arrow.

Experiment 1

In the Driver et al. counterpredictive gaze experiment (1999, Experiment 3), participants oriented reflexively to a gazed-at but unlikely target location at a short SOA of 300 ms, but there was no clear evidence of a switch to volitional orienting to a likely target location at a longer SOA of 700 ms. Two possible reasons for the absence of significant volitional orienting were advanced above. One possibility is that when gaze direction is counterpredictive there is an inherent tension between reflexive and volitional orienting, which delays or abolishes volitional orienting to the predicted location. A second possibility is that at an intermediate SOA both forms of orienting might be operating independently, and when performance at the two locations is contrasted there is no significant difference because performance is facilitated by attention at both locations.

Experiment 1 tested these two ideas. In order to explore the first possibility, we extended the range of cue-target intervals to include long SOAs of 1200 and 1800 ms. We reasoned that this would provide ample opportunity for attention to be oriented volitionally to the predicted (but not gazed-at) location, and that at these long SOAs any reflexive tendency to orient towards the gazed-at location should no longer be present. The second possibility was tested by increasing the number of target locations from two to four[1]. In this way, on any given trial there would always be potential target locations

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[1] The addition of up and down target locations raises the possibility of introducing differential cuing effects, depending on whether orienting occurs on the horizontal axis or the vertical axis. In their study with real faces, Langton and Bruce (1999) found that although gaze cuing effects occurred only on the horizontal axis with inverted faces (Experiment 4), the effects were equivalent on both axes with upright faces (Experiments 1 - 3). To rule out the possibility that there were axis effects in the present study, we conducted an ANOVA for each of our two experiments with the axis on which the target appeared (horizontal, vertical), SOA (105, 600, 1200, 1800 ms), and trial type (predicted, cued, NP-NC) as within-subject factors. There was no interaction between axis and trial type for either gaze cues ($F < 1$, $p > .95$) or arrow cues ($F < 1.7$, $p > .20$). Axis will therefore not be considered a factor in the present study.

that were neither gazed-at nor predicted. These locations would therefore provide a true baseline against which to assess the allocation of reflexive attention to the gazed-at location and volitional attention to the predicted location.

The gaze direction of a centrally presented schematic face served as the cue, and target onset could occur to the left, to the right, above, or below the face. In order to assess any transitions from reflexive orienting to volitional orienting, we measured performance at a short SOA (105 ms) when reflexive orienting is typically observed, at an intermediate SOA (600 ms) when reflexive and volitional effects might both occur, and at two long SOAs (1200 and 1800 ms) when volitional attentional effects should predominate.

Method

Participants

Twenty-four introductory psychology students (17 females and 7 males) reporting normal or corrected-to-normal vision participated in the experiment for course credit. All participants were unaware of the purposes of the experiment. Testing was divided over two sessions of less than one hour each, conducted on separate days.

Apparatus and Stimuli

The experiment was controlled by VScope software (Rensink, 1995) on a 6100 Power Macintosh computer. Stimuli were presented on a 14-inch Apple color monitor set to black and white and operating at a refresh rate of 66.7 Hz. Response time (RT) measures were based on keyboard responses.

The face display, illustrated in Figure 5.1, consisted of a black line drawing of a face presented on a white background. The round face outline subtended 6.8°, and contained two circles representing the eyes, a smaller circle in the center of the monitor representing the nose and serving as the fixation point, and a straight line representing

the mouth. The eyes subtended 0.9°, and the center of each eye was located 1.0° to the left or right of the central vertical axis and 0.8° above the central horizontal axis. The nose subtended 0.2°. The mouth was 2.2° in length and was centered 1.3° below the nose. Black filled-in circles appeared within the eyes and represented the pupils. The pupils subtended 0.5°. For the left and right gaze direction cues, the pupils were centered vertically in the eyes, and were just touching either the left or right of the eyes; for the up and down gaze directions, the pupils were centered horizontally in the eyes, and were just touching either the top or bottom of the eyes; and for straight-ahead gaze, the pupils were centered both horizontally and vertically in the eyes. Note that when the pupils were presented, they appeared in a left, right, up, down, or straight gaze position, and thus there was no motion artifact.

The target stimulus demanding a detection response was a black capital letter F or T that measured 0.75° wide and 1.35° high, and was presented to the left, to the right, above or below the face. Target letters were centered on either the horizontal or vertical meridian, and the distance between central fixation (the nose) and the center of the target letter was 6.25°.

Design

Cue-target SOA (105, 600, 1200, or 1800 ms), gaze direction (left, right, up, down, or straight), and target identity (F or T) were selected randomly and with equal probability. When gaze direction was left, right, up, or down, the target letter appeared at the location opposite to where the eyes were looking 75% of the time (e.g., if the eyes looked up, the target was most likely to appear below the face). If a target did not appear at the predicted location, target location was selected randomly and with equal probability from among the three remaining alternative positions. When gaze direction

was straight, a target was presented at one of the four locations (left, right, above, or below) randomly and with equal probability.

There were four trial types: predicted trials, in which the target appeared at the predicted location (i.e., at the position opposite to the gazed-at location); cued trials, in which the target appeared at the gazed-at location; not predicted - not cued (NP-NC) trials, in which the target appeared at one of the two locations that were neither predicted nor gazed-at; and nondirectional straight-gaze trials, in which the eyes looked straight ahead and the target could appear at any of the four target locations. Figure 5.2 illustrates the probabilities of the possible target positions for predicted, cued, NP-NC trial types.

Each of the two experimental sessions was composed of 20 practice trials followed by 12 blocks of 60 trials, for a total of 1440 test trials per participant. Approximately 8% of the test trials were catch trials randomly selected from the five gaze direction cues.

Procedure

The sequence of events on a target trial is illustrated in Figure 5. 1. All trials began with the presentation of a face with blank eyes. After 675 ms, pupils appeared within the eyes, looking left, right, up, down, or straight ahead. Then, after 105, 600, 1200 or 1800 ms, a target letter appeared to the left, to the right, above, or below the face. Both the gazing face and the target letter remained on the screen until a response was made or until 1500 ms had elapsed, whichever came first. RT was measured from the time of target onset. The intertrial interval was 675 ms.

Participants were seated approximately 57 cm from the monitor, and the experimenter ensured that they were centered with respect to the monitor and keyboard. They were told that each trial would begin with a line drawing of a face with

blank eyes, that pupils would appear in the eyes to create a face that was looking left, right, up, down, or straight ahead, and that after the appearance of the pupils, a capital letter (either F or T) would typically appear to the left, right, above, or below the face. Participants were instructed to press the spacebar with the index finger of their preferred hand as quickly as possible when a letter appeared on the screen. Also, they were told that occasionally there would be trials in which no target appeared, and that on these trials they should not respond, and just wait for the next trial to begin. The experimenter stressed that it was important to maintain fixation on the nose in the center of the face at all times.

It is important to note that the identity of the target was irrelevant to the response task — subjects were merely required to detect target onset. Past research has demonstrated that when subjects are required to detect target onset they will normally not move their eyes to the target before making a response (Posner, 1980). Indeed it is difficult to get subjects to move their eyes before making a manual detection response because it slows their RT performance significantly (Kingstone & Pratt, 1999). Thus we did not expect eye movements to be a confounding factor in our study. Moreover, we have confirmed elsewhere that the standard attention effects produced by nonpredictive gaze direction do not depend on eye movements of the participants (Friesen & Kingstone, 2003a). Nevertheless, we monitored the eye position of seven participants to be certain that this was the case. As our results will show, our expectations were confirmed: subjects who were eye-monitored rarely executed eye movements before responding, and their performance was indistinguishable from the performance of those who were not eye-monitored. Thus the evidence indicates that eye movements were rarely occurring in our study and are thus not an explanatory concern for our data.

Before beginning each session, participants were told that 75% of the time the eyes looked left, right, up, or down, the target letter would appear at the location opposite to where the eyes were looking, and that when the eyes looked straight ahead, the target was equally likely to appear at any of the four possible target locations.

Results

Mean RTs, standard deviations, and error rates for Experiment 1 are presented in Table 5.1. Anticipations (RTs < 100 ms), timed-out trials (no response), RTs longer than 1000 ms, and incorrect responses (accidentally pressing a key other than the spacebar), were classified as errors and were excluded from analysis. Each type of error accounted for less than 0.5% of the target trials. The false alarm rate on catch trials was 1.02%. Because these rates were so low, the error and false alarm data were not analyzed further.

An ANOVA was conducted with SOA (105, 600, 1200, and 1800 ms) and trial type (predicted, cued, and baseline) as within-subject factors[2]. Mean RTs for predicted, cued, and NP-NC trials at each SOA are illustrated in Figure 5.3. The ANOVA revealed that there was a significant main effect for SOA [$F(3,23) = 66.66$, $p < 0.0001$], with RT becoming shorter as SOA lengthened (a standard foreperiod effect, Friesen & Kingstone, 1998; Mowrer, 1940). There was also a significant main effect for trial type [$F(2,23) = 12.47$, $p < 0.0001$], with RT being shortest on predicted trials, intermediate on cued trials, and longest on NP-NC trials. Finally, the SOA x trial type interaction was

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[2] Note that this ANOVA excludes straight-gaze trials and thus is not subject to any confounds inherent in comparing performance across different cue conditions (cf. Jonides & Mack, 1984). In other words, for predicted, cued, and NP-NC trials, the cue conditions prior to target onset are identical, i.e., averted gaze. In this way similarities and differences between predicted, cued, and NP-NC can be attributed to attentional allocation without being compromised by factors such as changes in attentional set or response strategies between averted- and straight-gaze conditions. Performance on straight-gaze trials across both experiments is considered in detail in the General Discussion.

significant [F(6,23) = 2.66, p < 0.02]. An inspection of Figure 5.3 suggests that this interaction reflects changes in the cued condition and predicted condition relative to the NP-NC condition across SOAs. Specifically, it appears that for the cued condition there was early facilitation that persisted steadily across the two early SOAs (105 and 600 ms), and then disappeared at the 1200 ms SOA. Conversely for the predicted condition facilitation emerged first at the 600 ms SOA and persisted thereafter. Planned t-tests (Bonferroni corrected, two-tailed) confirmed these observations. For the cued condition, performance was significantly faster than the NP-NC condition only at the 105 and 600 ms SOAs. Conversely, for the predicted condition, performance facilitation relative to NP-NC was absent at the 105 ms SOA and present at the 600, 1200, and 1800 ms SOAs.

Finally, the data for the seven eye-monitored participants revealed that the eye movement rate was low (2.7%). RT performance for these seven eye-monitored participants was compared with that of the first seven nonmonitored participants we tested, using a two-within (SOA, trial type) one-between (monitored/nonmonitored) ANOVA. The interactions involving monitoring condition and trial type fell far short of significance (all Fs < 1, all ps > 0.50). Thus, we are certain that eye movements were not involved in producing our cuing effects, and that the orienting we observed was covert in nature.

Discussion

In the present counterpredictive gaze experiment, the use of four possible target locations made it possible to compare performance for targets appearing at a location that was gazed-at but was unlikely to contain a target (cued trials) with RTs for targets appearing at a location that was not gazed-at and yet equally unlikely to contain a target (NP-NC trials). Similarly, our design allowed us to compare RTs for targets appearing

at a location that was not gazed-at but was likely to contain a target (predicted trials) with RTs for targets appearing at a location that was not gazed-at and also not likely to contain a target (NP-NC trials).

At the 105 ms SOA, responses to targets occurring at a gazed-at and unlikely location were significantly faster than responses to targets occurring at a nongazed-at and unlikely location. This advantage for cued locations relative to the baseline locations that were neither predicted nor cued persisted at the 600 ms SOA, and then disappeared by 1200 ms SOA. These findings are consistent with the reflexive effects observed with nonpredictive gaze cues (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999), and they are also consistent with the Driver et al. (1999, Experiment 3) finding that at a short SOA, gaze direction can produce a covert attention shift even when subjects have incentive based on cue predictiveness to shift attention to some other location.

We also observed clear evidence that subjects can shift attention volitionally to a predicted location when it is not the gazed-at location: responses were reliably faster for predicted locations relative to locations that were neither predicted nor gazed-at at 600, 1200, and 1800 ms SOA. Our observation of this effect at the 600 ms SOA indicates that counterpredictive gaze does not delay volitional orienting, a possibility that was suggested by the results of Driver et al.'s counterpredictive gaze experiment (1999, Experiment 3). Rather, it suggests that in Driver et al.'s experiment, significant effects were not observed at 700 ms SOA because both reflexive and volitional orienting were occurring at that cue-target interval, with reflexive attention being directed to the gazed-at location and volitional attention being directed to the predicted location. As a result, when these two locations were directly compared, there was no significant difference between them. Consistent with this notion, a direct comparison between predicted and

cued trials in the present experiment revealed that the two were not statistically different at the 600 ms SOA [t (23) = 0.38 p > 0.70].

In sum, our data indicate that participants will orient attention to a gazed-at location even though a target is unlikely to appear there, and that they can also orient attention volitionally to a predicted, nongazed-at location. Thus, Experiment 1 replicates the Driver et al. (1999) finding that orienting to a gazed-at location is reflexive in the strong sense that it can occur even when participants are trying to direct their attention to a different location; and it adds the new finding that participants are indeed able to allocate attention volitionally to a location that is counter to the gazed-at location. In addition, it indicates why Driver et al. failed to observe a significant effect of volitional orienting with their counterpredictive gaze cues. That is, it appears that reflexive orienting to a gazed-at location and volitional orienting to a predicted location opposite to the gazed-at location overlap in time. Because in the Driver et al. study there were only two locations, facilitation effects at the gazed-at location and volitional orienting to the predicted location created the false impression that orienting was not occurring reliably at either location. Our study, which included baseline locations that were neither predicted nor cued, indicates that precisely the opposite is the case -- volitional orienting to the predicted location and reflexive orienting to the gazed-at location can both occur at an SOA (600 ms) that closely approximates the 700 ms SOA at which Driver et al.'s null finding was observed.

Importantly, our finding that there was an RT advantage for both predicted and cued trials compared to NP-NC trials suggests that both forms of orienting might be operating concurrently. The design of the present experiment does not allow for a conclusive demonstration of simultaneous orienting to two different locations because, necessarily, on each trial only one location was probed. However, a closer examination

of our data rules out the most plausible alternative explanations and favors our interpretation that our counterpredictive gaze cues produced concurrent reflexive and volitional orienting.

First, t-tests revealed that the reflexive cuing effect (NP-NC minus cued) at 600 ms SOA was not statistically different from the reflexive effect at 105 ms SOA [t (23) = 0.54, p > 0.58], and that the volitional cuing effect (NP-NC minus predicted) at 600 ms SOA was not statistically different from the volitional effect at 1200 ms SOA [t(23) = 1.51, p > 0.13]. This indicates that at the 600 ms SOA, RT benefits for the predicted target location are not replacing, or occurring at the expense of, RT benefits for the gazed-at target location.

Second, one could argue that our finding of facilitation on both predicted and cued trials at the 600 ms SOA might reflect volitional orienting by roughly half of the subjects at the 600 ms SOA, and reflexive orienting by the other half of the subjects at the 600 ms SOA. The data at the 600 ms SOA, however, do not support this proposal: RTs for 15 participants were shorter on both predicted and cued trials than on NP-NC trials, significantly more than would be expected by chance alone ($\chi^2 < 0.0005$).

A third possible explanation for the RT advantage for both predicted and cued trials relative to NP-NC trials at the 600 ms SOA is that individual participants were "switching" between the two types of orienting, i.e., that they were shifting attention volitionally to the predicted location on some trials and shifting attention reflexively to the gazed-at location on other trials. If this were the case, then one would expect that the RT variance of the predicted and cued distributions would be greater than the RT variance of the NP-NC distribution. This is because on predicted and cued trials sometimes the target would appear at an attended location and sometimes the target would appear at an unattended location. In contrast, on NP-NC trials the variance

would be lower because on every trial the target would appear at an unattended location. In other words, switching should result in greater variance because it entails the combined distribution of two component distributions with different means (attended and unattended target locations) compared to the baseline NP-NC condition which has only one component distribution (unattended target locations). We tested this switching explanation by conducting an analysis of the within-subject standard deviations at the 600 ms SOA, and the results were clear-cut: average standard deviations were not different between predicted trials (81 ms) and NP-NC trials (78ms) [t=0.74, p>0.45], and indeed standard deviations were smaller on cued (67 ms) trials than on NP-NC trials [t=2.81, p<0.01]. In agreement with this analysis, a visual inspection of individual subjects' RT distributions on predicted and cued trials at the 600 ms SOA revealed no evidence of bimodality. In sum, our ability to rule out these alternative explanations favors the conclusion that reflexive orienting to the gazed-at location and volitional orienting to the predicted location can occur concurrently.

<div align="center">Experiment 2</div>

The results of Experiment 1 indicate that orienting to gaze direction is reflexive in a strong sense. That is, target detection is facilitated at a gazed-at location despite the fact that gaze direction predicts that a target is likely to appear at a different, nongazed-at location. And, most impressively, this facilitation occurs even when attention is being oriented volitionally to the predicted nongazed-at location. Although it seems reasonable to speculate that the results of Experiment 1 are unique to gaze direction, this position remains untested. Indeed, recent evidence suggests that nonpredictive arrow cues can produce behavioral effects that look very similar to those produced by nonpredictive gaze cues (Ristic, Friesen & Kingstone, 2002; Tipples, 2002; for a discussion, see Kingstone, Smilek, Ristic, Friesen & Eastwood, 2003). The purpose of

Experiment 2 was to examine whether similar effects to those observed in Experiment 1 would be observed with a counterpredictive central arrow cue.

Experiment 2 was identical in every way to Experiment 1, except that an arrow served as the counterpredictive directional cue. Two different arrows were used. One half of our participants viewed a symmetrical arrow cue, with an arrowhead at one end and a tail at the opposite end (e.g., <---<). The other half of our participants viewed an asymmetrical arrow cue, with an arrowhead at the leading end but with no tail (e.g., <--). This latter modification was made to examine whether gaze cues were strongly reflexive because they were perceptually weighted in the direction that they looked toward. For example, when the eyes are looking to the left, the pair of black pupils is not centered on the midline of the display, but is instead centered on some point slightly to the left of the midline. If this is an important factor, then the symmetric and asymmetric arrows should produce different effects on reflexive attention, i.e., the asymmetrical arrow should produce stronger reflexive orienting.

Method

Participants

Twenty-four introductory psychology students (20 females and 4 males) reporting normal or corrected-to-normal vision participated in the experiment for course credit. All participants were unaware of the purposes of the experiment, and none had participated in Experiment 1. Testing was divided over two sessions of less than one hour each, conducted on separate days. Eye-monitoring was conducted as in Experiment 1.

Apparatus and Stimuli

The apparatus used was identical to that used in Experiment 1. Stimuli for Experiment 2 are illustrated in Figure 5. 4. The fixation display consisted of a black line drawing of a cross centered within a circle. The circle subtended 6.8° and was centered

in the middle of the monitor. The cross within the circle was composed of a horizontal line and a vertical line, each of which was 2.1° in length. The intersection of the two lines of the cross served as the fixation point. For half of the subjects, directional cues were provided by an arrow head and an arrow tail appearing at either end of one of the two lines of the cross (i.e., 1.2° from central fixation, as measured from the intersection of the cross to the pointed end of the arrow head or tail); for the other half of the subjects, cues were provided by only an arrow head appearing at one end of one of the two lines of the cross. The arrow heads (and tails) were composed of two lines 0.6° in length, and measured 0.8° high by 0.5° wide. A nondirectional cue (corresponding to the straight-gaze cue in Experiment 1) was provided by small lines appearing at the ends of both lines of the cross, such that each arm of the cross ended in a perpendicular line measuring 0.6°. The response stimuli and task were as in Experiment 1.

Design and Procedure

The experimental design and procedure were identical to those of Experiment 1, with the exception that the directional cues were arrows and the nondirectional cue was a cross with perpendicular lines on the end of each arm. Cue to target SOA (105, 600, 1200, or 1800 ms), cue type (left, right, up, or down arrow, or nondirectional cross), and target identity (F or T) were selected randomly and with equal probability. The probabilities of a target appearing at any one of the four locations were the same as in Experiment 1. When the cue was an arrow pointing left, right, up, or down, the target letter appeared at the location opposite to where the arrow was pointing 75% of the time and at one of the other three locations 25% of the time; and when the cue was the nondirectional cross, the target appeared with equal probability at any one of the four locations. Thus, there were four trial types with probabilities identical to those in

Experiment 1: predicted trials, in which the target appeared at the predicted location (i.e., at the position opposite to where the arrow was pointing); cued trials, in which the target appeared at the location toward which the arrow was pointing; not predicted - not cued (NP-NC) trials, in which the target appeared at one of the two locations that were neither predicted nor pointed at by the arrow; and nondirectional cross trials. Approximately 8% of the trials were catch trials randomly selected from the five cue types.

As was the case with Experiment 1, each of the two experimental sessions was composed of 20 practice trials followed by 12 blocks of 60 trials, for a total of 1440 test trials per participant. Figure 5. 4 provides an illustration of the sequence of events on a test trial.

Results

Mean RTs, standard deviations, and error rates for Experiment 2 are presented in Table 5.2. As in Experiment 1, anticipations, timed-out trials, RTs longer than 1000 ms, and incorrect responses were classified as errors and were excluded from analysis. Each type of error accounted for less than 0.4% of the target trials. The false alarm rate on catch trials was 1.38%. Because these rates were so low, the error and false alarm data were not analyzed further.

An ANOVA was conducted with SOA (105, 600, 1200, and 1800 ms) and trial type (predicted, cued, and NP-NC) as within-subject factors. Figure 5.5 illustrates RTs for predicted, cued, and NP-NC trials. As in Experiment 1, there was a significant main effect for SOA [$F(3,23) = 27.89$, $p < 0.0001$], reflecting a foreperiod effect, and there was a significant main effect for trial type [$F(2,23) = 36.55$, $p < 0.0001$], with RTs on predicted trials shorter overall than RTs on cued and NP-NC trials. The SOA x trial type interaction was also significant [$F(6,23) = 5.23$, $p < 0.0001$].

Planned t-tests (Bonferroni corrected, two-tailed) conducted as in Experiment 1 revealed that the predicted condition was significantly faster than the NP-NC condition at all but the shortest SOA. This was precisely the same result that was observed in Experiment 1. However, unlike Experiment 1, the cued and NP-NC conditions were statistically equivalent at all SOAs. Recall that in Experiment 1 reflexive orienting was observed at the gazed-at location at both the 105 and 600 ms SOAs.

An ANOVA with SOA (105, 600, 1200, and 1800 ms) and trial type (predicted, cued, and NP-NC) as within-subjects factors and with arrow type (symmetrical, asymmetrical) as a between-subjects factor revealed that there were no significant effects involving arrow type [all $Fs<2$; all $ps>0.16$], confirming that our arrow effects were equivalent when the arrow cues may have had less directional saliency than our gaze cues (symmetrical arrows) and when the arrow cues were given greater directional weight (asymmetrical arrows).

As in Experiment 1 the seven participants who were eye-monitored rarely produced eye movements (3.0%). And a comparison of RT performance for these seven eye-monitored participants with that of the first seven nonmonitored participants produced no significant effects (all $Fs < 1.4$, all $ps > 0.20$), once again confirming that eye movements were not involved in producing our cuing effects, and that the orienting we observed was covert in nature.

Discussion

Experiment 2 was identical to Experiment 1, with the exception that arrows were used instead of gaze as the centrally-presented counterpredictive cue. The pattern of RTs for predicted but not cued target locations versus locations that were neither predicted nor cued was very similar to that obtained with counterpredictive gaze in Experiment 1; that is, a reliable advantage for targets occurring at the predicted location

was observed at 600, 1200, and 1800 ms SOA, indicating that participants were able to shift attention volitionally to the location where a target was likely to occur. However, the pattern of RTs for cued but not predicted target locations versus locations that were neither predicted nor cued was very different from that obtained in Experiment 1: with arrows, there was never a significant advantage for targets occurring at the cued location. This difference between experiments was confirmed statistically, with an ANOVA comparing gaze and arrows (cue type) between groups and revealing significantly different cuing effects (trial type) both as a function of SOA (cue type x trial type x SOA [$F(9, 46) = 1.91$, $p < 0.05$]), and when collapsed across SOAs (cue type x trial type [$F(3,46) = 7.87$, $p < 0.0001$]). Note that this difference between gaze and arrows cannot be attributed to a perceptual weighting toward the cued (gazed-at) location in Experiment 1 because an asymmetrical arrow in Experiment 2 did not produce an advantage at the cued location, nor did it produce any difference from a symmetric arrow.

Given that nonpredictive arrows can produce relatively early facilitation (Ristic, Friesen & Kingstone, 2002), it may seem curious that in the present arrow cuing experiment the advantage for cued target locations did not reach significance. This discrepancy may be due to differences in design between the experiments, such as the difference in the number of possible target locations (two in the Ristic et al. study and four in the present study), or differences in the distance between cued and uncued locations (180° in the Ristic et al. study and 90° in the present study). However, in recent experiments with nonpredictive arrows and four target locations (Ristic, Olk, Ho, & Kingstone, 2003), we observed early facilitation similar to that observed in the Ristic et al. (2002) study with two target locations. Thus, we favor the more interesting and meaningful possibility that the discrepancy is due to differences in the predictive value

of the arrow cues across studies. In the Ristic et al. (2002) study the arrow cues were spatially nonpredictive. In the present study they were spatially counterpredictive. It appears then that the arrow cuing effect may be less strongly reflexive in nature than the gaze cuing effect, and may therefore be more vulnerable to observers' top-down goals and expectations. If so, then it is reasonable that volitional orienting in a direction opposite to the arrow direction might undermine the reflexive orienting effect of the arrow stimuli in the present study. At any rate, our data indicate that while gaze and arrows are similar in their ability to produce a volitional shift in covert attention, arrow cues do not trigger a reflexive shift of attention to a location where a target is unlikely to appear.

General Discussion

Our counterpredictive gaze experiment (Experiment 1) replicated the finding of Driver et al. (1999) that subjects orient attention reflexively to a gazed-at location at a short SOA even though they expect the target not to appear there. This confirms that orienting to gaze direction is reflexive in a strong sense, i.e., that it can occur even against subjects' intentions. Experiment 1 also demonstrated that subjects can direct attention volitionally to a nongazed-at location at longer SOAs. Moreover, the results of this experiment indicate that at an intermediate SOA, when both reflexive attention to the gazed-at location and voluntary attention to the likely location might be expected to occur, both may indeed have occurred. In other words, reflexive orienting to gazed-at locations and volitional orienting to likely locations exhibited different but overlapping timecourses. This suggests that gaze-triggered orienting and volitional orienting might occur somewhat independently of one another, such that attention can be directed reflexively to one location and volitionally to another location at the same time. Supplementary analyses supported this interpretation and failed to lend support to

alternative explanations, such as the possibility that our finding of reflexive and volitional co-occurrence was an artifact of averaging across different subjects or the possibility that it was due to subjects switching between one type of orienting on one trial and another type of orienting on another trial.

The results of our second experiment with counterpredictive arrows suggested that the data pattern observed in Experiment 1 may be unique to gaze direction cues. Experiment 2 was identical in every way to Experiment 1 with the exception that gaze direction cues were substituted with arrow cues. Yet the results were clearly very different. In both experiments, evidence of covert voluntary orienting to the predicted target location was observed at 600, 1200, and 1800 ms SOA. However, in contrast to our findings with counterpredictive gaze cues, with counterpredictive arrow cues there was no evidence of covert reflexive orienting to the cued location.

The difference observed in the present study between gaze and arrow cues lends support to the notion that gaze direction may be a special attentional cue that can trigger reflexive shifts of attention that are in opposition to, and concurrent with, volitional shifts of attention.

In the present study we chose to use a schematic face, rather than an image of a real face, to provide our gaze cue because such a simple stimulus is more perceptually equivalent to other directional cues in the environment, such as the arrow cue we used. Nevertheless, one might wonder whether the gaze effects we observed with schematic faces can be generalized to more realistic looking faces and eyes. To our knowledge, only one study to date has directly compared the gaze cuing effects of schematic faces with those of real faces. Using schematic and real faces with various emotional expressions, Hietanen and Leppänen (in press) found that schematic faces produced similar, albeit somewhat larger, cuing effects to those produced by real faces at a 200

ms SOA. In numerous other studies, the reflexive gaze cuing effect has been observed with schematic faces (e.g., Friesen & Kingstone, 1998, 2003a, 2003b; Kingstone, Friesen, & Gazzaniga, 2000; Ristic, Friesen, & Kingstone, 2002) and with real faces (e.g., Driver et al., 1999; Hietanen, 1999; Langton & Bruce, 1999); and comparisons across studies suggest that in general the performance effects are equivalent. With regard more specifically to the effects of counterpredictive gaze cues, Experiment 1 of the present study with schematic faces replicates the findings produced by Driver et al. (1999, Experiment 3) with real faces (i.e., there is reflexive orienting to the gazed-at but unlikely target location at a short SOA, and there is no difference between cued and predicted locations at an intermediate SOA).

Our paradigm was designed so that we could assess the effects of our directional cues by comparing performance at cued and predicted locations with performance at locations that were neither predicted nor cued. The inclusion trials on which the target would appear at a location that was neither predicted nor cued (NP-NC) by the directional stimulus (i.e., gaze or arrow) provided the ideal baseline for our purposes, because a target appearing at one of those locations is preceded by exactly the same type of cue as a target appearing at a cued location or a predicted location. As was first noted by Jonides and Mack (1984), failure to obtain such a baseline measure leaves open the very real possibility that performance differences between cued and neutral trials (such as the straight-gaze and cross cues, in the case of the present study) may have nothing to do with attentional orienting and everything to do with one or more confounding factors such as arousal, effort, or strategy. By using baseline trials that are directional cue trials we can make assessments of reflexive and volitional orienting at different time windows with confidence -- something that most studies have not been

able to do in the past (but see Kingstone & Klein, 1991, and Danziger & Kingstone, 1999, for two noteworthy exceptions).

In a previous study with nonpredictive gaze cues in which we treated straight-gaze trials as our neutral baseline, we concluded that gaze direction cues produced benefits at gazed-at locations without any corresponding costs at nongazed-at locations (Friesen & Kingstone, 1998). The inclusion of similar "neutral" trials (straight-gaze trials in Experiment 1, and cross trials in Experiment 2) in the design of the present study afforded us an opportunity to compare these neutral nondirectional cue trials (straight-gaze or cross) with our NP-NC directional cue trials. For each experiment, an ANOVA was conducted with trial type (directional NP-NC, nondirectional neutral) and SOA (105, 600, 1200, 1800 ms) as within-subject factors. For gaze cues (Experiment 1), there was a main effect for trial type, with RT 5 ms longer on NP-NC trials than on straight-gaze trials [$F_{(1, 23)}=11.11$, $p<0.005$]; and the trial type x SOA interaction was not significant [$F<1.0$]. For arrow cues (Experiment 2), the main effect for trial type was not significant [$F<1.0$]; but the SOA x trial type interaction was significant [$F_{(3, 23)}=7.11$, $p<0.0005$]. Inspection of the data suggested that this interaction was caused by <u>shorter</u> RTs on NP-NC trials than on central cross trials at the 105 ms SOA. In agreement with this interpretation, when the 105 ms SOA trials were removed from the ANOVA, a completely different result was obtained. Now, there was a marginally significant main effect for cue type, with RT 3 ms longer on NP-NC trials than on cross trials [$F_{(1, 23)}=3.11$, $p<0.10$], and the trial type x SOA interaction fell far short of significance [$F<1.6$].

The overall pattern of results with the nondirectional trials converges with the results we reported using directional trials as our baseline, i.e., that responses are primarily <u>facilitated</u> at cued and/or predicted target locations. As for the one anomalous

finding just discussed (shorter RT on NP-NC arrow trials than on central cross trials at 105 ms SOA), it provides an illustration of the inherent danger of failing to include an appropriate baseline measure at the time that attention is cued (Jonides and Mack, 1984). If we had not included directional baseline NP-NC trials in our experiment, and if we had compared predicted and cued trials to the nondirectional cross trials, we would have been misled into thinking that there was early facilitation on both predicted trials and cued trials. But our data reveal that directional baseline trials are also "facilitated" relative to neutral. Clearly, there really is no cuing effect occurring at the 105 ms SOA (predicted and cued trials are not significantly faster than NP-NC trials), and the "neutral" nondirectional stimulus (i.e., the cross) is being treated differently from the directional arrow cues at this early SOA. Thus, it is important to note that although nondirectional neutral cues (such as our straight gaze and cross cues) might generally serve as a reasonable baseline, they do not always do so.

The different but overlapping timecourses of reflexive orienting to a gazed-at location and volitional orienting to a likely target location observed in Experiment 1 suggests that the two forms of orienting may be independent, and thus that they may be subserved by different attentional systems or subsystems. There is considerable evidence in the attentional literature indicating that reflexive orienting to a sudden onset at a peripheral location and volitional orienting to an expected target location occur by way of different brain pathways. Reflexive orienting to a sudden onset in the periphery is thought to involve the superior colliculus (SC), working in concert with parietal cortex (Rafal, Henik, & Smith, 1991; Rafal, Posner, Friedman, Inhoff, & Bernstein, 1988), whereas volitional orienting to an expected target location is thought to involve frontal and parietal areas (Corbetta, Miezin, Shulman, & Petersen, 1993; Posner 1995; Posner

and Raichle, 1994). It seems likely, however, that reflexive orienting triggered by gaze direction does not occur by way of either of these pathways.

Several lines of evidence suggest that gaze-triggered orienting does not occur by way of the subcortical pathway. First, in their study with split-brain patients, Kingstone, Friesen, and Gazzaniga (2000) demonstrated that reflexive orienting to gaze direction is lateralized to one cortical hemisphere. Second, in a recent eye movement study, Friesen and Kingstone (2003a) found that gaze direction cues did not activate or predisengage the oculomotor system, suggesting that orienting to gaze direction does not engage the SC. And third, Friesen and Kingstone (2003b) demonstrated that reflexive orienting to gaze direction can co-occur with IOR (which is subserved by the SC).

Similarly, the finding of the present study that reflexive orienting to a gazed-at location and volitional orienting to a different location might co-occur suggests that attention to gaze does not occur by way of the frontal-parietal pathway that underlies volitional orienting. This conclusion is consistent with three other results suggesting that gaze-triggered orienting is not simply a well-learned form of volitional orienting. First, Ristic, Friesen, and Kingstone (2002) found that preschool children showed greater orienting effects than adults in response to nonpredictive gaze direction cues, despite the fact that young children are thought to be poor at volitional orienting (Brodeur, Trick, and Enns, 1997). Second, Hood, Willen, and Driver (1998) found that infants were faster to make saccades to peripheral targets that were cued nonpredictively by the gaze direction of a central face, and concluded that gaze-triggered orienting is in place very early in development (but see Farroni, Johnson, Brockbank, & Simion (2000) for an alternative explanation). And third, in their split-brain patient study, Kingstone, Friesen, and Gazzaniga (2000) found that although only the cortical hemisphere specialized for

face and gaze processing oriented reflexively in response to nonpredictive gaze cues, both hemispheres oriented volitionally in response to predictive gaze cues.

So what might the gaze-triggered reflexive attention pathway be? Kingstone, Friesen, and Gazzaniga (2000) proposed that orienting to gaze direction might be subserved by a temporal-parietal pathway, with cells in inferotemporal cortex (IT) processing face and eye information, cells in the superior temporal sulcus (STS) processing the direction of gaze, and cells in parietal cortex shifting attention to the gazed-at location. Each of these brain regions has since been implicated in gaze direction processing in a number of human neuroimaging studies (e.g., Hoffman & Haxby, 2000; Kato et al., 2001; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Wicker, Michel, Henaff, & Decety, 1998). Note that all three of the attentional pathways discussed here — the subcortical reflexive pathway, the cortical volitional pathway, and the proposed cortical gaze direction pathway — involve parietal cortex. How, then, could attention be shifted reflexively to a gazed-at location and volitionally to a different location at the same time? One possibility is that volitional inputs from frontal cortex and gaze inputs from temporal cortex activate different parietal neurons. In a recent fMRI study that compared peripheral target detection versus volitional orienting, Corbetta, Kincade, Ollinger, McAvoy, and Schulman (2000) found evidence for this type of dissociation, with temperoparietal cortex activated during target detection, and intraparietal cortex activated during volitional orienting.

To our knowledge, the present study is the first to demonstrate that gaze cues and arrow cues can produce qualitatively different behavioral results in intact observers. In their recent study with nonpredictive gaze and arrow cues, Ristic, Friesen, and Kingstone (2002) found that nonpredictive gaze cues and nonpredictive arrow cues produced similar RT patterns in normal participants (both adults and children).

Differences in the effects of the two types of directional cue were revealed only when the performance of a split-brain patient was examined: nonpredictive arrow cues triggered orienting in both hemispheres, whereas in a previous study of the same patient (Kingstone, Friesen, and Gazzaniga, 2000) nonpredictive gaze cues triggered orienting only in the hemisphere specialized for face processing. Based on this difference in lateralization for the two cue types, Ristic, Friesen, and Kingstone concluded that gaze is indeed special. The present study, however, demonstrates that apart from the issue of lateralization of face processing, gaze and arrow cues can trigger qualitatively different behavioral effects. When each of these directional cues is put into competition with volitional orienting, orienting to gaze direction persists, whereas orienting to arrows is abolished.

In sum, the results of the present study confirm that attentional orienting toward a gazed-at location is reflexive, not only in the sense that it occurs when participants do not have any incentive to attend to the gazed-at location (as is the case in nonpredictive gaze experiments), but also in the stronger sense that it can occur even when participants are attending volitionally to an opposite location. Our finding that reflexive and volitional orienting in response to gaze direction appear to co-occur suggests that the two may be subserved by distinct and separable mechanisms. Arrow cues can also produce reflexive shifts of attention (Ristic, Friesen & Kingstone, 2002; Tipples, 2002), but unlike eyes they do not do so when they are counterpredictive. The implication is that while many directional cues might trigger reflexive shifts of attention when they are spatially nonpredictive, they are not all equal. In particular, gaze cues appear to be more strongly reflexive than arrow cues, very possibly because they access a neural architecture that is specialized for processing eye direction.

Table 5.1

Condition		M	SD	%E
105 ms SOA				
	Predicted	390	55	0.94
	Cued	385	51	0.93
	NP-NC	397	58	0.85
	Straight-gaze	396	56	0.99
600 ms SOA				
	Predicted	355	53	0.92
	Cued	356	46	0.58
	NP-NC	367	54	1.69
	Straight-gaze	360	51	0.68
1200 ms SOA				
	Predicted	338	50	0.48
	Cued	354	55	0.56
	NP-NC	356	49	0.93
	Straight-gaze	347	46	0.69
1800 ms SOA				
	Predicted	346	46	0.55
	Cued	349	50	0.76
	NP-NC	357	47	0.38
	Straight-gaze	353	46	0.25

Table 5.1. Mean RTs (in ms), Standard Deviations, and Errors Rates (%) for Experiment 1. Note. N = 24. Error rates represent the percentage of test trials from each cell excluded as anticipations, key press selection errors, timed-out trials, or trials with RT > 1000 ms. SOA= stimulus onset asynchrony.

Table 5.2

Condition		M	SD	%E
105 ms SOA				
	Predicted	379	53	0.69
	Cued	377	56	0.97
	NP-NC	385	52	0.48
	Cross	398	54	0.83
600 ms SOA				
	Predicted	348	52	0.78
	Cued	374	61	0.19
	NP-NC	372	50	0.76
	Cross	366	46	0.44
1200 ms SOA				
	Predicted	333	49	0.66
	Cued	355	50	0.74
	NP-NC	353	45	0.56
	Cross	349	46	0.56
1800 ms SOA				
	Predicted	337	47	0.81
	Cued	358	50	0.19
	NP-NC	351	47	0.65
	Cross	352	48	0.75

Table 5.2. Mean RTs (in ms), Standard Deviations, and Errors Rates (%) for Experiment 2. Note. N = 24. Error rates represent the percentage of test trials from each cell excluded as anticipations, key press selection errors, timed-out trials, or trials with RT > 1000 ms. SOA= stimulus onset asynchrony.

Figure 5.1.

Fixation Display
675 ms

Gaze Cue Display
105, 600, 1200,
or 1800 ms

Target Display
until response,
or 1500 ms
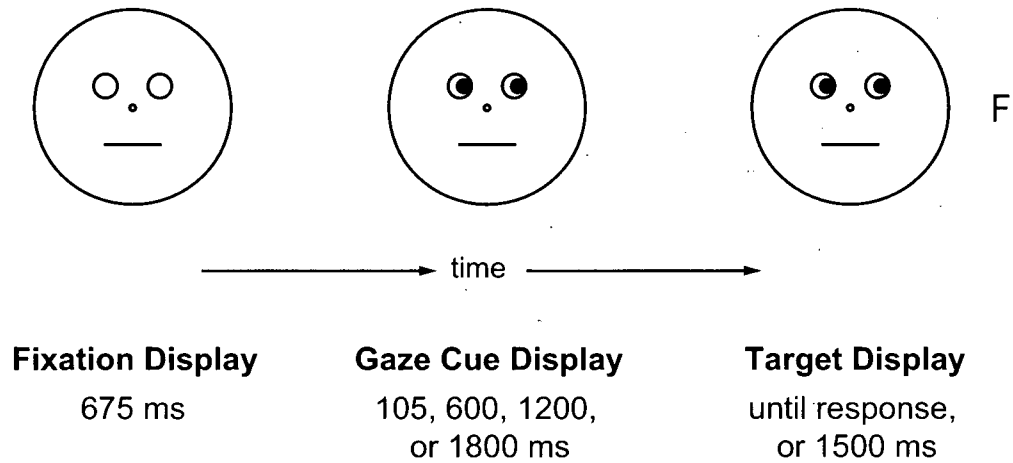
Figure 5.1. Illustration of the trial sequence in Experiment 1. Each trial began with the presentation of a face with blank eyes. After 675 ms, pupils appeared in the eyes, looking left, right, up, down, or straight ahead (the gaze cue). Then, after 105, 600, 1200, or 1800 milliseconds (ms), the letter F or T (the target) appeared to the left or to the right, above, or below the face. The target was likely to appear at the location opposite to the gazed-at location 75% of the time the eyes looked left, right, up, or down.

Figure 5.2.
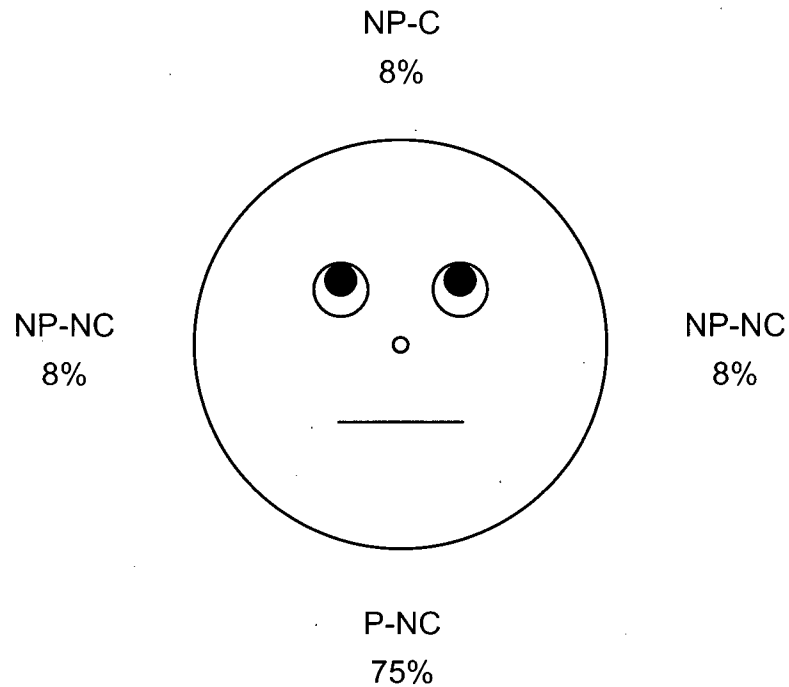
Figure 5.2. Illustration of the three trial types that were possible when gaze was directed at one of the four target locations in Experiment 1. Predicted = target occurs at the predicted (not cued) location. Cued = target occurs at the cued (not predicted) location. NP-NC = target occurs at a location that is neither predicted nor cued. Numbers represent the percent probability (rounded to the nearest percentage point) of the target's appearance at each location.

Figure 5.3.
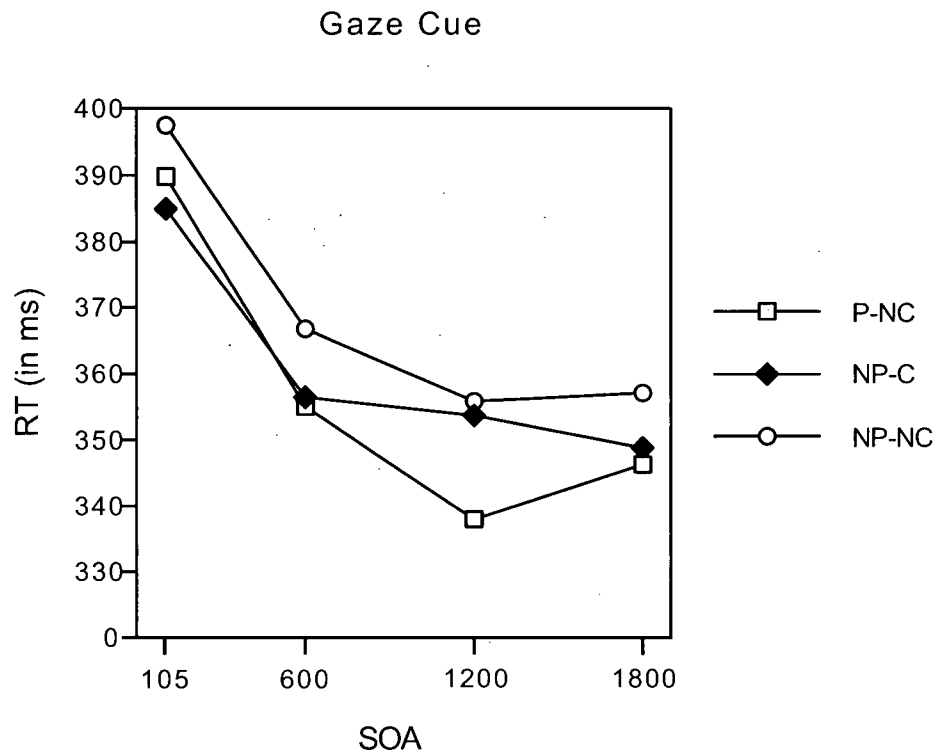
Gaze Cue

Figure 5.3. Experiment 1 mean RTs for counterpredictive gaze cues as a function of cue-target stimulus onset asynchrony (SOA) and trial type. Predicted = target occurs at the predicted (not cued) location. Cued = target occurs at the cued (not predicted) location. NP-NC = target occurs at a location that is neither predicted nor cued.

Figure 5.4.

A. Symmetrical Arrow Cue

time

Fixation Display	Arrow Cue Display	Target Display
675 ms	105, 600, 1200, or 1800 ms	until response, or 1500 ms
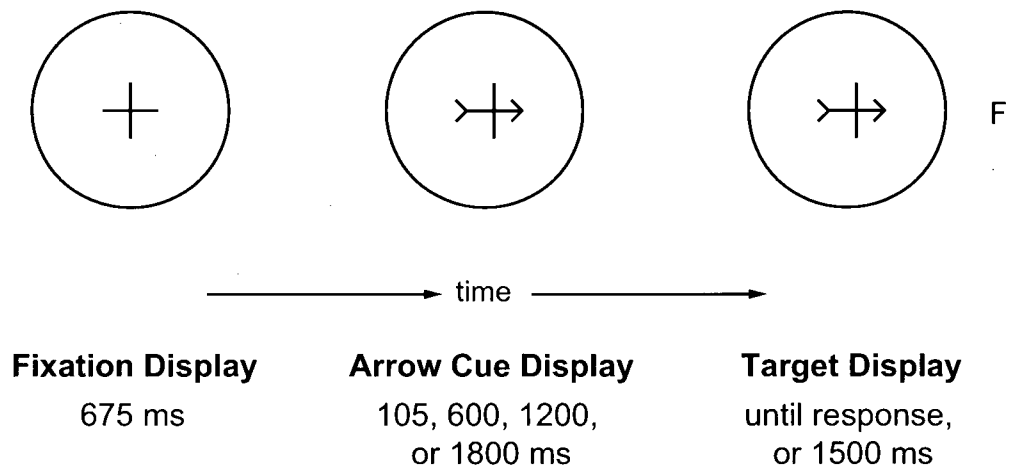
B. Asymmetrical Arrow Cue
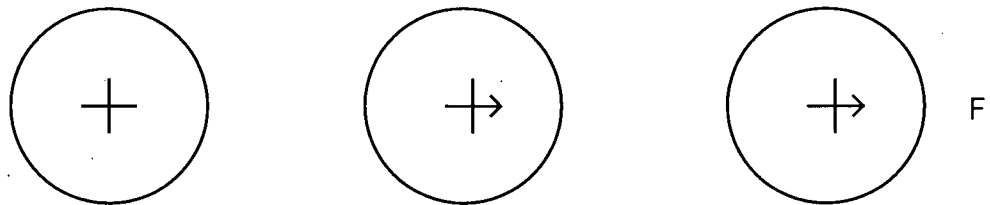
Figure 5.4. Illustration of the trial sequence in Experiment 2. Each trial began with a cross at central fixation. After 675 ms, an arrow with a head and a tail (A) or an arrow with only a head (B) appeared on one of the two lines of the cross, creating an arrow pointing left, right, up, or down. On nondirectional cross trials, small perpendicular lines appeared at the ends of the lines of the cross. Then, after 105, 600, 1,200, or 1,800 ms, a target letter (F or T) appeared to the left of, to the right of, above, or below the cross. Trial types and probabilities were the same as those for counterpredictive gaze direction cues (see Figure 6.2).

Figure 5.5.
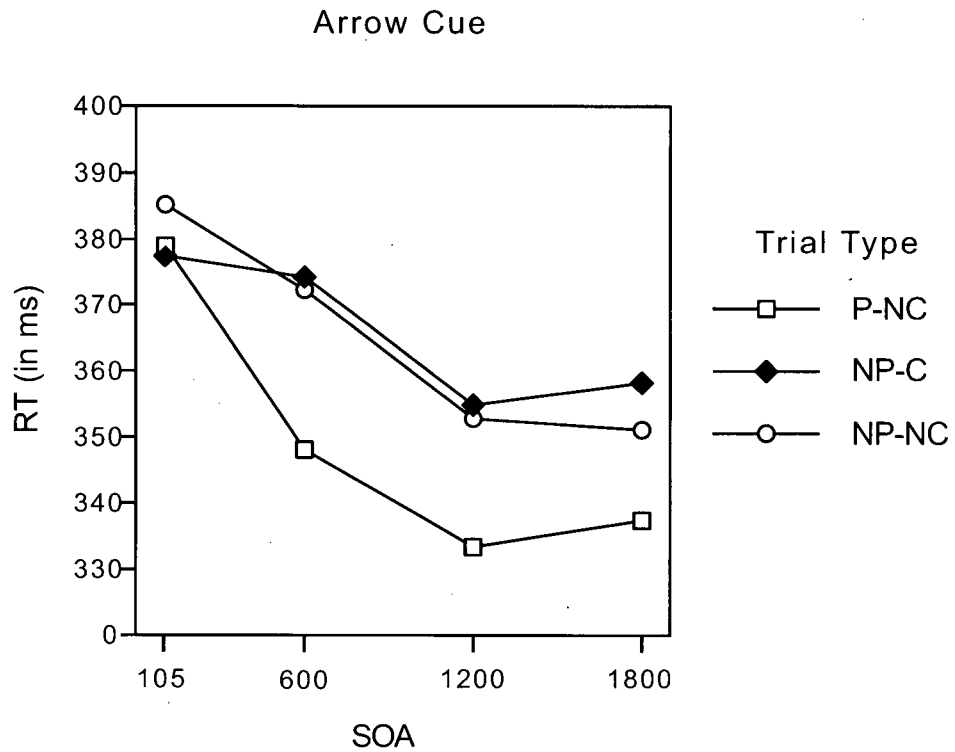
Arrow Cue

Figure 5.5. Experiment 2 mean RTs for counterpredictive arrow cues as a function of cue-target stimulus onset asynchrony (SOA) and trial type. Predicted = target occurs at the predicted (not cued) location. Cued= target occurs at the cued (not predicted) location. NP-NC = target occurs at a location that is neither predicted nor cued.

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CHAPTER 6

Attentional Control and Reflexive Orienting to Gaze and Arrow cues

In everyday life human eyes are a vital nonverbal social cue that enables fluent social communication between individuals. Transmission of gaze information is facilitated by a uniquely human eye morphology, with its dark iris surrounded by a high contrast white sclera, that allows people to accurately convey to others where they are looking (Kobayashi & Koshima, 1997). Perception of gaze information is also supported by a neural architecture, the superior temporal sulcus (STS) that is dedicated to the processing gaze information (Allison, Puce & McCarthy, 2000). Signs of eye gaze communication is evident shortly after birth, with infants as young as 2 or 3 days preferentially looking toward the eyes of another face (Batki et al, 2000; Farroni et al, 2002) and by the end of the first year most infants will look reliably toward where someone else is looking (Hood, Willen & Driver, 1998).

Researchers have developed a simple task to measure the tendency for children and adults to attend to where someone else is looking (Hood, Willen & Driver, 1998; Friesen & Kingstone, 1998). Friesen and Kingstone (1998) asked adult participants to detect, localize or identify visual targets that appeared to the left or right of a central face on a computer monitor. The key manipulation was that just before a target appeared, the eyes in the face on the computer screen would look to the left or right of center. Friesen and Kingstone found that the response time (RT) to a visual target was shortest when it appeared at the gazed-at location. This RT advantage for a target at the cued (gazed-at) location occurred despite the fact that the participants knew in advance that the eyes in the face did not predict where a target would occur. Based on these data, and the fact that the RT advantage at the cued location emerged very rapidly, Friesen and Kingstone suggested that the laboratory paradigm engaged brain mechanisms such as the STS that are dedicated to processing and orienting toward

where other people are looking (see also Driver et al. 1999; Langton, Watt & Bruce, 2000).

Subsequent to these original investigations, a body of evidence emerged showing very clearly that other directional cues, such as fingers, words, and arrows will produce an attention effect that is comparable to the attention effects produced by eyes (Gibson and Kingstone, in press; Hommel et al, 2001; Tipples, 2002; Watanabe, 2002). Collectively, these findings bring into question the original idea that the eye gaze paradigm described above is tapping into mechanisms that are specific to social orienting to eyes.

Friesen, Ristic and Kingstone (2004) addressed this issue directly by testing whether arrows trigger attention shifts that are as strongly reflexive as eyes. They compared performance elicited by eyes and arrows when each of these cues were counterpredictive, e.g., if a participant was shown eyes or arrows indicating a left location, the target was highly likely to occur at the opposite right location. Friesen et al., found that only eyes triggered an initial, rapid reflexive shift in attention to the cued (gazed-at) location. In other words, participants were unable to avoid attending reflexively to where the eyes were looking, but they were able to avoid attending reflexively to where arrows were pointing. This finding — that eyes are more strongly reflexive than arrows — lends support to the idea that the eye gaze paradigm is tapping into mechanisms that are specific to social orienting to eyes.

When these data are considered as a whole, it appears that there is a wide range of stimuli that can produce reflexive shifts in spatial attention. Some central cues, like gaze direction, trigger rapid reflexive shifts of attention that are strongly reflexive and hence they are relatively insensitive to top-down inhibitory control (Friesen, Ristic & Kingstone, 2004; Ristic & Kingstone, 2005). At the other end of the extreme are stimuli

like numbers, that can produce shifts of attention when they are spatially nonpredictive (Fischer et al. 2003) but this orienting effect is both slow to emerge and extremely sensitive to changes in the top-down mental set adopted by a participant (Ristic, Wright & Kingstone, in press; Galfano, Rusconi & Umilta, in press). Arrow stimuli would appear to fall somewhere in the middle, producing rapid shifts of attention even when they are known to be spatially nonpredictive, but their effects are relatively amenable to top-down control.

A recent study by Pratt and Hommel (2003) provides an excellent illustration of arrow cues' sensitivity to top-down control. Pratt and Hommel found that when participants are set to respond to a target stimulus of a particular color, a task irrelevant arrow stimulus that shares the target color will trigger a shift in spatial attention. For example, if the set is for a target that is colored green, attention is shifted to the location cued by a green arrow; and if the set target is for a target that is colored blue, attention is shifted to the location cued by a blue arrow.

In the present study we asked whether these arbitrary cue-target congruency effects found for arrows will also occur for eyes. Based on our hypothesis that the attention effects for arrows are more amenable to arbitrary top-down associations than eyes, the strong prediction is that arrows will be significantly more sensitive to cue-target color contingencies than eyes. Thus, we predict that arrows will produce cuing effects that are specific to congruent cue-target color contingencies (Pratt and Hommel, 2003). In contrast, because eyes are more strongly reflexive their attention effect may extend across congruent and incongruent cue-target color contingencies.

Finally, it is perhaps noteworthy that this is the first time that the effects of nonpredictive eyes and arorws are being tested directly against a benchmark effect established by nonpredictive arrows. To date comparisons between the reflexive

orienting effects of eyes and arrows have consistently examined whether arrows can produce an outcome that is comparable to the effect of eyes (e.g., Tipples, 2002; Ristic, Friesen & Kingstone, 2002; Bayliss, di Pellegrino & Tipper, 2005). In the present study the fundamental nature of this comparison is reversed, and hence the conceptual framework and questions that emerge are now being driven by the effects elicited by nonpredictive arrow stimuli.

Experiment 1

In Pratt and Hommel's (2003) original investigation participants were given a color precue that defined the response target, e.g., if the color precue was a blue patch then participants were to press a key if the target was colored blue and to refrain from responding if the target was not colored blue. Prior to a target appearing, four arrows appeared at central fixation, each colored differently and each pointing in different directions (left, right, up, down). The key finding was that RT was fastest when the colored target appeared at the location cued by a matching colored arrow (e.g., a blue target appearing at the location cued by a blue arrow). Importantly, this spatial color-target contingency effect occurred despite the fact that the location of the target was not predicted by the color or direction of the color-congruent arrow.

The aim of the present experiment is to establish that this reflexive spatial cue-target color contingency effect can be replicated in a simpler task, e.g., in a task that has no color precue and only one arrow cue. In Experiment 1 participants were asked to press one key if the target was white and another key if the target was black. Prior to target onset, a spatially irrelevant arrow cue, colored white or black, appeared at central fixation and pointed left or right. The color and direction of the arrow cue did not predict the color or location of the target. The question was whether a reflexive spatial effect of

the arrow cue would be greater for a congruently colored target compared to an incongruently colored target, as suggested by Pratt and Hommel (2003).

Method

Participants

Forty participants were assigned randomly to two different groups: one group received a white arrow cue, and one group received a black arrow cue.

Apparatus & Stimuli

All stimuli were black and white line drawings presented on a gray background. The stimuli were shown on a PowerPC Macintosh computer connected to a 15-in color monitor set to black and white. The central arrow cue was a triangle measuring 1° of visual angle at its base and 0.7° in height. The target (1° in size) was square- or diamond-shaped. The arrow cue was presented at the center of the screen and targets appeared peripherally 3° away from center fixation. Response keys were "z" and "/" on a computer keyboard, with the left index finger pressing the "z" key and the right index finger pressing the "/" key. Color assignment to the response keys was counterbalanced between participants.

Design

The stimuli and sample sequence of events are illustrated in Figure 6.1. The black arrow and white arrow groups each performed a color discrimination task, pressing one key if the target was black and the other key if the target was white. Each group performed 480 color discrimination trials.

For both black arrow and white arrow groups, the central arrow cue indicated one of the two possible directions (left or right), and the target could appear either on the left, right, up or down. This created two different cue validity conditions: *cued trials*, in which the target occurred either on the left or right side as indicated by the arrow

(p=.25); and uncued *trials* in which the target occurred at the location that was not cued by the arrow (uncued locations are collapsed as an analysis of variance revealed that this factor had no effect (F<1) on performance). Cue direction, target location, and target features (color and shape) were selected randomly and presented with equal probability. RT to press a key was measured in milliseconds (ms) and timed from target onset.

Procedure

All trials began with a 105 ms presentation of a central arrow cue pointing left or right. Following a 210 ms stimulus onset asynchrony (SOA) a target appeared left, right, above, or below the cue. The trial was terminated on response or after 1005 ms whichever occurred first. The intertrial interval was 2505 ms.

Participants were seated centered in front of the computer screen at an approximate distance of 57 cm. It was emphasized that the direction of the arrow and its color did not predict the location, color, or shape of the target. All participants were asked to respond as quickly and as accurately as possible and to maintain central fixation throughout the experiment.

Results

Anticipations (RT< 100 ms), timed-out responses (RT>1000ms), and incorrect key presses were classified as errors and excluded. These errors occurred on only 5.2% of the trials. Most importantly, as the subsequent analyses are conducted on correct RT, in no condition was the RT data contradicted by a speed-accuracy tradeoff, e.g., faster RT at the cued location than the uncued location accompanied by more errors at the cued location than the uncued location.

The mean RTs for cued and uncued targets are presented in Figure 6.2A as a function of cue-target color congruency. Note that a spatial attention effect (cued RT <

uncued RT) is greater for color congruent cue-target stimuli than incongruent cue-target stimuli. That is, for the black arrow group RT is faster for the cued location versus the noncued location when the target is black; and for the white arrow group RT is faster for the cued location versus the noncued location when the target is white. Separate ANOVAs for each group confirmed this observation, with cue validity (cued/uncued) and target color (black/white), interacting [Black arrow group $F(1,19)=4.7, p<.05$; White arrow group $F(1,19)=4.8, p<.05$]. The main effects of target color were also reliable [Black arrow $F(1, 19)= 24.6, p<.0001$; White arrow $F(1,19)=27.0, p<.0001$], indicating that for each group RT is faster overall for the target color that is congruent with the color of the arrow cue. No other effects were significant [all $Fs<2.4$, all $ps>.1$].

The above analyses strongly suggest that the cue x validity interaction varies with group, and this was confirmed by an ANOVA [$F(1,38)=9.0, p<.01$]. Group also interacted with target color, [$F(1,38)=51.5, p<.0001$], agreeing with the above observation that RT is faster overall when the color of the target is congruent with the color of the cue. No other effects were significant [all $Fs<3.5, ps>.05$].

Discussion

The data from this experiment show that the reflexive attention shift that is triggered by a nonpredictive arrow cue produces a performance benefit that is specific to color congruent targets. This result provides an important conceptual replication and extension to the Pratt and Hommel (2003) study, as it demonstrates that an arbitrary cue-target color contingency effect extends to the simple situation of one arrow cue presented in a single color.

The key question now is whether the reflexive attention effect that is elicited by eye direction will also demonstrate a cue-target color contingency effect. As outlined in the introduction, there are good reasons to think that eyes will be more strongly reflexive

and hence less sensitive than arrows to arbitrary cue-target color contingencies. Experiment 2 puts this hypothesis to the test.

Experiment 2

Black and white schematic gaze cues were run in Experiment 2 as matches for the black and white schematic arrow cues used in Experiment 1. In all other aspects the design of Experiment 2 replicated Experiment 1.

Participants

Forty additional naive participants were assigned randomly and equally to two different groups: one group received black schematic eyes, one received white schematic eyes.

Apparatus, Stimuli, Design & Procedure

All parameters mirrored those in Experiment 1 with the following exceptions that schematic black eyes and white eyes, served as fixation stimuli. These schematic eyes (measuring 2.6°) were constructed by combining a circle outline, with an inner filled-in circle representing the pupil (see Figure 6.1).

Cue direction, target location, instructions, and number of trials were in keeping with Experiment 1, e.g., participants were correctly informed that cue direction and its color did not predict the location, color, or shape of the target.

Results

Anticipations (RT< 100 ms), timed-out responses (RT>1000ms), and incorrect key presses were classified as errors and were excluded from the analysis. The errors occurred on only 4% of trials and did not contradict the correct RT data.

Correct mean RTs are summarized in Figure 6.2B. In contrast to Experiment 1, the spatial attention effect (cued RT < uncued RT) appears to be present for both cue-target color congruent and cue-target color incongruent stimuli. Separate within-subject

ANOVAs with cue validity (cued/uncued) and target color were performed for each group as in Experiment 1. These analyses returned significant main effects of cue validity for each group [Black eyes $F(1,19)=4.8, p<.05$; White eyes $F(1,19)=19.4, p<.0001$]. However, unlike Experiment 1, cue validity never interacted with target color [all $Fs<2.2$, all $ps>.1$]. Note that cue validity did not interact with target color even though a main effect of cue color was significant for both conditions [Black eyes $F(1,19)=14.0, p<.01$; White eyes $F(1,19)=10.1, p<.01$]. No other effects were significant [all $Fs<1$].

As suggested above, when group is included as a between subject factor it only interacts with target color, [$F(1,38)=24.0, p<.0001$], reflecting again that for each group RT is faster overall for the target color that is congruent with the color of the gaze cue. The only other significant effects are main effects of target color and cue validity [$Fs>19, p<.0001$; all other $Fs<3.9, p>.05$], the latter indicating that targets are responded to most quickly when they appear at the gazed-at location.

Discussion

The main finding in Experiment 2 is that the reflexive spatial attention effect for gaze (cued RT < uncued RT) occurred for both the black eyes group and the white eyes group, and that this orienting effect for gaze direction was the same for congruent- and incongruently-colored targets. This stands in sharp contrast to the results of Experiment 1 where the spatial attention effect for both arrow groups occurred only for color congruent target stimuli.

It is important to note that the overall cue-target color congruency effect observed in Experiment 1 reappeared in Experiment 2. That is, the color congruency between gaze cues and target stimuli *did* affect overall RT, just as it did in Experiment 1 for arrow cues. The critical difference is that in Experiment 2 this factor did not interact with the

attention effect of gaze direction. Thus our observation that an interaction does not occur between cue validity and cue-target is not simply a matter of confirming the null. Both critical factors — reflexive orienting to gaze direction and cue-target color congruency — produced significant effects on performance. They did not, however, interact within or between groups. This positive finding supports the hypothesis that the attention effect for eyes is more strongly reflexive than the attention effect for arrows, and as such it is less vulnerable to the arbitrary cue-target color contingency attention effects that occur for arrows.

General Discussion

In recent years there has been an explosion of interest in the finding that central directional cues can trigger reflexive shifts of attention to peripheral locations (e.g., (Friesen and Kingstone, 1998; Driver et al., 1999; Langton & Bruce, 1999; Hommel et al, 2001; Ristic et al, 2002; Friesen et al, 2004; Ristic & Kingstone, 2005). Originally, this work focused on the fact that reflexive orienting occurred to biologically relevant stimuli. This research usually concerned the effects of gaze direction (Friesen and Kingstone, 1998; Driver et al., 1999; Langton & Bruce, 1999); but it also considered the attention effects of other biologically relevant stimuli like head direction and finger pointing (see Langton, Watt, and Bruce, 2000 for a review).

More recently, research on the attention effects for directional cues has been extended to other directional cues such as arrows and words with spatial meaning (Tipples, 2002; Ristic et al. 2002; Hommel et al. 2001). Importantly, direct comparisons between these reflexive effects have been relatively infrequent, and when they have occurred they have tended to be grounded in the question of whether an effect that occurs for biologically relevant stimuli, like eyes, also occurs for other directional cues, like arrows (Baylis et al., 2005; Tipples, 2002; Ristic et al. 2002; Friesen et al. 2004).

Based on these studies the conclusion has been that the behavioral effects produced by gaze and arrow cues are very similar but the attention effect for gaze cues is more strongly reflexive than the attention effect elicited by arrow cues (Friesen et al., 2004).

The present study took a different tack than those in the past. Rather than comparing the effects of arrow cues against a reflexive attention effect that has been benchmarked by gaze, the present study compared the effects of eye gaze against a reflexive attention effect that has been benchmarked by arrows. Two experiments examined the influence of cue-target color congruency on the reflexive attentional orienting effect that is observed when arrows and eyes are presented as spatially nonpredictive.

The results of these experiments represent a conceptual replication of Pratt and Hommel's (2003) original finding that the emergence of a reflexive spatial attention effect for an irrelevant arrow cue is specific to a target stimulus that is colored the same as the arrow cue. Like Pratt and Hommel, the present findings demonstrate that the reflexive orienting effect of arrows is highly sensitive to trial-by-trial changes in the attentional set for color that is established by a color-irrelevant stimulus at fixation (see Pratt and Hommel, Experiment 4).

In addition, the present results demonstrate that the reflexive spatial attention effect for nonpredictive gaze cues applies equally to congruent and incongruently colored targets. This fundamental difference between the effects of arrows and eyes is consistent with the notion that the spatial attention effect for eyes is more strongly reflexive than the attention effect triggered by arrows. That is, the spatial attention effect triggered by gaze cues generalizes across significant congruent and incongruent cue-target color contingency effects.

Note the conclusions that the reflexive orienting to gaze is uniquely resistant to a change in attentional set vis-à-vis the cue-target color congruency dovetails with the findings and conclusions of Friesen, Ristic and Kingstone (2004). In that investigation, participants were informed that a target was likely to appear opposite to where the eyes looked. The outcome was that participants could not help but attend first to where the eyes were directed before shifting attention to the opposite location where a target was likely. In contrast, participants were able to avoid attending to where an arrow pointed, and simply shifted their attention to the likely opposite location. A similar finding of resistance to change in attentional set was also demonstrated by Ristic and Kingstone (2005). In that study, participants were unable to avoid orienting to where an ambiguous stimulus was gazing once they had been informed that the stimulus depicted eyes. Thus we find that the present study joins a growing list of investigations that converge on the conclusion that the attentional effects of eyes are strongly reflexive, and that as such their effect on attentional orienting appears to be highly resistant to changes in attentional control settings.

Conclusion

There are at least three important implications of these data. First, they provide an important replication and extension of Pratt and Hommel (2003) who had first shown that trial-by-trial changes in cue-target attentional set can affect whether a reflexive orienting effect for arrows is observed. Second, the present data converge with the notion that gaze cues produce a more strongly reflexive effect than arrow cues (e.g., Friesen et al., 2004). The reason that the attention effect of eyes is so powerful may stem from the fact that this attention effect is driven by the operation of brain mechanisms, like the STS, that are dedicated to processing eye direction (e.g., Allison et al, 2000) and whose operation appears to be resistant to top-down modulation (e.g.,

Vuilleumier et al, 2001; Rees et al, 2000). Finally, the current data agree with the proposal that there are a range of stimuli that can engage spatial attention reflexively, with the strength of this reflexive orienting effect varying across stimuli (see also Ristic & Kingstone, 2005). Some items, like eye direction, produce strongly reflexive effects and are thus highly resistant to modification by control settings. Other items, like arrows, and to a greater extreme numbers, are sensitive to changes in the control setting that is adopted at any given time (e.g., Ristic, et al, in press; Galfano, et al, in press). Appreciation of this point may represent an important and positive step toward the development of a coherent theory of reflexive orienting and its impact on human performance.

Figure 6.1.

Experiment 1: Arrow

Black Arrow   White Arrow

cue
105ms

SOA
212ms

target
120ms

Experiment 2: Eyes

Black Eyes   White Eyes
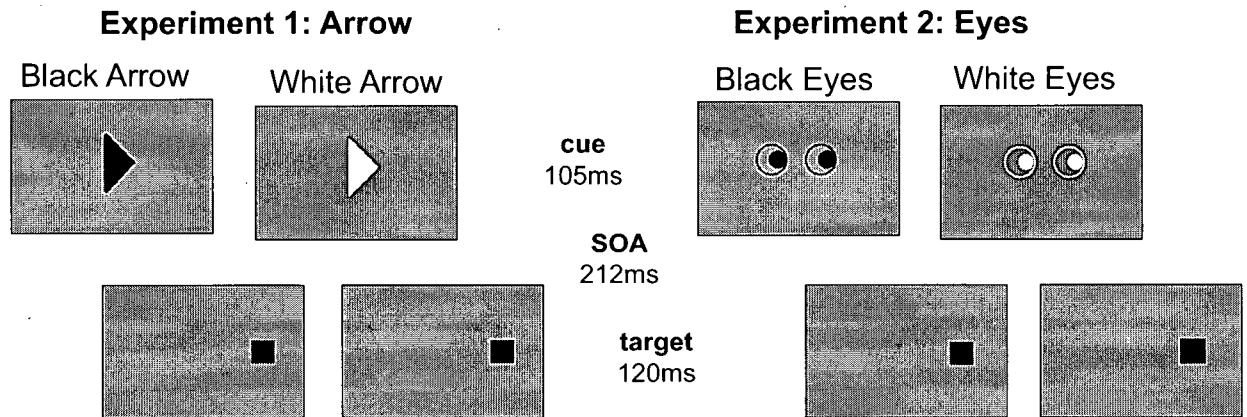
Figure 6.1. Illustration of stimuli and sample sequence of events. In Experiment 1, a black or a white arrow served as a fixation stimulus. In Experiment 2, a pair of black or white schematic eyes served as fixation stimulus. Note that the stimuli are not drawn to scale.

Figure 6.2.

Figure 6.2A. Experiment 1 Results.
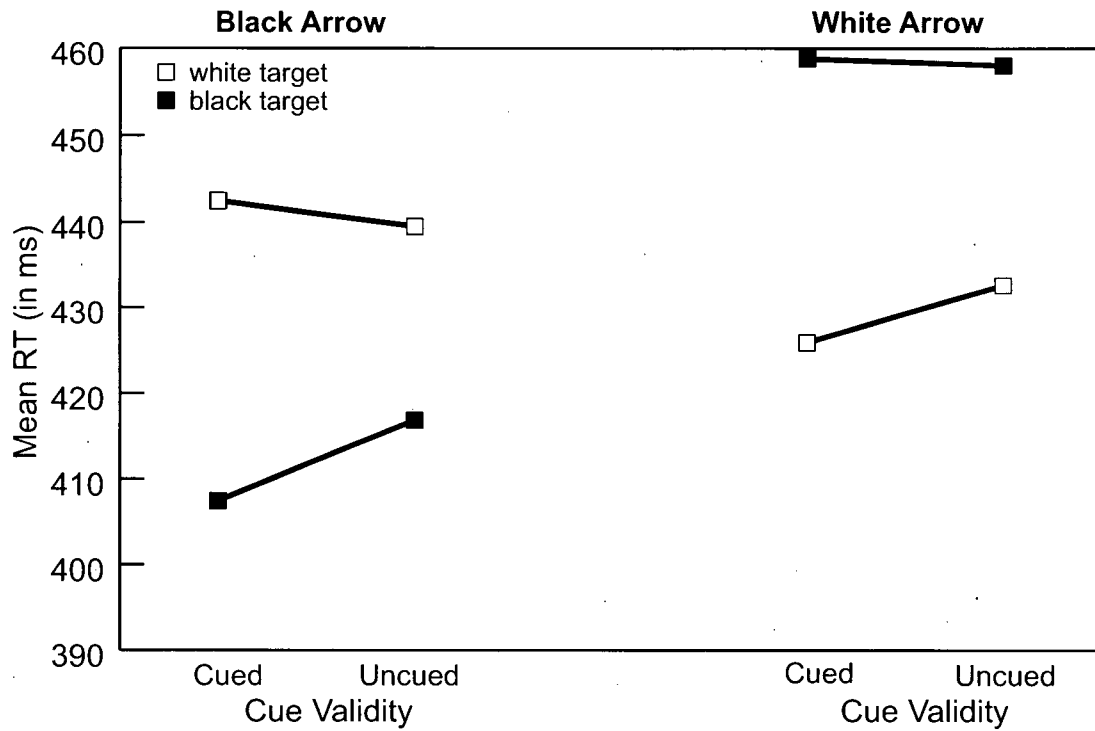
Figure 6.2B. Experiment 2 Results.
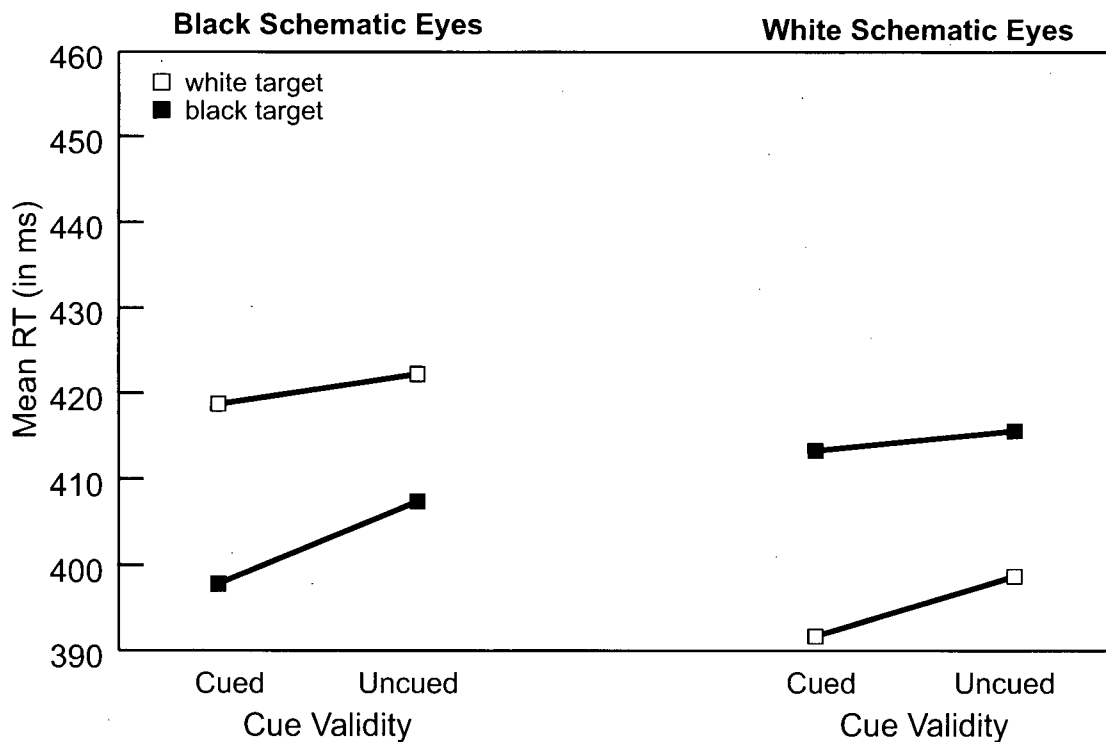
Figure 6.2. Experiment 1 and Experiment 2 cued and uncued RTs as a function of target color. Figure 6.2A illustrates performance for Black and White arrow groups. Figure 6.2B shows Black and White gaze groups.

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SECTION III: IMPLICATIONS FOR TRADITIONAL MEASURES OF ATTENTION

Introduction

Each study presented in this dissertation has demonstrated that a directional, spatially nonpredictive attentional cue presented at central fixation will trigger a reliable <u>reflexive</u> shift in spatial attention toward a peripheral location (Ristic & Kingstone, 2005; Ristic et al, 2005; Ristic & Kingstone, 2002; Friesen, Ristic & Kingstone, 2004; Ristic, Wright & Kingstone, Chapter 6). This finding contrasts with the traditional conceptualization and measurement of attentional orienting. In the standard cuing paradigm, reflexive spatial orienting is triggered by presenting a <u>spatially nonpredictive</u> stimulus in the periphery, and volitional orienting is engaged by presenting a <u>spatially predictive</u> directional cue at central fixation (e.g., Posner, 1980; Jonides, 1981).

Importantly, the attention effect of a central spatially nonpredictive central stimulus, such as a gaze cue or arrow cue, displays properties that are suggestive of both reflexive orienting and volitional orienting. In keeping with reflexive orienting these cues are spatially nonpredictive and their effects occur shortly after a cue is presented. In keeping with volitional orienting these cues produce a sustained performance benefit at the cued location that does not appear to be replaced by the inhibition of return (IOR) effect.

In this final section of the thesis, Chapter 7, the reflexive attention effect when it is triggered by a central nonpredictive cue is compared directly against traditional measures of reflexive and volitional orienting, that is, orienting to nonpredictive peripheral onsets and predictive central cues, respectively. To achieve this end, I developed a novel paradigm that allows an unbiased comparison between two different types of attentional cues by integrating them simultaneously with the same task. The result is that on any given trial, two attention cues are presented, and they may either diverge spatially (cuing different locations) or converge spatially (cueing the same location). Note that this manipulation allows for an estimation of the attentional effects

when each cue indicates a different spatial location and the attentional effects when the two cues indicate the same spatial location. Participants are always asked to detect a single target that occurs in one of four possible target locations following different stimulus onset asynchrony (SOA) intervals (100, 300, 600 or 900ms). In this way one can purchase a clear picture of the dynamics of the two orienting processes, and how they may impact each other, across time.

The reasoning is straight-forward. If the attentional effects elicited by the two cues are independent, then the attention effect of each cue will proceed in a manner that is unaffected by the location that is cued by the other stimulus or its spatial predictiveness. On the other hand, if the cues are not independent, the performance of one cue will be impacted by the location or spatial predictiveneess of the other cue. The results of this investigation demonstrate independence between each of the cues (nonpredictive central, nonpredictive peripheral, and predictive central cues). One of the main implications of this finding is that indicates that reflexive orienting to a nonpredictive central cue is distinct from reflexive orienting to an abrupt peripheral onset or volitional orienting to a predictive central cue. The broader implications of this study, and those that have preceded it in Chapters 2-6, are considered in depth in the General Discussion that forms Chapter 8.

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CHAPTER 7

Nonpredictive Central Cues Trigger Independent Reflexive Effects

The allocation of spatial attention is often conceptualized as being committed reflexively or volitionally. Reflexive orienting is understood to occur exogenously, that is, in response to an external stimulus event; and volitional orienting is understood to occur endogenously, in response to one's internal goals and expectations (Posner, 1978; Klein, Kingstone and Pontefract, 1992). This division of attentional selection has been formalized by two prominent behavioral testing procedures — the peripheral cuing task and the central cuing task. These two tasks set out to isolate, engage and measure reflexive and volitional orienting by manipulating both the spatial position of the attentional cue and its ability to predict where a response target is likely to appear.

In the peripheral cuing task, the abrupt onset of a spatially nonpredictive cue at a parafoveal location is understood to engage reflexive spatial orienting. This type of orienting is characterized by targets being responded to more quickly at the cued versus noncued location when the cue-target stimulus onset asynchrony (SOA) is less than about 300 ms.When the SOA is longer, RT to targets tend to be shorter at the uncued versus cued location. This latter effect is known as "inhibition of return", or IOR, and is thought to reflect the fact that attention is withdrawn from the cued location and then is inhibited from returning there (Posner, 1980; Posner & Cohen, 1984).

In the central cuing task, a spatially predictive cue presented at a foveal location is understood to engage volitional spatial orienting. This effect is measured by typically presenting a central arrow cue that predicts the location of a response target. This type of orienting is characterized by targets being responded to more quickly at the location likely to contain the target (Jonides, 1981). Since the development of the expectancy is a cognitively demanding task, the effect of volitional attention are typically seen first when the cue-target SOA approximates 300 ms (Müller & Rabbitt, 1989). Voluntary orienting is never characterized by the presence of an IOR effect as participants have

an incentive to maintain attention at the location that is likely to contain the target (Taylor & Klein, 1998).

Several recent studies have demonstrated a variety of central cues, such as eyes looking to the left or right, or an arrow pointing to the left or right, will produce shorter RT latencies for targets at the cued versus noncued location (e.g., Eimer, 1997; Tipples, 2002; Ristic et al, 2002). Because the directional cue <u>does not predict</u> the target location and the attention effect emerges shortly at cue-target SOAs as short as 100 ms, this cue is understood to engage reflexive orienting. Unlike the orienting effect for peripheral cues, however, this facilitory RT effect persists well beyond 500 ms and is not accompanied by the emergence of an IOR effect (e.g., Tipples, 2002; Friesen & Kingstone, 2003). In this important way, the reflexive orienting effect also shares properties of volitional orienting as it is normally defined, i.e., orienting is engaged by a central cue, its facilitory effect is long-lasting, and IOR does not occur.

In light of this overlap between reflexive orienting to central cues and the more traditional understandings of reflexive orienting to peripheral cues and volitional orienting to central cues, the present study set out to examine the relationship between these three attention tasks and the orienting effects they are thought to engage. This effort brings forward two main questions. First, what is the relationship between reflexive orienting when it is triggered by a peripheral cue and when it is triggered by a central cue? In particular, should reflexive spatial orienting to peripheral and central cues be thought of as different ways of engaging the same underlying attention system, or two different attention systems? Second, what is the relationship between volitional and reflexive orienting when they are both engaged by a central cue? The literature suggests that volitional and reflexive attention, as elicited by the two classic tasks are subserved by two different brain networks (e.g., Corbetta & Shulman, 2002). However,

the link between volitional orienting and reflexive orienting when both cues are shown at central fixation is an area that has not been investigated.

The present study addressed these questions by taking the three cuing tasks and pitting one against the other in three separate test conditions: Nonpredictive Peripheral - Nonpredictive Arrow (NP-NA) cues; Predictive Central - Nonpredictive Arrow (PC-NA) cues; Nonpredictive Peripheral - Predictive Central (NP-PC) cues. This approach is grounded in additive factors logic, which provides a well-established method for understanding the relationship between cognitive processes (Sternberg, 1969; Posner 1978). Effectively, if two cognitive processes, such as two types of reflexive attention or reflexive and volitional attention, are mediated by different mechanisms, their effects should co-occur without interacting, i.e., they are independent. In contrast, if the two processes are mediated by a common mechanism, their effects will combine in an interactive manner, e.g., they may interfere or accentuate one another indicating that they are not independent. Note that any suggestions of independence for a particular type of cuing can also be tested by examining whether the orienting effect varies as a function of the cue condition it was paired with. So, for example, if the effects of nonpredictive peripheral onsets do not interact with the effects of nonpredictive arrows or predictive central cues (thereby suggesting independence of peripheral orienting from the other two forms of orienting), it follows that the orienting effect for nonpredictive onsets should remain the same when paired with the nonpredictive arrow cue and the predictive central cue.

In order to gain a detailed insight into performance across time, RT was measured at four different cue-targets SOAs (100, 300, 600, and 900 ms). This allows one to assess whether RT facilitation occurs early at a cued location as expected for reflexive orienting, and also to examine whether the effects diverge at later SOAs, e.g.,

an IOR effect at the cued location as expected for nonpredictive peripheral (NP) cues versus a facilitory effect at the cued location as expected for predictive central (PC) cues.

Finally it should be noted that because nonpredictive arrow (NA) cues produce reflexive orienting when they are presented centrally, arrows are not suitable central cues for the PC cue condition. It has now been demonstrated in two studies that number cues presented at central fixation do not produce reflexive orienting when they are made spatially nonpredictive, but that they readily enable volitional orienting when they are made spatially predictive (Ristic & Kingstone, in press; Ristic, Wright & Kingstone, in press). Hence in the present study spatially predictive number cues were used in the PC condition.

Method

Participants

The intention had been to assign 15 participants to each NP-NA and NP-PC group and 30 participants to PC-NA group, to ensure adequate sampling in the condition, which presents two cues foveally. Due to participant over scheduling 19 participants were assigned to the NP-NA group, 15 to the NP-PC group and 30 to the PC-NA group. All participants were naïve to the purpose of the experiment.

Apparatus and Stimuli

Testing was performed on a Macintosh power PC computer connected to a 15-in monitor set to black and white. All stimuli were black line drawings shown on a white background. Peripheral cues were created by thickening the outline of one of the 2° x 2° placeholder boxes, positioned 7.5° away from central fixation along horizontal and vertical planes. A central arrow cue was created by combining a straight line (2°) with an arrowhead and an arrowtail. The central number cue (either 1, 3, 6, or 9) measured 2° in

height and 1.2° (3, 6, 9) or 0.3° (1) in width. The target was an asterisk, subtending 0.8° of visual angle, appearing with 7.5° eccentricity, as measured from the center fixation to the center of the target. The stimuli, sample sequence of events and cue validity conditions for the NP-NA condition are illustrated in Figure 7.1, for the PC-NA condition in Figure 7.2 and for the NP-PC condition in Figure 7.3.

Design

Each condition was as a within-subjects design, setup as a four location cuing task. On each trial, participants were presented with two attentional cues simultaneously. In the NP-NA condition, a spatially nonpredictive peripheral onset cue and a spatially nonpredictive central arrow cue were shown. In the PC-NA condition, a spatially predictive central number cue and a spatially nonpredictive central arrow cue were shown. Finally, in the NP-PC condition, a spatially nonpredictive peripheral onset cue and a spatially predictive central number cue were shown. A single target appeared at one of the four target locations following one of four randomly determined SOA intervals of 100, 300, 600 or 900 ms. In all conditions peripheral onset cues were presented for 90 ms while central cues (both arrow and number) were presented for the duration of the trial.

In the NP-NA condition, the position of the peripheral cue and the direction of the arrow cue was determined randomly, with the target appearing with equal probability at each location (p=.25). In the PC-NA and NP-PC conditions, the central number cue indicated the correct target location with .77 probability. Number 1 predicted a target occurring on the top; number 6 a target on the bottom, number 3 a target on the right and number 9 a target on the left. In both of these conditions, the peripheral onset cue and the central arrow cue indicated a correct target location equally often with .07 probability. It is worth noting that since PC-NA condition utilized two foveal cues, the

number cue was always positioned above fixation and the arrow cue was always positioned below fixation at an equal distance of 3.5°, as measured from the center of the number cue to the center of an arrow cue.

On each trial, two attentional cues either diverged spatially, indicating two different spatial locations, or converged spatially, indicting the same spatial location. As illustrated in Figures 7.1, 7.2, and 7.3 in the spatially divergent condition, the effect of each cue was assessed by a comparison against uncued trials in which the target appeared at one of the two locations that were not cued. In the spatially convergent condition the effect of both cues was compared against uncued trials in which the target appeared at one of the three locations that were not cued.

Procedure

Each trial began with a presentation of a fixation display for 1000 ms. Then, the two attentional cues appeared. In the NP-NA condition, one of the four boxes was cued for 90 ms and an arrow, pointing in one of the four directions appeared at the center. In the PC-NA condition, an arrow cue, pointing in one of the four directions and a number cue (1, 3, 6, or 9) appeared at the center. In the NP-PC condition, one of the four boxes was cued for 90 ms and a number cue (1, 3, 6 or 9) appeared at the center. The onset of the two cues was always simultaneous. Following a randomly selected SOA of 100, 300, 600 or 900 ms, a target demanding a simple detection response appeared at one target location (left, right, up, down). The trial was terminated on response or after 2600ms had elapsed, whichever came first. The intertrial interval was 675ms. RT was measured from the onset of the target until the response key was pressed. Randomly, on approximately 6% of the trials, a target was not presented (catch trial) and participants were required to withhold a keypress detection response.

Participants were seated centered with respect to the computer screen at an approximate distance of 57 cm. They were instructed to maintain central fixation throughout the experiment and to press the spacebar with the index finger of their preferred hand as fast and as accurately as possible as soon as they detected the target. All participants were informed, and it was confirmed that they understood, the predictiveness of each cue.

Cue direction, target position, and SOA were presented equally and in random order. All participants completed a total of 960 trials divided into 16 testing blocks of 60 trials in each condition. Ten practice trials were run at the beginning.

Results

One participant was excluded because of extremely deviant RT performance. The mean correct RT for each cue condition as a function of cue validity and SOA were computed. Anticipations (RT<100), timed-out responses (RT>1000), incorrect key presses, and false alarms were infrequent and were removed from the analysis. The error rate on target present trials was 1.05%, 0.6% and 1.95% with false alarm rate on target absent trials of 1.64%, 2% and 4% for the NP-NA, PC-NA and NP-PC conditions respectively.

The behavioral effects for the nonpredictive peripheral cuing task, nonpredictive arrow cuing task and predictive central cuing task are well established and have been replicated on numerous occasions. As outlined in the introduction, nonpredictive peripheral onset cues elicit reflexive orienting that is marked by a biphasic RT pattern with RT facilitation for short cue-target intervals which is replaced by IOR at longer cue-target delays (e.g., Posner, 1980; Posner & Cohen, 1984). Nonpredictive central cues elicit reflexive orienting with a RT pattern marked by facilitation occurring for early and late cue-target intervals which is never replaced by IOR (e.g., Tipples, 2002; Ristic et al,

2002). Finally, predictive central cues produce volitional orienting that is marked by facilitation for predicted targets for delays exceeding 300ms that is never replaced by IOR (e.g., Jonides, 1981; Taylor & Klein, 1998).

First we examined for the presence of each of these well-replicated effects and their stability as a function of the cue they were paired with. Figure 7.4 plots the mean RTs for each individual cue type as function of its cue pairing, cue validity and SOA. As suggested by Figure 7.4, the orienting effect for each cue type is what one would expect to find based on past research and, most importantly, the effects appear to be stable for each cue type regardless of the cue it is paired with. This observation was confirmed by a mixed analysis of variance (ANOVA) conducted on each cue condition. The first analysis compared the effects elicited by a nonpredictive peripheral onset cue across the nonpredictive arrow and predictive central cue conditions, with type of cue pairing (NA, PC) as a between subject factor and cue validity (cued; uncued), and SOA (100, 300, 600, 900) as within-subject factors. A second ANOVA similarly examined the attentional effects elicited by a nonpredictive arrow across the nonpredictive peripheral and predictive number conditions (NP, PC). A third and final ANOVA in a similar manner compared the effects elicited by a predictive central cue across the nonpredictive peripheral onset and nonpredictive arrow conditions (NP, NA).

The first ANOVA confirmed that nonpredictive peripheral onset cues elicited reflexive orienting effects marked by early facilitation and later inhibition, regardless of whether they were paired with a nonpredictive arrow or a predictive central cue. That is, there was a significant SOA x cue validity interaction [$F_{(3, 96)}=8.5$, $p<.0001$] which did not interact with cue type [$F_{(3, 96)}=1.3$, $p>.25$]. Four two-tailed paired t-tests verified that the facilitation effect at the cued location was significant at 100 ms ($t(33)=-2$, $p=.05$), disappeared at 300 ms ($t(33)= -1.4$, $p>1.7$), and gave way to the IOR effect at

the two longest SOAs (both ts>3, ps<.01). The only other significant effect was SOA [F (3, 96)= 19.6, p<.000], reflecting a standard foreperiod effect whereby overall RT declines as SOA increases (Bertelson, 1967). No other effects or interactions were reliable (all Fs<1.6, all ps>.2). In sum, these data indicate that nonpredictive peripheral onset cues produced a standard biphasic RT pattern of reflexive orienting that was stable across the two cue conditions (NA, PC).

The second ANOVA confirmed that a nonpredictive arrow cue elicited the predicted reflexive orienting effect, marked by RT facilitation across all SOAs. This effect occurred regardless of whether the nonpredictive arrow was paired with a nonpredictive peripheral onset cue or a predictive central cue. Main effects of SOA [F (3, 138)=40, p<.0001] and cue validity [F (1, 46)=12, p< .01] were reliable, with no other significant effects or interactions emerged, including those involving the cue-type pairing (all Fs<1).

The final ANOVA confirmed that a predictive central cue elicited volitional orienting, marked by facilitation for targets appearing at the cued (likely) location, that emerged at approximately 300 ms SOA and grew and persisted thereafter, regardless of whether the predictive cue was paired with the nonpredictive peripheral onset or the nonpredictive arrow cue. There were the standard main effects of SOA [F (3, 129)=65, p<.0001] and cue validity [F (1, 43)=24, p< .0001] as well as an SOA x cue validity interaction [F (3, 129)=5.8, p< .001] reflecting the development of the cuing effect over time. Paired two-tailed t-tests verified that the facilitation effect at the cued location was nonsignificant at 100 ms (t(44)=-.8, p>.4), and significant thereafter (all ts>-2.7, ps<.01). No other effects or interactions were significant, including any involving the cue-type pairing [all Fs<1.7, all ps>.2]. In sum, these data indicate that predictive central number

cues engaged a classic volitional orienting effect that was stable across cue-type pairings.

In all the above analyses the expected effects for each cue type was observed across the SOA conditions, and these effects did not vary as a function of the cue-type that they were paired with. Collectively, these analyses strongly suggest that the attention effects for each cue type are independent from each other. That is, the nonpredictive peripheral cues and nonpredictive arrow cues trigger reflexive orienting effects that are independent from one another as well independent from the volitional orienting effects engaged by predictive central cues.

To verify this interpretation, three within-subjects ANOVAs were conducted for each cue condition (NP-NA, PC-NA, and NP-PC) comparing the effects of each individual cue when they indicated different spatial positions and when they indicated the same spatial condition. If their effects are independent, then the sum of their attention effects (uncued RT- cued RT) when divergent locations are cued should equal the magnitude of the attention effect (uncued RT- cued RT) when they converge on the same location. To anticipate the outcome of these analyses, the attention effects for all cue-types were found to operate independently. These data are illustrated in Figures 7.5-7.7.

Nonpredictive Peripheral - Nonpredictive Arrow (NP-NA) Cues. A within-subjects ANOVA comparing peripheral cued and uncued RTs in the spatially divergent case revealed a significant main effect of SOA [3, 54)=24.5, p<.0001] and an interaction between cue validity and SOA [F(3, 54)=3.6, p<.05], again reflecting the emergence of an IOR effect.

A separate ANOVA comparing the arrow cued and unced RTs revealed significant main effects of SOA [$F_{(3, 54)} = 30$, $p < .0001$] and cue validity [$F_{(1, 18)} = 19$, $p < .001$] and no interactions ($p > .2$).

An ANOVA with cue validity (both cued; both uncued) and SOA conducted on the spatially convergent condition revealed a significant main effect of SOA [$F_{(3, 54)} = 7$, $p < .001$] and SOA x cue validity interaction [$F_{(3, 54)} = 5$, $p < .05$] indicating that the early facilitation effect is later abolished, presumably because the facilitation effect for a nonpredictive arrow is countered by the addition of an IOR effect triggered by a nonpredictive peripheral cue.

To test the notion that the sum of the cuing effects for divergent NP and NA cues approximates the cuing effect when the cues are convergent, the magnitude of the attention effect (uncued RT - cued RT) for the divergent cues was calculated and summed for each SOA. These data were compared against the attention effect for each convergent cue at each SOA. This resulted in a 2 (divergent sum/convergent) x 4 (SOA) within-subject ANOVA that produced only a significant main effect of SOA [$(3, 54) = 7.4$, $p < .001$] reflecting that the attention effect was present at the short SOAs but that it was abolished later by the IOR effect. All other $Fs < 1$. Thus, the attention effects of the divergent cues add together and equal the magnitude of the attention effects for the convergent cues for all SOAs. The equality of the overall magnitudes between divergent and convergent cues is illustrated in Figure 7.5B.

Nonpredictive Arrow - Predictive Central (PC-NA) Cues. A within-subjects ANOVA comparing arrow cued and uncued RTs in the spatially divergent case revealed a significant main effect of SOA [$F_{(3, 84)} = 19$, $p < .0001$] and an effect of cue validity that brushed significance [$F_{(1, 28)} = 3.5$, $p < .06$] due to the inclusion of one outlier. When this participant is excluded the nonpredictive arrow effect becomes highly significant, with a

p-value of 0.01. This fact, coupled with the previous observation that this arrow effect is equivalent to the statistically significant arrow effect in the NP-NA condition, suggests that the NP arrow effect here is reliable.

A separate ANOVA comparing cued and uncued RTs for predictive number cues revealed significant main effects of SOA [F (3, 84)= 38.5, p<.0001], cue validity [F (1, 28)=12.3, p<.01] and an SOA x cue validity interaction [F (3, 84)=4.2, p<.01]. An ANOVA conducted on the spatially convergent case revealed significant effects of SOA [F(3, 84)=33.3, p<.0001] and cue validity [F (1, 28)=31, p<.05] with no interaction (p>.1).

The magnitudes of divergent and convergent attention effects were compared in a 2 (divergent sum/convergent) x 4 (SOA) within-subject ANOVA as before. This analysis returned no significant effects or interactions (all Fs<1.7, all ps>.1) indicating that the sum of the attention effects in the divergent cue case are equivalent to the attention effects observed in the convergent cue case. The equality of the overall magnitudes between divergent and convergent cues is shown in Figure 7.6B.

Nonpredictive Peripheral - Predictive Central (NP-PC) Cues. A within-subjects ANOVA comparing peripheral cued and uncued RTs in the spatially divergent case revealed a significant main effect of SOA [F (3, 42)=5.4, p<.01] and an interaction between cue validity and SOA [F(3, 42)=4.2, p<.01] again demonstrating the emergence of the IOR effect.

A separate ANOVA comparing cued and uncued RTs for predictive number cues revealed significant main effects of SOA [F(3, 42)= 28, p<.0001] and cue validity [F (1, 14)=10, p< .01] with no interaction (p>.05). An ANOVA conducted on the spatially convergent case revealed significant effects of SOA [F(3, 54)=7, p<.001], validity [F (1, 14)=7.4, p<.05] as well as an SOA x cue validity interaction [F (3, 42)=3.8, p<.05].

The magnitudes of divergent and convergent attention effects were compared in a 2 (divergent sum/convergent) x 4 (SOA) within-subject ANOVA as described above. This analysis returned no significant effects or interactions (all Fs<1.5, all ps>.2) indicating that the sum of the attention effects in the divergent cue case are equivalent to the attention effects observed in the convergent cue case. The equality of the overall magnitudes between divergent and convergent cues is shown in Figure 7.7B.

Discussion

This study set out to answer two main questions. What is the relationship between reflexive orienting when it is triggered by a peripheral cue and when it is triggered by a central cue? And what is the relationship between volitional and reflexive orienting when they are both engaged by a central cue? We also examined the classic relationship between reflexive orienting to a peripheral cue and volitional orienting to a predictive central cue.

The results of this investigation are clear-cut. All results show consistently that each of the three cuing effects — nonpredictive peripheral (NP), nonpredictive arrow (NA) and predictive central (PC) — produce the RT effects that would be expected if the cues were presented in isolation. The new finding is that these attention effects can co-occur in an independent manner. This was demonstrated both in the stability of the effects across cue-type pairings and within cue-type pairings.

Across cue-type pairings it was found that peripheral onset cues triggered the same classic biphasic RT effect regardless of whether peripheral cues were paired with a nonpredictive arrow cue that engages reflexive orienting or a predictive central cue that engages volitional orienting. Similarly, nonpredictive arrows triggered the expected early and prolonged RT facilitation effect at a cued location that was evident regardless of whether the nonpredictive arrow was paired with a nonpredictive peripheral cue that

triggers a biphasic RT effect or a predictive central cue that engages volitional orienting. Finally, a predictive central cue engaged volitional orienting that was the same regardless of whether it co-occurred with reflexive orienting to a peripheral onset cue or volitional orienting to a central cue.

This independence of the attention effects across different groups of cue-pairings was cross validated by a within-subjects comparison of the magnitude of the attention effects when the two cues diverged spatially and when they converged spatially on the same location. For each cue pairing the results showed consistently that the attention effects for divergent cues summed to equal the magnitude of the attention effects when the cues converged on the same location.

Together then these data strongly suggest that spatially nonpredictive cues elicit reflexive orienting effects that are independent of each other, and that each of these reflexive attention effects is independent from the volitional orienting effect that is generated endogenously in response to a spatially predictive symbolic central cue. While there is good evidence from past studies that reflexive orienting to a nonpredictive peripheral cue and volitional orienting to a central cue are independent and subserved by qualitatively different brain mechanisms (e.g., Corbetta & Shulman, 2002), this is the first study to demonstrate that reflexive orienting to nonpredictive peripheral and central cues occur independently, and that reflexive orienting to nonpredictive central cues is distinct from volitional orienting to central cues.

These novel findings offer a resolution to a potentially contentious issue in the literature regarding the nature of the attentional effects elicited by spatially nonpredictive central cues. Our data show that these effects are independent from both reflexive and volitional effects elicited by two classic tasks and as such argue against the hypotheses that the attention effects elicited by reflexive central cues represent a hybrid form of

classic reflexive and volitional orienting (Klein & Shore, 2000; Klein, 2004) or even more mundanely a variant of classic volitional orienting (Vecera & Rizzo, 2006). The first hypothesis predicts interactive effects between nonpredictive arrow cues and both nonpredictive peripheral cues and predictive central cues. This was clearly not the case. The second hypothesis predicts that the effects of nonpredictive arrow cues will interact with the effects of predictive central cues. Again, this prediction was disconfirmed. Instead, our data support the conclusion that central nonpredictive arrows elicit reflexive attention effects that are independent from the reflexive effects elicited by peripheral cues and the volitional orienting effects elicited by predictive central cues.

These data carry a number of important implications for the field's characterizations of reflexive and volitional orienting. First, they suggest that reflexive orienting in a cuing paradigm need not be characterized by a behavioral response that occurs in response to a peripheral cue, nor can volitional orienting be characterized simply as a behavioral response that occurs in response to a central cue. This follows from the result that central nonpredictive cues produce reflexive orienting from a foveal location. Second, the data suggest that reflexive orienting need not be characterized as a behavioral response that is followed by IOR and volitional orienting cannot be characterized simply as a behavioral response that is never followed by IOR, i.e., by a sustained facilitation at a cued location. This follows from the result that central nonpredictive cues do not a trigger IOR and exhibit sustained facilitation at the cued location. Finally, these points above suggest that an attribution of reflexive orienting to ventral brain systems that are activated by peripheral onsets and superior systems that are engaged by symbolic central cues may need to be reexamined (e.g., Corbetta & Shulman, 2002).

The present data also open interesting questions for future investigation. In light of the behavioural dissociations between reflexive and volitional orienting to central and peripheral cues demonstrated here, one wonders what brain mechanisms are critical to the independence of the attention effects (and conversely, what brain mechanisms are shared between cues and are therefore not critical to behavioural dissociations). Currently there are no investigations that have systematically examined the reflexive and volitional orienting effects that occur in response to spatially nonpredictive central and peripheral cues or spatially nonpredictive and predictive central cues.

There is also the outstanding question concerning the relationship between reflexive and volitional orienting when eye movements are withheld and when they are executed. The present investigation examined covert attentional orienting controlling for eye movements by using a task that requires detection of suprathreshold targets (e.g., Posner, 1980; Kingstone & Pratt, 1999; Friesen et al, 2004;). Typically, however, people move their eyes toward those things that are of interest (Findlay & Gilchrist, 2003). The extent that the present findings apply to this performance domain, and by extension, to real-world behavior is unknown.

Finally, it is worth noting that while a range of central attentional cues (e.g., eye direction, arrow direction, head direction, finger pointing, words with spatial meaning) produce similar attention effects in simple behavioral tasks, it appears that different classes of central cues produce reflexive attention effects that range from strongly reflexive (resistant to cognitive control) to weakly reflexive (easily modified by top-down set). For example, the attentional effects of central eye direction are resistant to interruption (Friesen et al, 2004), contextual top-down modulation (Ristic & Kingstone, 2005), and attentional control settings (Ristic, Wright & Kingstone, submitted [see also Chapter 7]). In contrast, attentional effects of central arrow cues are not resistant to

interruption (Friesen et al, 2004) and are highly amenable to changes in attentional control settings. This raises the very real possibility that a range of central cues engage reflexive attention differently by engaging dissimilar brain mechanisms.

Figure 7.1.
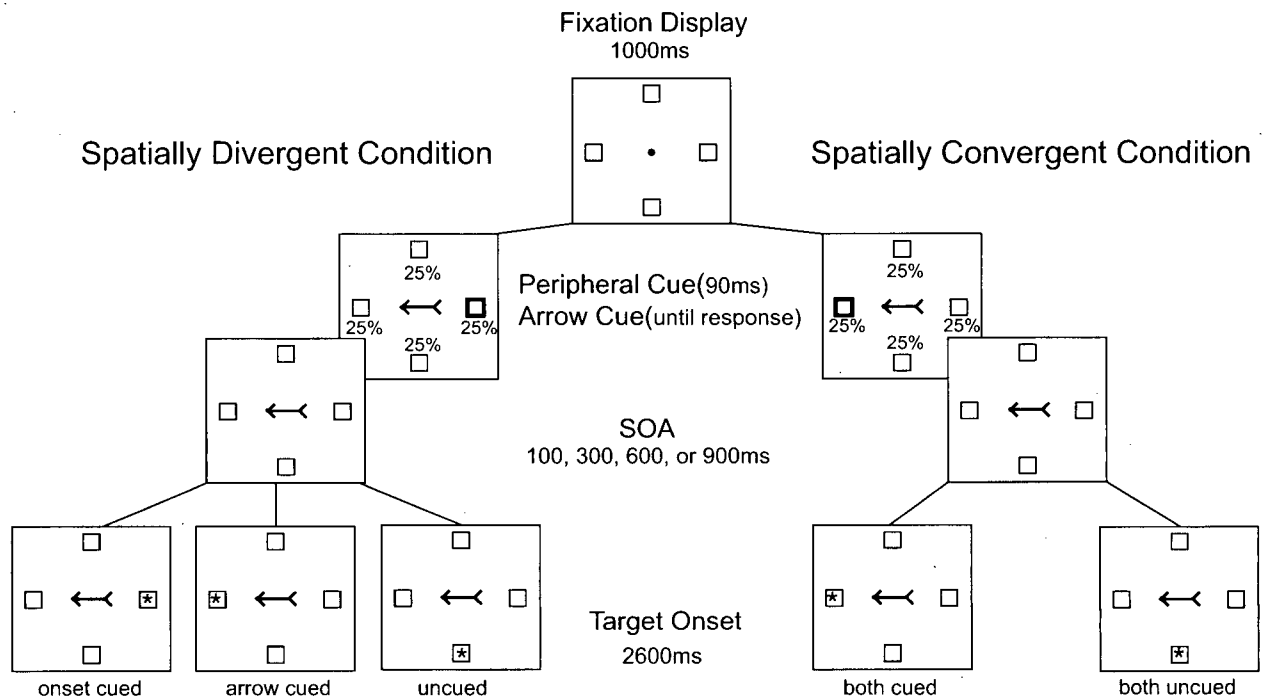
Figure 7.1. Illustration of stimuli (not to scale) and sample sequence of events for the nonpredictive peripheral - nonpredictive arrow (NP-NA) cues condition. Every trial began with a 1000 ms presentation of a fixation display followed by a simultaneous presentation of two cues: a spatially nonpredictive peripheral onset cue and a spatially nonpredictive central arrow cue. Both the peripheral and the central arrow cues were spatially nonpredictive with a target appearing at the cued location on only 25% of the trials. On any given trial, a peripheral onset and arrow cue could diverge spatially (Spatially Divergent) or converge spatially (Spatially Convergent). The peripheral cue was presented for 90 ms while the central arrow cue remained on the screen for the duration of the trial. There were three cue validity conditions in the Spatially Divergent case: onset cued trial, where the target appeared at the location indicated by the peripheral cue; arrow cued trial, where the target appeared at the location indicated by the central arrow cue; and an uncued trial, where the target appeared at remaining two locations. There were two cue validity conditions in the Spatially Convergent case: both cued trial, where the target appeared at the location indicted by both cues; and both uncued trial, where the target appeared at any of the noncued locations. The stimulus onset asynchrony (SOA) separating the presentation of the two cues and the target was 100, 300, 600, or 900 ms.

Figure 7.2.

Fixation Display
1000ms

Spatially Divergent Condition

·

Spatially Convergent Condition

7.7%

77% | 9 ⟩→ | 7.7%

Number Cue (until response)
Arrow Cue (until response)

7.7%

77% | 9 ←⟨ | 7.7%

7.7%

7.7%

9
⟩→

SOA
100, 300, 600, or 900ms

9
←⟨

* | 9 ⟩→

9 ⟩→ | *

9 ⟩→ *

Target Onset
2600ms

* | 9 ←⟨

9 ←⟨ *

number cued

arrow cued

uncued

both cued

both uncued
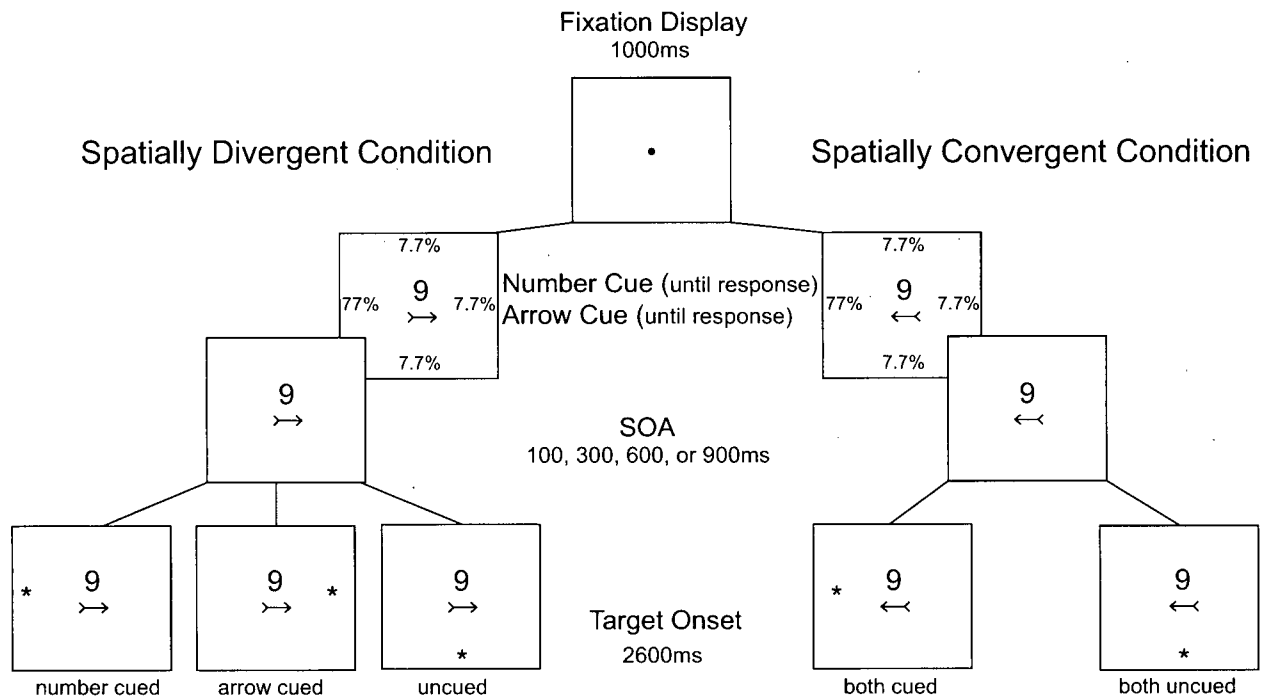
Figure 7.2. Illustration of stimuli (not to scale) and sample sequence of events for the predictive central - nonpredictive arrow (PC-NA) cues condition. Every trial began with a 1000 ms presentation of a fixation display followed by a simultaneous presentation of two cues: spatially predictive central number cue (1, 3, 6 or 9) and a spatially nonpredictive central arrow. Central number cues were spatially predictive (with a target appearing at the cued location on 77% of trials), and central arrow cues were spatially nonpredictive (with a target appearing equally often at the cued and uncued location on 7.7% of trials). On any given trial, number direction and arrow direction could diverge spatially (Spatially Divergent) or converge spatially (Spatially Convergent). Both cues were present on the screen for the duration of the trial. There were three cue validity conditions in the Spatially Divergent case: number cued trial, where the target appeared at the location predicted by the central number cue; arrow cued trial, where the target appeared at the location indicated by the arrow cue; and an uncued trial, where the target appeared at remaining two locations. There were two cue validity conditions in the Spatially Convergent case: both cued trial, where the target appeared at the location indicted by both cues together; and both uncued trial, where the target appeared at any of the noncued locations. The stimulus onset asynchrony (SOA) separating the presentation of the two cues

Figure 7.3.
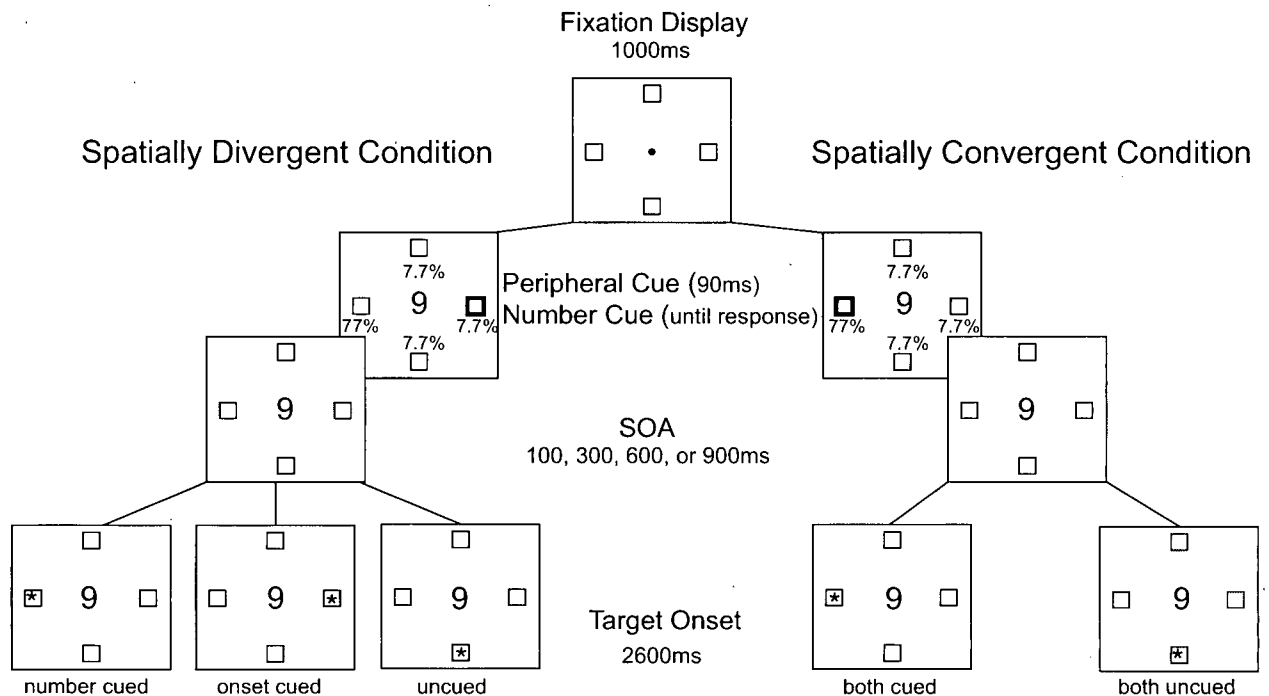
Figure 7.3. Illustration of stimuli (not to scale) and sample sequence for the nonpredictive peripheral - predictive central (NP-PC) cues conditions. Every trial began with a 1000 ms presentation of a fixation display followed by a simultaneous presentation of two cues: a spatially nonpredictive peripheral onset cue and a spatially predictive central number cue (1, 3, 6 or 9). Peripheral cues were spatially nonpredictive (with a target appearing equally often at the cued and uncued location on 7.7% of trials) and central number cues were spatially predictive (with a target appearing at the cued location on 77% of trials). On any given trial, the peripheral onset location and the number direction could diverge spatially (Spatially Divergent) or converge spatially (Spatially Convergent). The peripheral cue was presented for 90 ms while the central number cue was present on the screen for the duration of the trial. There were three cue validity conditions in the Spatially Divergent case: number cued trial, where the target appeared at the location predicted by the central number cue; onset cued trial, where the target appeared at the location indicated by the peripheral cue; and an uncued trial, where the target appeared at remaining two locations. There were two cue validity conditions in the Spatially Convergent case: both cued trial, where the target appeared at the location indicted by both cues together; and both uncued trial, where the target appeared at any of the noncued locations. The Stimulus Onset Asynchrony (SOA) separating the presentation of the two cues and the target was 100, 300, 600, or 900 ms.
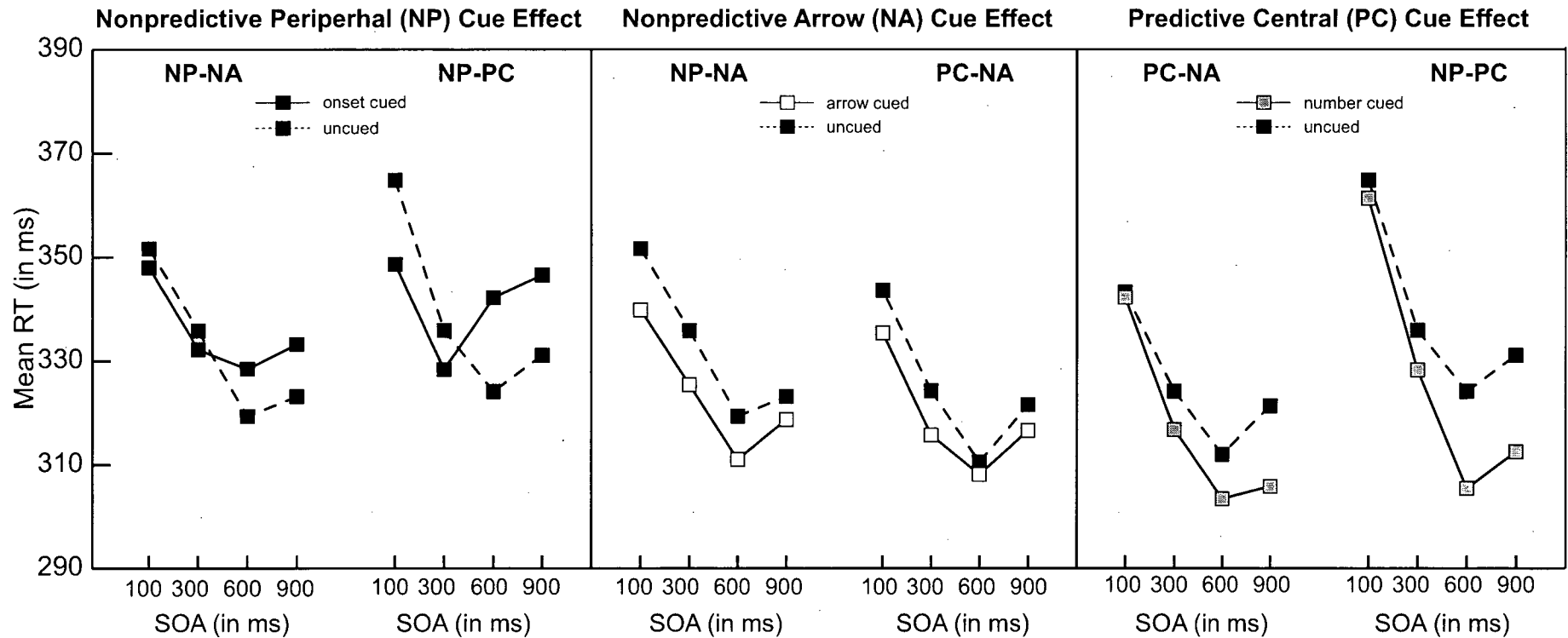
Figure 7.4. Mean RTs for each individual cue type as function of its cue pairing, cue validity and SOA. Left panel shows mean cued and unced RTs as a function of SOAs elicited by nonpredictive peripheral cues (NP) across nonpredictive central arrow (NP-NA) and predictive central (NP-PC) cue conditions. Middle panel shows mean cued and unced RTs as a function of SOA elicited by nonpredictive central arrow cues (NA) across nonpredictive peripheral (NP-NA) and predictive central (PC-NA) cue conditions. Right panel shows mean cued and unced RTs as a function of SOAs elicited by predictive central cues (PC) across nonpredictive central arrow (PC-NA) and nonpredictive peripheral (NP-PC) cue conditions.

Figure 7.5.

A.

B.
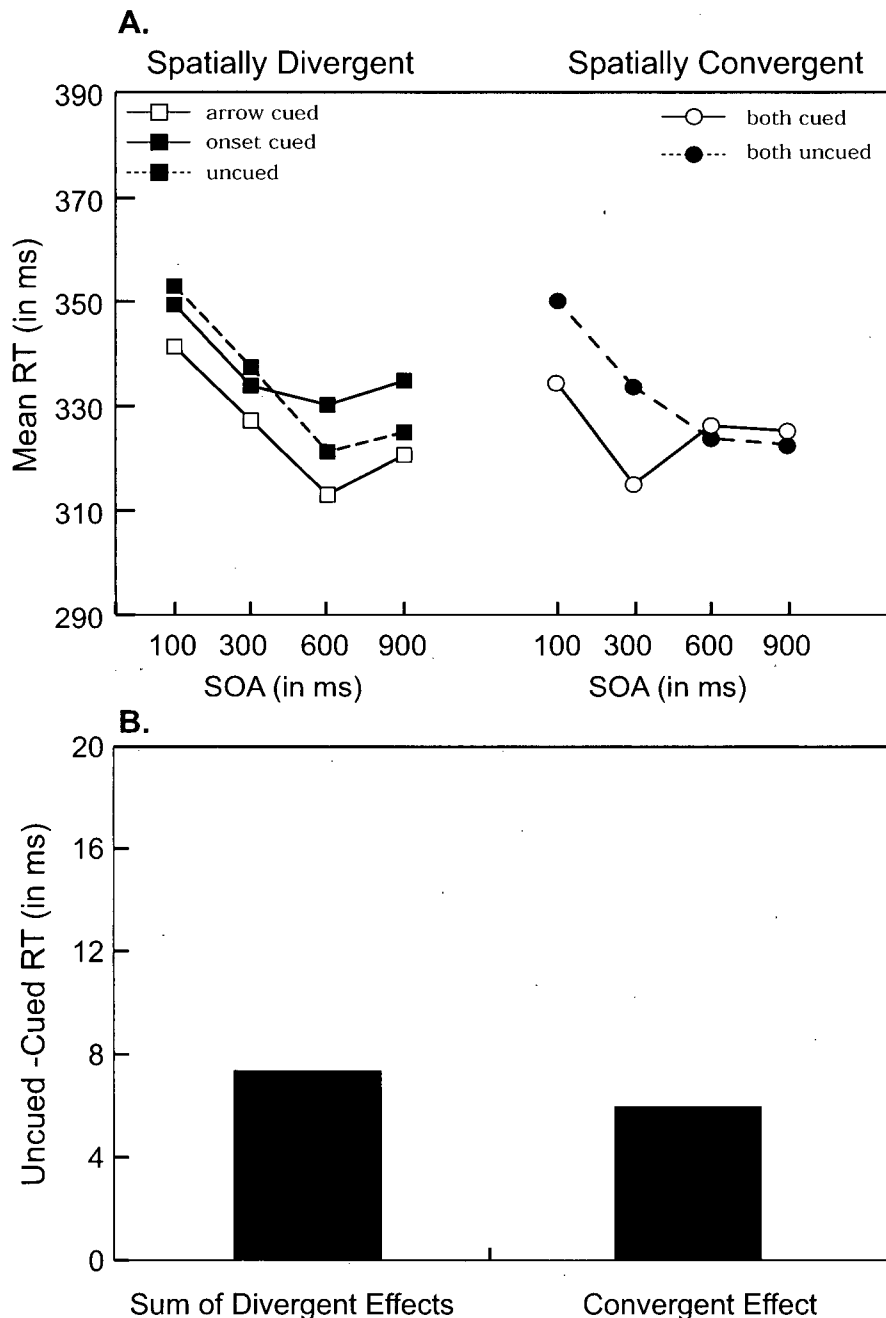
Figure 7.5. Mean RTs for the nonpredictive peripheral - nonpredictive arrow (NP-NA) cue condition. **Figure 7.5A**: Left panel illustrates spatially divergent condition, i.e., where the two cues indicated two different spatial locations and the right panel illustrates results for the spatially convergent condition where the two cues indicated the same spatial location. Mean RTs for arrow cued, onset cued and uncued trials are plotted as a function of SOA for the Spatially divergent case, and mean RTs for both cued and both uncued trials are plotted for the spatially convergent case. **Figure 7.5B** shows the overall magnitudes of attentional orienting (Uncued RT-Cued RT) for the sum of the two spatially divergent effects and the spatially convergent effect.

Figure 7.6.

A.

B.
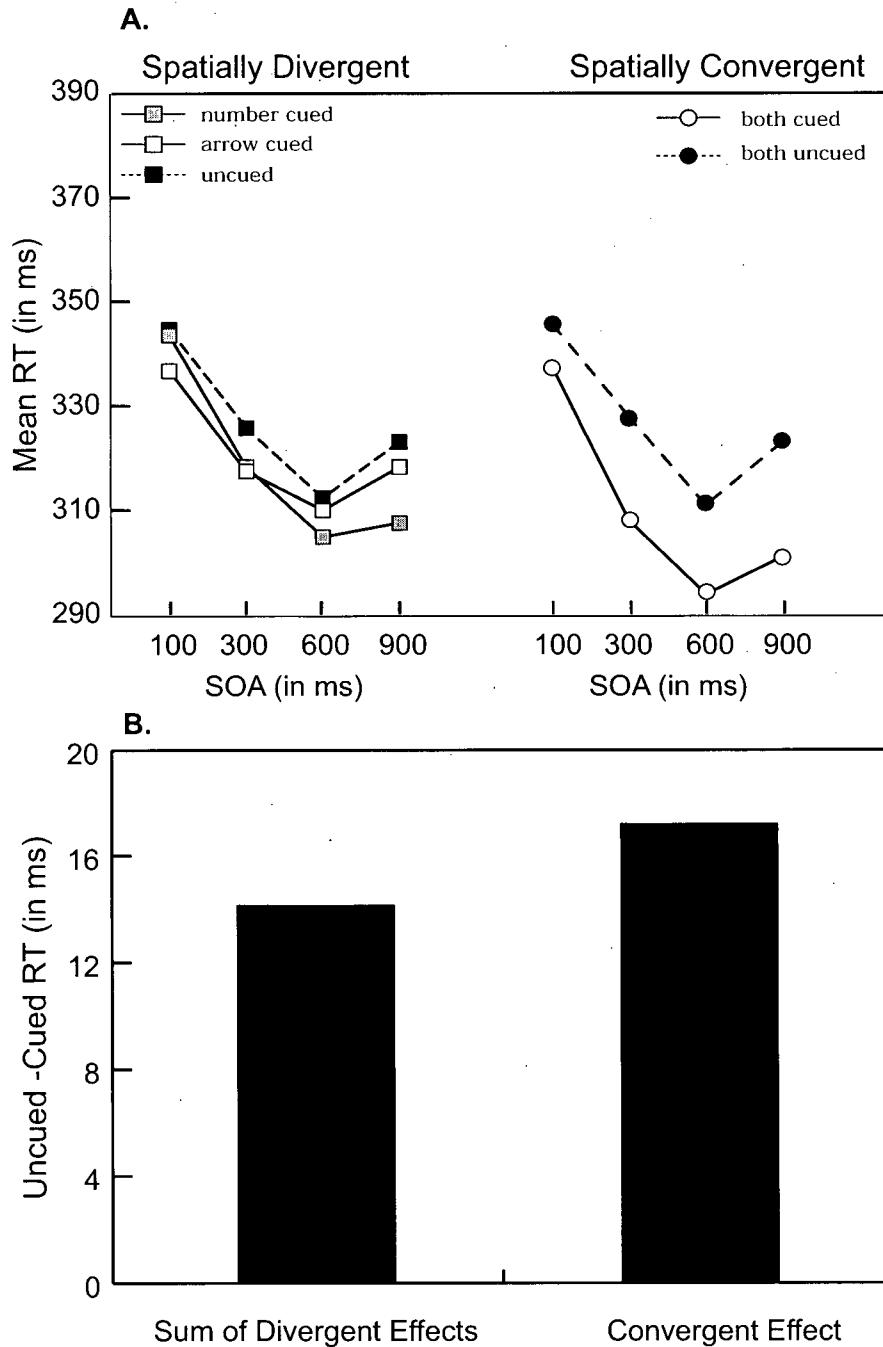
Figure 7.6. Mean RTs for the predictive central - nonpredictive arrow (PC-NA) cue condition. **Figure 7.6A**: Left panel illustrates spatially divergent condition, i.e., where the two cues indicated two different spatial locations and the right panel illustrates results for the spatially convergent condition where the two cues indicated the same spatial location. Mean RTs for number cued, arrow cued and uncued trials are plotted as a function of SOA for the Spatially divergent case, and mean RTs for both cued and both uncued trials are plotted for the spatially convergent case. **Figure 7.5B** shows the overall magnitudes of attentional orienting (Uncued RT-Cued RT) for the sum of the two spatially divergent effects and the spatially convergent effect.

Figure 7.7.
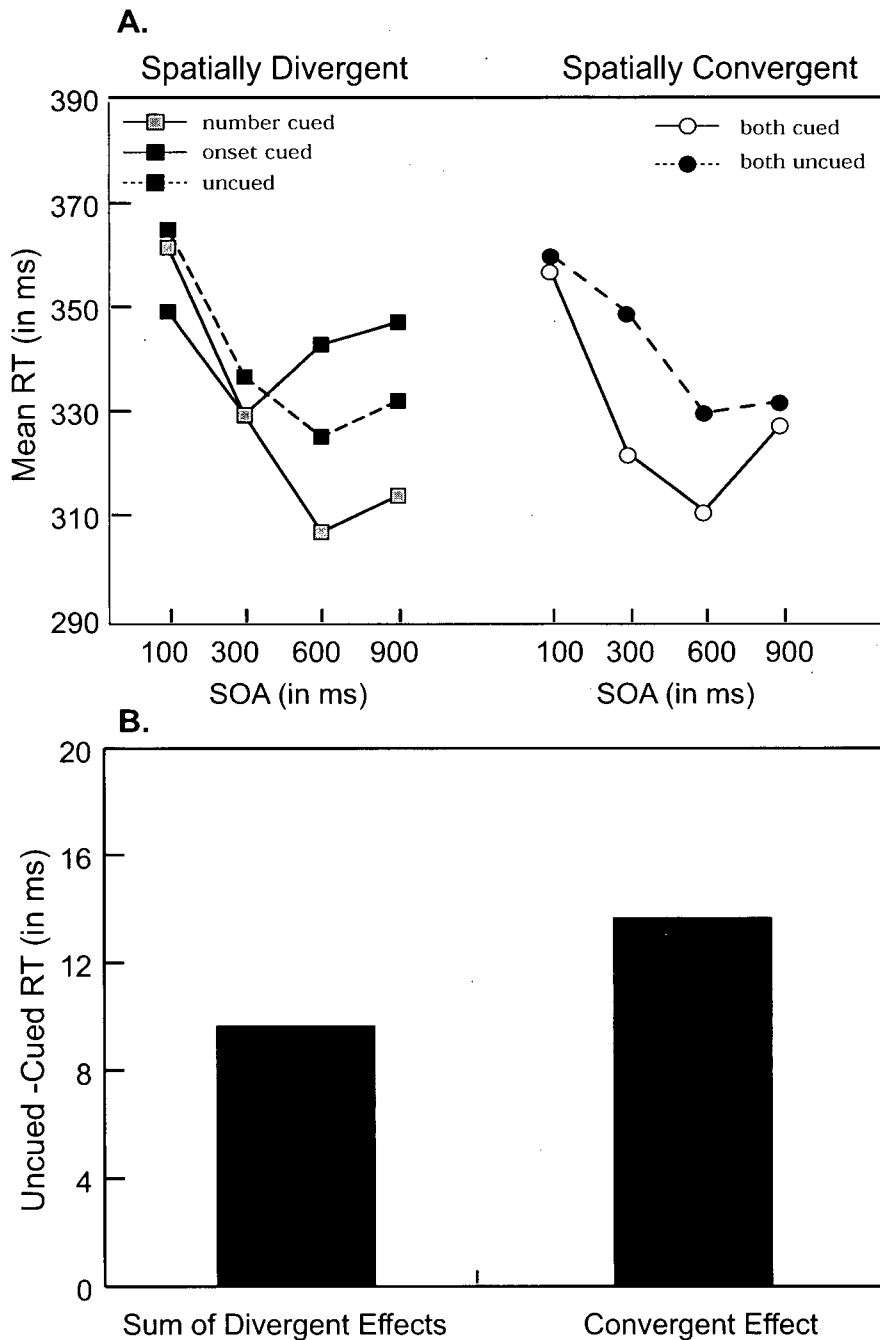
Figure 7.7. Mean RTs for the nonpredictive peripheral - predictive central (NP-PC) cue condition. **Figure 7.7A**: Left panel illustrates spatially divergent condition, i.e., where the two cues indicated two different spatial locations and the right panel illustrates results for the spatially convergent condition where the two cues indicated the same spatial location. Mean RTs for onset cued, number cued and uncued trials are plotted as a function of SOA for the Spatially divergent case, and mean RTs for both cued and both uncued trials are plotted for the spatially convergent case. **Figure 7.5B** shows the overall magnitudes of attentional orienting (Uncued RT-Cued RT) for the sum of the two spatially divergent effects and the spatially convergent effect.

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CHAPTER 8

General Discussion

The eleven experiments that compose the six studies presented in this dissertation have investigated the nature of social attentional orienting, its potential uniqueness relative to other attentional cues, and its relationship with the two classically defined modes of attentional orienting — reflexive and volitional attention. Overall the results indicate that eye direction triggers strongly reflexive attentional effects but that other centrally presented spatially nonpredictive cues, such as arrow direction, although less strongly reflexive, elicit similar behavioral effects.

The results of the study presented in Chapter 3, carried out with individuals with autism and typically developing persons, suggest that social reflexive orienting is triggered because humans normally perceive eye direction as conveying key socially relevant information, such as attentional engagement or disinterest. It is perhaps because orienting to another person's eye direction is so important for everyday social communication that social orienting is difficult to inhibit (Chapter 2) and that it is relatively insensitive to the level of ongoing cognitive activity (Chapter 5) or idiosyncratic cue-target relations (Chapter 6). In other words, the attentional shift that is triggered in response to another individual's gaze is powerful and strongly reflexive.

Nevertheless, it is clear that other directional cues, such as arrows, can produce similar behavioral results. The results of Chapter 4 clearly indicated that the standard cuing effects of eye gaze and arrow cues were behaviorally indistinguishable in both young children and adult observers. Reflexive orienting of similar timecourse and magnitude occurred regardless of whether the central cue was a schematic face looking left or right or an arrow pointing left or right. However, subsequent examination revealed some key differences between these two effects. In contrast to the strongly reflexive attentional effects elicited by eye direction, the attentional effects elicited by a central arrow cue cannot interrupt an ongoing cognitive activity (Chapter 5) and the effects of

an arrow are influenced by arbitrary cue-target contingencies (Chapter 6). The distinction drawn between biologically relevant and biologically irrelevant cues exemplifies the difference between attentional cues that are typically conveyed by people (e.g., eye direction or finger pointing) and those conveyed by inanimate directional objects (e.g., an arrow).

The final study in this thesis (Chapter 7) demonstrated that the attentional effects elicited by central spatially nonpredictive cues operate independently from both the reflexive attention effects elicited by spatially nonpredictive peripheral cues and volitional attention effects elicited by spatially predictive nondirectional central cues. This finding supports a main conclusion that spatially nonpredictive attentional cues shown at central fixation, such as eye direction and arrow direction, trigger reflexive shifts of attention that are distinct from both traditionally defined reflexive orienting and volitional orienting.

Collectively, the findings of this thesis raise several key issues for one's understanding of social attention as well as for understanding of the human attention system, its components, behavioral performance measures, and underlying brain mechanisms. In the following sections these issues will be discussed in turn. One issue concerns reflexive social attention, its properties and putative uniqueness. A second issue concerns the behavioral effect that centrally presented cues have on human attention. The results from the final study in this thesis (Chapter 7) have demonstrated that central spatially nonpredictive directional cues trigger orienting effects that are independent from the attentional effects elicited by the two classic cue tasks, nonpredictive peripheral onsets and predictive central cues. Supporting the present conclusion that central nonpredictive cues, like eyes and arrows, trigger reflexive orienting, a review of the past literature indicates that these cues meet the standard

criteria for 'reflexivity'. This will be demonstrated by a comparison of central nonpredictive cues and peripheral nonpredictive cues against seven commonly accepted behavioral characteristics of reflexive attention. A third issue concerns the implications of recognizing central cues as reflexive and what this means for one's future understanding and conceptualization of reflexive orienting. A fourth issue concerns how the present thesis may have important implications for one's understanding of volitional orienting. Although this dissertation did not examine volitional orienting directly, my finding indicating that central spatially nonpredictive arrows produce reflexive orienting suggests that the results obtained with the classic task using central spatially predictive arrows need to be reevaluated and reinterpreted. Finally, in the future direction section, an attempt will be made to reconcile the present data within the classic framework as well as within a conceptually different framework. An alternative way of understanding and measuring attention behaviorally will also be presented.

<center>Reflexive Social Attention</center>

Faces are significant and biologically highly relevant. Accurate perception and recognition of faces and facial components is critical for successful negotiation of the multifaceted social environment and interpretation of the complex human social signaling system. Indeed, numerous animal (e.g., Perrett, 1985) patient (Moscovitch, Winocur, & Behrmann, 1997), and neuroimaging studies, employing both functional (e.g., Kanwisher, McDermott & Chun, 1997; Kanwisher, 2000) and electrophysiological methods (e.g., Allison et al, 1994; Bentin et al, 1996), strongly suggest that perception of faces and their facial features is accomplished by a distinct and a highly specialized brain network located in the temporal lobe of both primates and humans. This network for analysis of faces is hypothesized to encompass parts of the fusiform gyrus, involved

in detection of faces, and the superior temporal suclus (STS), engaged in the analysis of biological motion and eye gaze direction (e.g., Allison, Puce & McCarthy, 2000; Hoffman & Haxby, 2000).

Perception and accurate interpretation of eye direction of another human appears to be fundamental to healthy social cognition, underlying such complex behaviors as turn-taking in conversation, as well as enabling one to infer the emotional and cognitive mental states of others (Baron-Cohen, 1995). In fact, as suggested by the results in Chapter 3, an appreciation of the social importance of eye gaze seems to be absent in individuals with autism who display profound deficiencies in social functioning. It has also been argued that the ability to interpret and follow eye direction is facilitated by the unique morphology of the human eye, which displays a high contrast between the iris and the sclera (Kobayashi & Koshima, 1997). Consistent with this idea, adult humans appear to be remarkably accurate in perceiving fine shifts in gaze position and attributing it to other objects in the environment. For instance, a recent psychophysical examination of the perceptual threshold for resolving eye gaze position indicated that accurate discrimination of eye position is achieved when the iris is shifted by approximately 30s/arc (Symons et al, 2004). In other words, people can identify where someone else is looking at within 1° of visual angle.

Given this specialized role that eye gaze seems to play in social cognition, the result indicating that eye direction triggers shifts in attention towards the gazed-at location is readily understandable. The present data revealed several properties of this social orienting effect. First, the behavioral impact and time course of social reflexive orienting is approximately equivalent for children as young as 3 years of age and adults (Chapter 4). This agrees with the results of other developmental studies suggesting that newborns prefer to scan the eyes of the face (Batki et al, 2002) and that by 12 weeks of

age children begin to follow the direction of eye gaze reliably (Hood, Willen & Driver, 1998; Farroni et al, 2002). Thus, it appears that there is rapid developmental progression regarding social reflexive orienting. Second, reflexive social orienting occurs because eye direction conveys socially relevant information and not because eye direction of another person is typically correlated with important events in the environment (Chapter 3). This distinction is important as it suggests that training individuals with impairments in social functioning to utilize eye direction as a predictive social cue may not capture how eye direction is used normally. Finally, the thesis demonstrated in several ways that the strength of the attentional effect that is elicited by eye direction is highly resistant to modulation by cognitive factors, such as task relevance, ongoing mental activity or the representation of the stimulus (Chapters 6, 5, 2). This agrees with the neuroimaging and patient data indicating that the activation of the STS is largely unaffected by top-down factors (Vuilleumier et al, 2001), and that the STS seems to be critical to processing gaze (Hoffman & Haxby, 2000) and is activated when attention is oriented to eye direction (Kingstone, Tipper, Ristic & Ngan, 2004).

Thus the spatial attention shift initiated in response to perceived eye direction appears to be strongly reflexive, as compared to the effects elicited by other directional central cues; and it is likely to be mediated by unique brain networks responsible for analysis of eye direction.

Reflexive Attention and Central Cues

Even though socially relevant eye direction triggers reflexive orienting, the fact remains that other central cues, such as arrows for example, display very similar behavioral effects. Specifically, the investigations presented in Chapters 4-7 indicate that central spatially nonpredictive arrows produce orienting effects that are often indistinguishable from those produced by eye gaze direction in simple behavioral tasks.

Indeed, the data in Chapter 7 indicated that the reflexive attention effects of arrow cues occurred independently and concurrently with the reflexive effects elicited by peripheral cues and the volitional effects elicited by predictive central cues. The result indicating that the attention effect elicited by arrow cues did not interact with reflexive orienting to peripheral onsets or volitional orienting to a central predictive cue, are consistent with the interpretation that central arrow cues trigger a unique form of reflexive orienting.

However it is presently unclear how the behavioral effects of a nonpredictive central arrow cue compares to five commonly accepted behavioral characteristics of reflexive orienting, and two criteria of automaticity, which have been established over the past 20 years based largely on the RT patterns of facilitation and inhibition triggered by nonpredictive peripheral cues. The aim of this present section is to compare the reflexive orienting effect triggered by central nonpredictive arrows against these seven behavioral standards.

The standard characteristics of reflexive orienting are as follows. The first standard is based on the notion that direct location mapping between the cue and the target, as the peripheral cuing task accomplishes, is necessary for reflexive orienting to occur (e.g., Posner, Snyder, Davidson, 1980; Müller & Findlay, 1988). The second is that spatial reflexive orienting occurs in response to stimulation that does not predict where a target is likely to appear. Thus, any benefits in RT that are observed for targets presented at the cued versus noncued locations can be attributed to reflexive orienting because performance was affected by a sensory event to which participants had no incentive to attend to (e.g., Posner, 1980). Third, according to one of the earliest definitions, a physical reaction that occurs less than 100 ms after stimulation constitutes a reflexive response (Posner, 1978). Fourth, when nonpredictive peripheral cues are

manipulated in experimental tasks, the early behavioral benefits are typically replaced by a RT cost for targets appearing at the cued location. Because the IOR effect is typically observed after an initial RT facilitation effect in the peripheral cuing task, the IOR effect is commonly considered to represent one of the key behavioral markers of reflexive orienting (Friesen & Kingstone, 2003). Fifth, because reflexive attention, as elicited by peripheral cues, has been found to influence selection of targets presented both within and between sensory modalities, (e.g., Ward, 1994), it has been hypothesized that the mechanisms underlying reflexive orienting display supramodal qualities. That is, it has been found that attention is oriented reflexively both when the cue and the target match in sensory modality and when they mismatch in sensory modality (e.g., Ward, 1994; Driver & Spence, 1998; McDonald & Ward, 2000).

Additionally, the reflexivity of a process is also assessed against the two criteria of automaticity. One is a load insensitivity criterion, whereby automatic processes display insensitivity to the level of ongoing goal-directed activity, such that the process is not extinguished or modulated with an increase in the current cognitive load. The second is the intentionality criterion, whereby automatic processes display insensitivity to voluntary, goal-directed control, such that an automatic process is not extinguished or modulated by deliberate voluntary control (e.g., Hasher & Zacks, 1978; Yantis & Jonides, 1990).

Below the behavioral effects elicited by nonpredictive peripheral cues and nonpredictive central arrow cues are compared according to the five characteristics of reflexive orienting and two criteria of automaticity.

Cue Spatial Position

One of the primary differences between peripheral onsets and central arrow cues is their spatial position. Peripheral stimuli are presented in the parafoveal area of the

visual field, typically 5 to 8 degrees of visual angle away from central fixation. In contrast, central attentional cues are presented directly at fixation. This difference in cue location is important as, for example, peripheral vision affords relatively poor spatial acuity and it is very sensitive to stimulus changes in movement or luminance; while foveal vision displays relatively high spatial acuity and permits a fine-grain analysis of the features of the fixated stimuli (e.g., Todd & van Gelder, 1979).

A key argument put forward as to why uninformative peripheral stimulation triggers reflexive orienting is that its spatial location provides information directly about a possible target location. As such, these direct cues do not require any significant cognitive interpretation, i.e., they simply "tag" directly a location in visual space. In contrast, a key argument put forward as to why spatially informative central cues engage volitional orienting is that these attentional cues, such as left- and right-pointing arrows, require a relatively high-level of cognitive interpretation before their spatial meaning can be determined. This dichotomy, which is reflected by the two classic cuing tasks, was perhaps solidified by the seminal paper published by Jonides in 1981. In his study subjects were asked to search a briefly presented array of letters for the target letter (L or R). Before the array appeared, an arrow cue, either randomly pointing to one of the target locations or reliably indicating one of the target locations, was flashed momentarily either at fixation or at a peripheral location. If subjects were told to ignore the central arrow, orienting to the cued location was absent compared to the condition where subjects were told to utilize the central arrow. This difference suggested to Jonides (and many others) that a nonpredictive central arrow cue does not trigger reflexive orienting. In contrast, a peripheral arrow cue always triggered a shift in attention to the cued location regardless of whether the participants were told to ignore the peripheral arrow cue or not. Based on these data Jonides (1981) concluded that a

peripheral cue is more effective in attracting attentional resources than a central cue, because the latter requires encoding and an analysis of the cue's meaning before a shift of attention is initiated.

However, a closer inspection of the literature suggests that this division based on spatial position may be quite superficial. Indeed, the studies investigating the utility of attentional cues presented at peripheral and central locations indicate that both cues cause a shift in attention only when they are interpreted as being meaningful. Thus, it is the meaning attached to this transient change in the display, which is also reflected by the peripheral cuing task, that is responsible for reflexive orienting toward a peripherally cued location. The results indicating that a peripheral onset stimulus draws reflexive attention to its location only when it signals an appearance of a new object support this conclusion (e.g., Yantis, 1993; Yantis & Hillstrom, 1994; Yantis & Jonides, 1996; Yantis & Egeth, 1999; Enns et al, 2001). That is if the visual transient in the display (i.e., stimulus motion or luminance change) does not signal the appearance of a new object it also fails to capture attention reflexively. When these findings are extended to the attentional cuing literature, which postulates that luminance increments summon reflexive attention to the cued location, it appears that this holds true only when participants adopt a particular attentional set which is sensitive to detection of new objects (e.g., Folk, Remington & Johnston 1992, Yantis & Hillstrom, 1994). Hence, collectively these data strongly suggest that a peripheral luminance transient triggers a shift of attention to the cued location because it signals an appearance of a new object in visual space. The attentional cuing effect therefore seems to be largely dependent to the top-down attentional set adopted by the observers. Thus it appears that while peripheral attentional cue may stimulate the spatial location directly, the attentional orienting effect is dependant on the meaning that participants attach to that cue.

Similarly, central arrow cues are thought to shift attention reflexively only after adequate time is allowed for cue processing. Although the result reported by Jonides (1981), indicating that central cues do not trigger reflexive orienting of attention was taken as supporting evidence that peripheral cues are more efficient than central cues in triggering attentional orienting, this finding has not been replicated by several more recent investigations. In contrast to Jonides' data, current studies (e.g., Eimer, 1997; Hommel et al, 2001; Ristic, Friesen & Kingstone, 2002 (Chapter 4); Tipples, 2002) indicate that spatially uninformative central arrows trigger a shift in spatial attention to the pointed-at location. Gibson and Bryant (2005) recently addressed this discrepancy between the classic study by Jonides (1981) and the more recent findings, and concluded that the recent nonreplications of Jonides' data may be due to key, methodological differences. Specifically, in the Jonides' study, arrow cues and target displays were presented very briefly, for 25 ms, and with a very brief cue-target stimulus onset asynchrony (SOA) of 50 ms while in the more recent investigations arrow cues are presented for a longer period of time, anywhere between 75ms up to the length of the trial and target displays routinely remain on once they are presented. Gibson and Bryant (2005) adapted Jonides' methodology and included both short (25ms) and longer (200ms) arrow cue durations. The authors observed that the attentional orienting effect did not emerge when both the cue and the cue-target SOAs were very short (25 and 50 ms respectively), replicating the original Jonides' (1981) study. However, this null finding did not hold true for other cue durations and SOA conditions, in which orienting effects triggered by spatially nonpredictive central arrows were observed for both short and long arrow cue durations. Thus the emergence of the reflexive orienting triggered by central arrow cues may depend critically on the extent to which the cue has been processed (Gibson & Bryant, 2005), suggesting that orienting triggered by central

nonpredictive cues proceeds only when sufficient time is allowed for the cues' attributes to be processed.

Therefore, it appears then that while peripheral and central cues may occupy different spatial positions, the attentional effects elicited by both cues are not devoid of cognitive influences. In the case of peripheral onset cues, studies on attentional capture suggest that visual transients capture attention reflexively only when they signal the appearance of a new visual object. Similarly, in the case of central arrow cues, sufficient cue exposure time is necessary for the attentional orienting to occur, thus permitting an interpretation of cue's shape and its meaning (Gibson & Bryant, 2005). Thus, both reflexive attention effects triggered by peripheral and central cues appear to rely fundamentally on meaning-based cue interpretations.

Cue Information

Reflexive behavioral processes are assumed to arise in situations when the response occurs independently from an observer's immediate goals and expectations. Capturing this important idea, attentional cues chosen to engage reflexive attention are spatially uninformative with regard to a forthcoming target's spatial position, i.e., because the cue does not predict where a target is likely to appear, an observer should not generate an expectancy that the target will appear at the cued location. Hence, any spatial orienting effects of a cue can be attributed to reflexive processes.

Experimentally, in a cuing task where a target can appear at one of two possible locations, this means that half the time the target occurs at the cued location and half the time the target occurs at the uncued location. Participants are typically informed about this random pairing between the cue and the target, and more often than not the participants are instructed to ignore the attentional cue (e.g., Jonides, 1981; Posner, 1980). Despite this explicit forewarning with regard to the arbitrary contingency

between the cue and the target, a cue that attracts attention reflexively displays behavioral facilitation at the cued location relative to a noncued location. Consistent with this logic, both spatially nonpredictive peripheral cues and spatially nonpredictive central cues can be said to trigger reflexive shifts of attention toward the cued location, insofar as they result in a processing facilitation at the cued location when participants are informed that the cue does not, in any way, predict the subsequent location of the target.

In a seminal study, Posner (1980) asked participants to detect targets occurring randomly either at the location of a spatially nonpredictive peripheral cue or at the mirror opposite location. The result was that target detection time was facilitated at the cued target location compared to the uncued target location despite the fact that the luminance onset did not indicate reliably where the target would appear. Numerous other studies conducted since then have replicated this behavioral result (e.g., Jonides, 1981; Posner & Cohen, 1984; Briand & Klein, 1987; Müller & Rabbitt, 1989; Rafal et al, 1989; Pratt & Abrams, 1995; Reuter-Lorenz, Jha & Rosenquist, 1996; Danzinger & Kingstone, 1999).

Similarly, in an early demonstration of reflexive orienting elicited by a central cues, Friesen and Kingstone (1998) asked participants to localize, identify and detect targets randomly occurring either at the location gazed-at by a central schematic face or at the opposite location. As noted previously, the results indicated that RT was facilitated for targets appearing at the cued (gazed-at) location compared to the uncued (not gazed-at) location. Subsequent investigations, including those in the present thesis, extended this result indicating comparable results occurring for other directional cues, like head direction, finger pointing, and arrow direction (e.g., Hood, Willen and Driver, 1998; Driver et al 1999; Langton & Bruce, 1999; Hommel et al, 2001; Ristic et al, 2002;

Tipples et al, 2002). In sum, like the tasks using peripheral onset cues, there is now a wealth of studies reporting that central spatially nonpredictive cues trigger reflexive orienting when cue direction and target location are randomly associated.

Early Facilitation

A fundamental characteristic of an attentional reflex, in addition to its emergence in the absence of any deliberate intent, is that it should occur rapidly, within 100 ms or less after the initial appearance of the stimulating event (Posner, 1978). The cuing effect for peripheral cues satisfies this characteristic of reflexive orienting. Importantly, however, so does the cuing effect for nonpredictive central cues (e.g., Friesen & Kingstone, 1998; Ristic et al, 2002; as well as thesis chapters 4, 5, 7). The rapid effects of early RT facilitation observed for peripheral and central cues is corroborated by electrophysiological evidence, in which the early attention-directing ERP waveform is manifested as increased amplitude of the first positive deflection, the P1 component, peaking at about 90-140ms after cue presentation (e.g., Luck, Woodman & Vogel, 2000). Overall, the ERP data indicate that both spatially nonpredictive peripheral onset cues (Luck et al, 1994) as well as nonpredictive central gaze and arrow cues (Eimer, 1997; Schuller & Rossion, 2001; Schuller & Rossion, 2004) trigger P1 attention effects as early as 100 ms after the stimulus onset.

Inhibition of Return (IOR)

One of the most critical and most often cited differences between the effects of peripheral and central attentional cues is that the early facilitation effect for peripheral cues is replaced by a later inhibitory effect; whereas the early facilitation effect for central directional cues persists for up to a second or more, with the IOR effect rarely, if ever, emerging (see Frischen & Tipper, 2004). In the first experimental demonstration of the IOR effect, Posner and Cohen (1984) observed that, in the peripheral cuing task, as

the cue-target onset delay interval increased beyond 300 ms, participants' RT was longer for targets appearing at the cued locations compared to uncued target locations. Denoting the idea that reflexive attention was inhibited in returning to previously attended locations, Posner and Cohen (1984) named this effect the "inhibition of return (IOR) effect. Because the IOR effect was typically observed following early facilitation to a peripherally cued location, it has come to be considered as one of the key behavioral markers of reflexive orienting (e.g., Friesen & Kingstone, 2003).

In contrast, investigations that have used central nonpredictive cues typically fail to observe the IOR effect (e.g., Friesen & Kingstone, 1998; Langton & Bruce 1999; Driver et al, 1999; Ristic et al, 2002; Tipples, 2002; Langton, 2000; Hommel et al, 2001; Friesen et al, 2004; but see Frischen & Tipper, 2004), with the RT effects displaying shorter RTs for targets appearing at cued compared to uncued target locations at short and long cue-target intervals.

One of the first theoretical accounts of the IOR effect postulated that it occurs as a consequence of reflexive attention being oriented away from the cued location, the result being that search efficiency of the environment is enhanced by inhibiting reorienting to recently attended locations (e.g., Klein, 1988). Therefore, IOR was considered to arise as a consequence of reflexive orienting of attention. This notion predicts that IOR should always be preceded by a reflexive shift of attention. This conclusion is not, however, supported by the data. Several lines of evidence indicate that an IOR effect can be triggered independent of, or concurrent with, a shift in reflexive attention. For example, when the attended location and to-be inhibited location are spatially dissociated (these two locations are typically confounded in the classic cuing paradigm with two possible target locations) facilitation at the attended location and IOR at the to-be-inhibited location can co-occur at an SOA as brief as 50 ms

(Danziger & Kingstone, 1999; see also Maruff et al, 1999). Dovetailing with this finding that reflexive orienting and IOR are dissociable, Friesen and Kingstone (2003) demonstrated independent orienting effects of reflexive attention and IOR using eye direction cues. In their experiment, a schematic face cue served both as a spatial nonpredictive eye gaze cue and as an abrupt onset cue. They reported that the detection of targets presented at the gazed-at locations was facilitated at the same time that detection of targets presented at the abrupt onset location was inhibited, with the magnitude of the IOR effect not varying as a function of the observed facilitation effect.

If IOR does not occur as a consequence of a reflexive attention being drawn to the cued location, why does it occur? A considerable amount of evidence now indicates that IOR occurs as a consequence of oculomotor inhibition (see Taylor & Klein, 1998; and Klein, 2004 for reviews; although it should be noted that whether the entire IOR effect can be attributed to oculomotor processes is still an issue of considerable discussion with several recent studies suggesting an attentional role the IOR effect (e.g., Prime & Ward, 2004; Snyder & Kingstone, in press). An abrupt onset in the visual periphery can reflexively capture both attention and the eyes (Theeuwes, et al, 1998). However, this does not demand the conclusion that both the attention and the eyes are attracted to salient external events because the two forms of orienting are linked by a common neural architecture as it could also be the case that each is independently activated by an abrupt onset. Indeed, it appears that the latter is the case, with attentional attraction leading to a RT facilitation effect, and eye movement activation leading to IOR (Klein, 2004; Hunt & Kingstone 2003a; 2003b). In one of the classic demonstrations of this notion Rafal et al (1989) varied both the type of the cue presented (peripheral vs. central) with an instruction to execute or withhold eye movements (eye movements vs. no eye movements). Their results indicated that the

IOR effect was observed in all conditions in which an eye movement was generated or programmed regardless of whether the cue was peripheral or central cued, suggesting that inhibition does not arise as a consequence of attentional orienting towards the cued location but largely (if not exclusively) as a consequence of occulomotor activation.

In summary, when one examines the important issue of the relationship between the IOR effect and reflexive orienting triggered by peripheral and central cues, it is apparent that both attentional cues display a similar relation to IOR. For instance, both central and peripheral cues produce concurrent effects of longer lasting facilitation and IOR when to-be attended and to-be-inhibited locations are separated spatially and when the involvement of the oculomotor system is minimized (Danziger & Kingstone, 1999; Friesen & Kingstone, 2003).

Supramodal Reflexive Orienting.

Recent crossmodal research strongly suggests that, in addition to influencing the selection of stimuli within the same sensory modality, attentional system may have a substantial influence on the selection of stimuli presented in different sensory modalities.

One of the most fundamental questions relating to attentional orienting across sensory modalities concerns the issue of whether reflexive attention is modality specific or whether it displays supramodal qualities, such that its effects are evident across sensory modalities. Adopting the experimental methods for studying attention in the visual domain, crossmodal links in reflexive attention orienting have typically been investigated using the attention cuing paradigm (e.g., Spence & Driver, 1994; Ward, 1994; Spence & Driver, 1997; McDonald & Ward, 2000). In this variant of the classic cuing task, a subject's attention is typically attracted towards a position in space using an attentional cue (e.g., a visual peripheral onset cue). The target, demanding either a

detection or localization response, is then presented either in the same sensory modality, (e.g., visual) or in different sensory modality (e.g., auditory). The results indicate that, with very few exceptions (e.g., Ward, 1994; Spence & Driver, 1997), a nonpredictive attentional cue presented in one sensory modality facilitates processing of targets presented in a different sensory modality. For example, in one of the earliest experimental demonstrations of reflexive crossmodal attentional modulation, Ward (1994) investigated the effects of nonpredictive auditory and visual attentional cues on localization of auditory and visual targets. Auditory cues triggered attentional orienting to targets presented in the auditory modality whereas visual cues triggered attentional orienting to targets presented in both the visual and auditory domain. Extending these findings to include other sensory modalities, Spence et al (1998) investigated the attentional effects of vision, audition, and touch in a series of three experiments. In this study participants were asked to either discriminate tactile targets after being cued by a spatially nonpredictive tone or a flash, or to discriminate auditory and visual targets after being cued by a spatially nonpredictive tactile cue. Their results indicated that spatially uninformative audio-visual cues triggered orienting toward tactile targets. Similarly, spatially uninformative tactile cues triggered reflexive orienting toward targets presented in both visual and auditory modalities. Thus, the results indicate that reflexive orienting proceeds crossmodally such that attentional cues presented in one modality (e.g., visual, auditory, or tactile) trigger orienting towards events presented in another modality (e.g., visual, auditory, or tactile). And of critical importance here, reflexive attentional shifts triggered by spatially nonpredictive peripheral visual cues facilitate behavioral responses towards targets presented in other sensory modalities (e.g., Ward, 1994; Spence et al, 1998; Ward, McDonald & Lin, 2000; McDonald et al, 2001).

Similarly, a recent study by Soto-Faraco et al (2005) demonstrated that a central nonpredictive eye gaze cue influenced allocation of reflexive attention to tactile targets. Participants saw a schematic face at central fixation, gazing either to the left or to the right. Participants were asked to detect or discriminate a vibrotactile stimulation delivered to the left or right finger, occurring 100, 300 or 1000 ms after the presentation of the central face cue. Data from speeded detection, speeded discrimination and signal detection tasks converged on the conclusion that a nonpredictive central gaze cue triggered reflexive orienting which facilitated the processing of tactile stimuli at the gazed-at location. This result was replicated with a nonpredictive arrow stimulus. Thus the Soto-Faraco et al (2005) study provides strong evidence that the attentional effects of central attentional cues, similarly to the attentional effects of peripheral attentional cues, trigger supramodal shifts of covert reflexive spatial attention.

Criteria for Automaticity

In the 1980s, considerable research effort was devoted to understanding and developing criteria for the definition of automatic cognitive processes (e.g., Jonides, 1981; Hasher & Zacks, 1984; Jonides et al, 1985, Naveh-Benjamin & Jonides, 1986; Palmer & Jonides, 1988). Two general features of automatic processing emerged. First, because automatic processing should require little cognitive resources, its effects should be unaffected by manipulations that change (e.g., increase) the demands for cognitive resources. Second, because automatic processes are thought to occur as a result of automatic pathway activation, their emergence and the magnitude of their effect should not be influenced by the amount of top-down voluntary cognitive control exerted by individuals (Palmer & Jonides, 1988). These two criteria have been coined the load insensitivity criterion and the intentionality criterion of automaticity, respectively.

The two criteria have been operationalized in experimental manipulations in a number of different ways. For example, load insensitivity has been tested by manipulating the amount of cognitive resources required by a secondary task and the effects these manipulations have on performance of a primary, putatively automatic, task (e.g., Jonides, 1981). Alternatively, load insensitivity has been tested by assessing whether reflexive orienting interrupts a goal directed activity (e.g., Müller & Rabbitt, 1989), or by assessing whether the emergence of reflexive orienting is affected by changes in stimulus presentation frequency (e.g., Jonides, 1981). Likewise, the influence of voluntary control over automatic processes, or the intentionality criterion, has been tested in manipulations examining, for example, the circumstances under which reflexive process may be resistant to suppression (e.g., Jonides, 1981; Yantis & Jonides, 1990).

Evaluation of the literature on reflexive orienting of spatial attention, elicited both by traditional peripheral onsets and nonpredictive central cues indicate the attentional effects triggered by these two cues both satisfy the load insensitivity criterion and, similarly, both fail to satisfy the intentionality criterion. These two issues are discussed below.

Load Insensitivity Criterion. In attentional cuing tasks the load insensitivity criterion has typically been investigated using a secondary task procedure, manipulating the demands for cognitive resources (Jonides, 1981) or using a counterpredictive cuing task procedure that sets reflexive and volitional orienting in direct competition (Müller&Rabbit, 1989; Friesen, Ristic & Kingstone, 2004, Chapter 5). Returning to the seminal study by Jonides (1981), in his second experiment participants were asked to perform both a target search task and a secondary memory span task. Attentional orienting elicited by peripheral cues was relatively unimpaired by this secondary

manipulation whereas attentional orienting elicited by central cues was significantly compromised. These data suggested that reflexive orienting is far less dependant on cognitive resources than volitional orienting.

However, there is evidence that central and peripheral cues behave similarly in cuing tasks that test the load insensitivity criterion by pitting the effects of reflexive and volitional attention directly against one another. In 1989, Müller and Rabbitt published the now classic study, which tested the load insensitivity criterion for reflexive orienting elicited by peripheral cues. In their task observers were cued by a central arrow, which correctly indicated a target's position on 75% of trials. Before the target was presented, a task irrelevant peripheral luminance cue appeared randomly in one of the possible target locations. The critical question was whether the appearance of the task irrelevant stimulus cue at an unlikely target location would disrupt a voluntary act of attentional orienting towards the likely target location. Müller and Rabbitt (1989) found that presenting an irrelevant stimulus at an unlikely location interrupted volitional orienting to the predicted target location, demonstrating that reflexive orienting triggered by peripheral cues satisfies the load insensitivity criterion of automaticity.

In a comparable study that examined the load insensitivity criterion for orienting to central nonpredictive cues, Friesen, Ristic and Kingstone (2004, Chapter 5; Experiment 1; see also Driver et al, 1999) employed a so-called counterpredictive cuing paradigm. Participants were presented with a central schematic gaze cue, the direction of which indicated that the target was likely to appear at the opposite spatial location. In the majority of all the trials (i.e., 80%) the cue correctly indicated the target position, but in the remaining trials (20%), the target appeared at some other possible location. The key comparison of interest was again whether targets that appeared at the cued location would be detected most quickly despite the fact that participants were

instructed to voluntarily allocate their attention towards the opposite, likely target location. Friesen et al (2004) observed that central eye direction cues triggered <u>reflexive</u> orienting to the cued location indicating that similarly to peripheral onset cues, reflexive orienting triggered by central eye direction satisfied the load insensitivity criterion of automaticity in that reflexive orienting towards the unlikely target location was observed despite the explicit instruction and act of orienting attention volitionally to a different location.

Interestingly, Friesen et al (2004) observed that not all central cues are alike in their ability to trigger attention reflexively. In their Experiment 2, Friesen et al (2004) used counterpredictive central arrow cues instead of central eye gaze cues. These data demonstrated a nonsignificant trend towards reflexive orienting of attention toward the cued target location at an early SOA of 100 ms and as such did not strictly replicate the early reflexive effects obtained with eye direction stimuli (Experiment 1). Therefore, while in general central attentional cues display behaviorally indistinguishable effects in simple RT tasks, there appear to be differences between the individual central cues in terms of their strength to attract attention reflexively (see also Chapter 6).

In sum, the research evidence suggests that reflexive orienting triggered by both spatially nonpredictive peripheral and central cues can interrupt or co-occur with volitional orienting in experimental tasks that contrast the effects of reflexive and volitional attention directly. Therefore, reflexive orienting triggered by both peripheral and central attentional cues appears to satisfy the load insensitivity criterion.

<u>Intentionality Criterion</u>. The second criterion of automaticity, the intentionality criterion, has been operationalized by tasks that require subjects to deliberately suppress orienting to irrelevant stimuli. The first support for the intentionality criterion comes from the results indicating that reflexive attentional orienting is observed despite

the instructions that the cues are spatially nonpredictive. More stringent tests of the intentionality criterion include experimental manipulations examining the effects of increased task practice (Warner, Juola & Koshino, 1990) and the effects of deliberate voluntary control (e.g., Yantis & Jonides, 1990).

Thus the critical question of interest is whether the effects of a reflexive, either peripheral or central cue, can be overridden? Research evidence suggests that, for both types of the cue, the answer is yes. That is, it appears that both cues violate intentionality criterion similarly in that the reflexive effects can be abolished by top-down volitional control.

Several lines of evidence indicate that reflexive orienting in response to peripheral cues does not satisfy the intentionality criterion of automaticity. First, it appears that a peripheral cue's ability to interrupt voluntary orienting diminishes with increased practice. Warner et al (1990) trained participants to orient away from the location indicated by a peripheral cue and demonstrated that, in contrast to Müller and Rabbitt (1989), after extensive training, an infrequently occurring peripheral cue ceased to interrupt voluntary orienting of attention. Second, at least two other studies indicated that an irrelevant peripheral transient failed to capture attention when subjects had no reason to attend to the onset event at all. Yantis and Jonides (1990, Experiment 2) asked subjects to discriminate the target (E or H) among distractor letters arranged in along vertices of a hexagon. Before a sudden onset of the distractor, an arrow cue, indicating the location of a subsequent target with 100% certainty appeared at the center of the screen. This perfectly reliable information conveyed by the arrow cue effectively eliminated any attentional effects of the peripheral onset. The same result was replicated in Experiment 3, which manipulated the reliability of the central arrow cue. The data obtained with 100%, 75% and 20% valid central cues indicated that while

a completely reliable cue, i.e., 100% valid, eliminated any reflexive orienting towards the onset location, partially reliable cues did not, suggesting that the effects of peripheral onset cues can be overridden when the observer has no intention of attending to the onset cue (cf. Theeuwes, 1991).

Like peripheral cues, reflexive orienting in response to central nonpredictive cues, strictly speaking, also fails to satisfy the intentionality criterion of automaticity. Ristic and Kingstone (2005, Chapter 2) examined whether reflexive orienting triggered by spatially nonpredictive eye direction proceeds in a purely automatic fashion, such that it is completely insensitive to top-down modulation. Participants in all conditions were shown an identical ambiguous central stimulus, containing a left or right pointing eye gaze cue that could be interpreted either as representing "eyes" or a "car". The critical variable of interest was whether this top-down representation of the central cue would in any way modulate reflexive orienting triggered by a spatially nonpredictive eye direction. The results indicated that the emergence of reflexive attention triggered by eye direction is influenced by top-down mechanisms, in that the physically identical directional cue failed to trigger orienting effects when the observers adopted an irrelevant cognitive interpretation of the cue's meaning. However, after the participants adopted the relevant interpretation of the cue (i.e., eyes) its effects could no longer be overridden.

Thus, the evidence indicates that reflexive orienting triggered by both spatially nonpredictive peripheral and central cues fails to satisfy the intentionality criterion of automaticity. That is, the attention effects of both peripheral and central cues can be influenced by top-down factors. Peripheral onset cues do not always capture attention in the absence of current goals and intentions of an individual, and similarly, the emergence of the orienting effect triggered by central attentional cues seems to be

critically influenced by the top-down representation adopted by the observers. Interestingly, in a direct contrast between peripheral and central cues, it would appear that eyes are if anything "more automatic" than peripheral onsets, in that their effects could not be overridden once observers represented the ambiguous stimulus in Chapter 2 (Ristic & Kingstone, 2005) as depicting eyes.

Summary

The outcome of this analysis has shown that the attentional effects triggered by spatially nonpredictive peripheral and central attentional cues produce behaviorally effects that are extremely similar. Both cues trigger orienting effects (1) that depend on the meaning of the cue despite the difference in their spatial position at the time of presentation; (2) even when the relationship between the cue's position and the target position is random; (3) that emerge rapidly, by 100 ms after the cue presentation; (4) that are long lasting and not accompanied by inhibition of return when the involvement of eye movement system is minimized; and (5) that are evident both within and across sensory modalities. When the orienting effects produced by the two types of cues are assessed against the two criteria for automaticity, the results indicate that both nonpredictive peripheral and central attentional cues trigger reflexive effects that have an ability to interrupt or co-occur with an ongoing cognitive activity but that the attentional effects of both peripheral and central attentional nevertheless can be modulated intentionally by top-down processes.

Consequently, it follows that insofar as orienting to peripheral abrupt onsets is conceptualized as being reflexive, as conventional wisdom maintains (e.g., Jonides, 1981; Müller& Rabbit, 1989), for the same reasons, orienting in response to central cues must also be conceptualized as being reflexive.

Implications for Understanding Reflexive Orienting

According to Kahneman and Treisman (1984), who advanced a more fine-grained distinction between automatic processes, automatic processes are hypothesized to vary in strength according to whether one or both of load insensitivity or intentionality criteria are satisfied. Strongly automatic processes always satisfy both criteria, weakly automatic processes satisfy one of the two criteria, and non-automatic processes never satisfy either of the two criteria.

A range of spatially nonpredictive central attentional cues, including eye direction, arrow direction, head deviation, finger pointing, words with spatial meaning and even numbers, produces RT facilitation for targets appearing at a cued location. This broad result is stable and well replicated across the different types of central cues. As previously suggested, this behavioral effect is best conceptualized as an instance of reflexive attentional orienting as central nonpredictive cues meet the five characteristics of reflexive orienting and two criteria of automaticity that have been applied to the traditional form of reflexive orienting observed for peripheral onset stimuli.

Within this general domain of central stimuli that can trigger reflexive orienting, it does appear that some cues produce effects that are more strongly reflexive than others. At the strongly reflexive extreme, as reviewed above, there appear to be abrupt onsets and gaze cues. Arrows however, seem to be less reflexive than eyes. As indicated by Friesen, Ristic and Kingstone (2004, Chapter 5), eyes but not arrows trigger an attention shift to the cued location even when the goal of participants is to direct attention volitionally to a different location. And as shown in Chapter 6, the reflexive orienting effect for gaze is unaffected by arbitrary cue-target contingency relationships. In contrast, arrow cues are affected by such contingencies (see also Pratt and Hommel, 2003).

At the other end of this continuum of reflexivity there resides the reflexive orienting effect produced by spatially nonpredictive central number cues. Fischer et al. (2003) reported that spatially nonpredictive central digit cues produce reflexive shifts of attention as if representing numbers on a mental number line running from left to right. In their study, participants were fastest to detect a target appearing on the left side of the screen when the central number cue was numerically low (1 or 2), and participants were fastest to detect targets appearing on the right side of the screen when the central number cue was numerically high (8 or 9). However, unlike the effect for abrupt onsets, eyes and arrows, this effect was relatively slow to emerge suggesting that it may not be as strongly reflexive at cues like onsets, eyes and arrows. Two recent studies have confirmed this hypothesis.

Ristic, Wright and Kingstone (in press) have reported that merely adopting a simple mental set abolishes the proposed reflexive effect of the number mental line. After replicating the basic finding of Fischer et al. (2001) — with faster RTs for targets on the left when preceded by a low number cue and faster RTs for targets on the right when preceded by a high number cue — Ristic et al. asked participants to imagine a number line running from right to left, e.g., low numbers on the right and high numbers on the left. The result was a profound reversal of the Fischer et al. finding. Now, RTs were faster for targets on the right when preceded by a low number cue and faster for targets on the left when preceded by a high number cue. In a follow-up experiment, participants were asked to imagine a clock face and targets could appear above, below, to the left or to the right of center. The results indicated that the highest number cue (12) resulted in targets being detected most quickly at the 12 o'clock position, and similarly, the number cues 3, 6, and 9 resulted in targets being detected most quickly at the 3, 6, and 9 o'clock position. This result emerged despite the fact that the central

number cues did not predict where a target was going to appear. In a similar study Galfano et al. (in press) have shown that when participants are asked to orient attention volitionally in response to a low or high number cue, with the number 1 predicting a target on the right and the number 9 predicting a target on the left, there is no evidence of reflexive orienting as suggested by Fischer et al. (2003). Collectively these two studies indicate that reflexive attentional orienting elicited by number cues occurs under very limited circumstances and is extremely vulnerable to changes in mental set. For instance, the number line effect is determined by the current cognitive top-down representation (Ristic et al., in press) and it is unable to interrupt volitional orienting (Galfano et al, in press).

Taken together these data argue against the notion of reflexive orienting as an all-or-none phenomenon. As demonstrated by the data presented in this dissertation, as well as by other recent behavioral investigations, reflexive orienting appears to exist on a continuum from strongly reflexive (such as eye direction) to weakly reflexive (such as number cues).

Implications for Understanding Volitional Orienting

In contrast to reflexive attention, voluntary orienting is conceptualized as arising from the conscious allocation of attentional resources by an observer towards sensory events of interest. In the central arrow cuing task that is typically used to measure voluntary orienting, the fundamental volitional characteristics of spatial attentional orienting are thought to be revealed by requiring subjects to detect a target light at a peripheral location that is, or is not, pointed at by a central arrow. Importantly, in this task a central arrow cue predicts where a target stimulus is likely to appear. Because the spatial effects of a central arrow are assumed to occur only when the arrow is

informative as to where a target is likely to appear, its attention effects are attributed to volitional orienting of spatial attention (e.g., Jonides, 1981).

Of course, the studies in this thesis have shown that the above assumption is incorrect. That is, shifts of attention to a cued location will occur even when a central arrow cue does not predict where a target is likely to appear. This finding raises the following issue: If spatially nonpredictive central cues, such as arrows, trigger a reflexive shift in spatial attention to the cued location, then what has the traditional spatially predictive central arrow cuing task been measuring?

There are several possibilities. One is that the many past studies that used a predictive arrow cue to study volitional attention, have been measuring reflexive attention rather than volitional attention. A second possibility is that previous investigations have been measuring volitional attention correctly when a central arrow cue is spatially predictive, i.e., only volitional orienting is engaged when the arrow cue is predictive. A third possibility is that a central spatially predictive arrow engages both reflexive and volitional attention, with these effects combining in an additive fashion. A fourth possibility is that a central spatially predictive arrow engages both reflexive and volitional attention, with these effects combining in an interactive manner.

To distinguish between these four alternatives, in a recent study, Ristic and Kingstone (in press) used a central cue that does not trigger reflexive shifts of attention when it is spatially nonpredictive, and does engage volitional attention when it is spatially predictive. These two effects were compared against the reflexive attentional effect of an arrow cue when it is spatially nonpredictive and the attentional effect of an arrow cue when it is spatially predictive. In this way, Ristic and Kingstone were able to determine whether a central predictive arrow engages: (i) only reflexive attention; (ii) only volitional attention; (iii) the summation of reflexive and volitional attention; or (iv) the

interaction of reflexive and volitional attention. The results indicated that the magnitude of the orienting effect produced by a spatially predictive arrow cue always exceeded the magnitude of the individual reflexive attention and volitional attention effects, as well as the sum of the reflexive and volitional components. That is, the data indicated that the orienting effect that is generated by a predictive arrow reflects an interaction between reflexive and volitional attention, and not volitional attention in isolation as has been assumed in the past (e.g., Jonides, 1981).

This point cuts across all levels of behavioral investigation that have used the predictive central arrow cuing paradigm to measure volitional orienting. From those studies focused on discovering the time-course of voluntary orienting (e.g., Jonides, 1980; Jonides, 1981; Müller & Rabbit, 1989; Müller & Humphreys, 1991), to those that sought to understand the effects of volitional attention on response time and response accuracy (e.g., Posner, et al 1980; Cheal & Lyon, 1991), to those that attempted to understand the effect of volitional attention on perceptual sensitivity and response bias (e.g., Müller & Findlay, 1988; Hawkings et al, 1990), to those that compared space-based and object-based attention (e.g., Egly, Driver & Rafal, 1994), to recent attempts to develop a single test to evaluate human attentional networks (e.g., Fan et al 2002). It would appear that these and many studies like them concluded incorrectly that they had engaged and measured volitional orienting.

A similar limitation is found when one considers studies that have sought to examine deficiencies in volitional attention and its neural underpinnings. Difficulties in deploying or maintaining volitional attention, typically defined by performance deficits on the predictive central arrow cue task, have been subscribed to a range of complex disorders such as neglect (e.g., Rafal, 2000), frontal lobe damage (e.g., Henik, Rafal & Rhodes, 1994), Parkinson's disease (e.g., Kingstone et al, 2002), autism (e.g.,

Wainwright-Sharp & Bryson, 1993; Iarocci & Burack, 2004), and attention-deficit and hyperactivity disorder (e.g., Pearson, et al, 1995). The Ristic and Kingstone (in press) data indicate that these studies and the diagnostic and rehabilitative applications that they have spawned (see Park & Ingles, 2001 for a recent review) need to be questioned and reevaluated.

Finally, a body of attentional literature indicates that reflexive and volitional attention are subserved by distinct neural networks, with reflexive orienting engaging a ventral frontoparietal system and volitional orienting engaging a dorsal frontoparietal system (e.g., Corbetta & Shulman, 2002). Because the vast majority of the investigations that have examined brain networks that subserve reflexive and volitional orienting have used the two classic peripheral and central cuing tasks, the resulting neural distinction that has been proposed may itself be brought into question.

Final Reflections and Future Directions

The work in this dissertation has shown that central spatially nonpredictive attentional stimuli, such as eyes and arrows, trigger reflexive shifts of attention toward the cued location. Importantly, the reflexive orienting effect triggered by central cues does not seem to be equal across all stimuli. Gaze direction produces effects that are strongly reflexive, possibly because the processing of eye direction is subserved by brain mechanisms that appear to be specialized for that task. Other cues, like arrows, produce behavioral effects that are often similar to those produce by gaze, but in particular situations it has been found that arrows are not as strongly reflexive as gaze cues, e.g., arrows are more vulnerable to cognitive control and the effects of attentional set than gaze direction (Chapters 5 and 6). Thus, a main proposal to emerge from the present dissertation is that central nonpredictive attention cues produce reflexive orienting that is best conceptualized as existing along a continuum.

Importantly, these findings and ideas depart significantly from the traditional framework that has been applied to attentional orienting, where reflexive orienting is triggered by spatially nonpredicitive peripheral cues and volitional orienting is engaged by spatially predictive central arrow.

What is a productive course of action to take when trying to reconcile the present findings of this thesis within the classic attentional framework? One route would be to redefine reflexive and volitional orienting within the classic framework by recognizing that the physical location of the attention cues — peripheral versus central — is not a valid indicator of whether a cue triggers reflexive or volitional attention. As has been discussed previously, in very many important ways, both nonpredictive peripheral cues and nonpredictive central cues produce similar reflexive attention effects. Indeed, the only substantial difference appears to be one cue stimulates parafoveal vision and the other stimulates foveal vision. What appears to be critical to whether a cue triggers reflexive attention or volitional attention is not <u>where</u> it is presented, but <u>what information</u> it conveys. That is, a reflexive shift in spatial attention is triggered by a stimulus cue if that cue does not predict where a target is likely to appear; and a volitional shift in spatial attention occurs if that cue does predict where a target is likely to appear. Here, the distinction would be made based on the reliability of the spatial information of the attention cue and not its spatial position.

However, even this redefinition fails to accurately distinguish between reflexive and volitional orienting. This is because Ristic and Kingstone (in press) have shown that spatially predictive arrow cues engage both reflexive and volitional processes. Thus it is clear that the predictive value of the cue alone fails to accurately distinguish between cues that engage reflexive and volitional attention. At the very least, one would

have to include the notion that a predictive attention cue engages volitional attention only if it does not trigger attention reflexively when it is spatially nonpredictive.

An alternative approach that departs from the classic framework and its notion of reflexive and volitional attention considers how an attention cue refers to another object in space (Logan, 1995). What is interesting about this framework, and markedly different from the classic framework, is that the same attentional cue could potentially have very different effects on spatial attention allocation depending on the spatial reference frame adopted by an observer. Logan (1995) considered three types of spatial relations. Basic spatial relations specify the location of a single object based on the reference frame of the observer. Thus, a basic relation would indicate simply that "The target is there", where the spatial reference frame is centered on the observer. Deictic spatial relations take two arguments and specify the location of one object with respect to the location of another object. This may be expressed in a sentence like "The target is above the cue". In this case, the location of the target is specified by the reference frame that is centered on the cue. Finally, intrinsic spatial relations specify the location of one object with respect to another object, like deictic relations, except that the spatial reference frame is fixed within the intrinsic axes of the referent object. Thus, according to this conceptualization of attentional cues, it is not a cues' position in space or even whether a shift is "reflexive" or "volitional" that is important; what is critical is the way the spatial relations between a cue and an object is conveyed.

Recently, Gibson and Kingstone (in press) extended the original work by Logan (1995) by examining the effects of spatial reference frames on the orienting effects elicited by peripheral and central cues. Specifically, the authors hypothesized that attentional cues such as peripheral onsets, central arrows and gaze cues, conveyed basic spatial relations between the cue and the target. In contrast, central word cues,

such as left, right, above or below, communicated <u>deictic</u> spatial relations. In keeping with this proposal, Gibson and Kingstone found that peripheral onsets, central arrows and central gaze cues, all produced behavioral effects that were grounded on an observer-centered reference frame; whereas central word cues produced behavioral effects that were grounded on a cue-centered reference frame. What is particularly noteworthy given the findings of the present dissertation is that this alternative framework naturally groups peripheral onsets with central cues like eyes and arrows. In addition it offers a way of gaining insight into differences that may arise between different classes of central cues, such as arrows and words.

Finally, a more fundamental way of reexamining human attention, and the one that departs most dramatically from the original framework, is to advocate for a research focus that seeks to understand how human attention operates outside the lab and within more complex real world situations. There is a growing body of evidence indicating that cognitive and neural processes change as the task situation changes (e.g., Neisser, 1976; Monsell, 1996). As a result even the most minor changes <u>within</u> a lab situation can compromise the replicability of an effect (Berry & Klein, 1993; Soto-Faraco, Morein-Zamir & Kingstone, 2005; Wolfe & Pokorny, 1990). Collectively these studies suggest that attention effects obtained within simple lab settings must be examined against more complex real world settings (see Kingstone et al., 2003). This point is driven home by the present dissertation. In trying to address one of the core attention research issues in the field — determining how people use real world attention cues, such as the eyes of others — it was discovered that attention is oriented reflexively in response to central nonpredictive cues. In turn, this finding has led to the clear indication for a reevaluation of the classic division of human attention in terms of reflexive orienting that is triggered by peripheral cues and volitional orienting that is triggered by central cues. It is

noteworthy that Michael Posner had long ago anticipated that real world considerations may ultimately demand that the classic reflexive/volitional division of human orienting, grounded on the cuing paradigm, may need to be revised substantially. At the end of his seminal book <u>Chronometric Explorations of Mind</u>, he wrote:

"I am aware of the speculative nature of these relationships between the findings of experimental studies and their application... Whether or not the principles emerging from experimental laboratories and the methods of mental chronometry will be helpful in laying bare some of these mechanisms will remain for the future to determine" (p. 240).

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APPENDIX I

UBC Behavioral Research Ethics Board Certificate of Approval