

**INVESTIGATING HEMISPHERIC LATERALIZATION OF REFLEXIVE
ATTENTION TO GAZE AND ARROW CUES**

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ABSTRACT

Recent studies have demonstrated that central cues, such as eyes and arrows, reflexively trigger attentional shifts. However, it is not clear whether the attentional mechanisms induced by these two cues are similar or rather differ in some important way. We investigated hemispheric lateralization of the orienting effects induced by the two cue types in a group of 48 healthy participants comparing arrows and eye gaze as central non-predictive cues in a discrimination task, in which a target stimulus was briefly presented in one of two peripheral positions (left or right of fixation). As predicted by neuropsychological data, reflexive orienting to gaze cues was only observed when the target was presented in the left visual field, whereas reflexive orienting to arrow cues occurred for targets presented in both left and right visual fields.

Keywords: spatial attention, hemispheric specialization, gaze cue, arrow cue

1. Introduction

Several studies have provided evidence supporting the notion that gaze acts as a special attention cue that reflexively triggers attentional shifts (e.g., Driver, Davis, Ricciardelli, Kidd, Maxwell & Baron-Cohen, 1999; Friesen, Ristic, & Kingstone, 2004; for a review, see Frischen, Bayliss, & Tipper, 2007). These studies applied a spatial cueing paradigm, first introduced by Posner (1980) and reviewed by Friesen and Kingstone (1998). In this paradigm, a drawing/photograph of a face looking to the left or right is presented in the centre of the screen. The participant is required to respond to a target that might appear either at the looked-at (valid) or at the opposite location (invalid). Quicker reaction times for validly cued targets are thought to indicate an allocation of attention to the looked-at location (i.e. gaze cueing effect). This effect occurs even when the gaze direction is not predictive of the subsequent target location and the time interval between the presentation of the cue and the target is short (around 100 ms; Langton and Bruce 1999; Ristic, Friesen and Kingstone 2002; Friesen and Kingstone 2003) and even when participants are told to expect targets at the opposite location (see, e.g., Driver et al., 1999). In addition to these behavioral evidences, the evolutionary and social significance of eye gaze (Emery, 2000) and the existence of an innate, specialized mechanism for processing eye gaze (Baron-Cohen, 1994) have been taken as evidences of reflexive orienting to gaze direction. However, contrary to the notion that gaze is a special attentional cue, many studies have provided behavioral evidence for similar shifts of attention when arrows instead of eye-gaze are used as cues (Hommel, Pratt, Colzato, & Godijn, 2001; Ristic, Friesen, & Kingstone, 2002; Tipples, 2002; 2008). For example, participants are quicker to

respond to targets appearing congruently to the arrow direction (arrow cueing effect) even when it is not predictive of the subsequent target location and the target appears very quickly after the cue onset (around 100 ms; Tipples, 2002; Bayliss, Di Pellegrino, & Tipper, 2005).

An initial comparison between gaze and arrow cues has shown that eye-gaze cues are more resistant to voluntary control (Friesen, Ristic, & Kingstone, 2004). In particular, Friesen et al., (2004) used a so-called counter-predictive cueing paradigm (the target was more likely to appear in the location opposite the one indicated by the cue) and showed that attention shifts to the cued locations were only observed when eye-gaze were used as cues. In contrast, when counter-predictive cueing was tested with arrows, participants' attention did not shift to the cued locations. However, in a more recent study using the same counterpredictive paradigm as that of Friesen et al. (2004), Tipples (2008) found that both eye and arrow cues produce similar reflexive shifts of attention (for a different result, see also a recent study of Guzzon, Brignani, Miniussi & Marzi, 2010).

Despite the behavioral research has generally failed to reveal robust differences between gaze and arrow cueing, it is possible that the underlying neural architecture are differently engaged. However, again, electrophysiological and neuroimaging studies have generally yielded mixed results concerning brain activity dissociations between gaze and arrow cueing conditions. While some studies reported similar activation for social and nonsocial cues in frontoparietal regions (Brignani, Guzzon, Marzi, Miniussi, 2009; Greene, Mooshagian, Kaplan, Zaidel, & Iacoboni, 2009; Sato, Kochiyama, Uono, Yoshikawa, 2009; Tipper, Handy, Giesbrecht, & Kingstone et al., 2008), other studies found a different

cortical activation during social cueing compared to nonsocial cueing, including greater activity in bilateral extrastriate cortices (Engell et al., 2010; Greene et al., 2009; Hietanen et al., 2006; Tipper et al., 2008) right ventral regions (Tipper et al., 2008) as well as in the right STS (Kingstone, Tipper, Ristic, & Ngan, 2004).

In addition, some neuropsychological studies have suggested that there are distinct neural systems for gaze and arrow cueing (Akiyama et al., 2006; Kingstone, Friesen, & Gazzaniga 2000; Ristic, Friesen, & Kingstone, 2002)¹. For instance, a study with split-brain patients has shown that the reflexive gaze-cueing effect is lateralized to the right hemisphere, which is specialized for face processing (Kingstone et al. 2000). This laterality effect was not found in a later study using non-predictive arrows cues, in which the same split-brain patient showed no lateralization of reflexive orienting, with the cueing effect occurring in both hemispheres (Ristic et al. 2002). Furthermore, Akiyama and colleagues (2006) found that a patient with focal lesion in her right superior temporal gyrus showed no gaze-cueing effect, but preserved orienting to non-predictive arrow cues.

Taken together, these neuropsychological findings are consistent with the idea that reflexive orienting to arrow cues is subserved by brain mechanisms that are shared between the two hemispheres, whereas reflexive orienting to gaze cues

¹ Vecera and Rizzo tested a frontal lesion case, EVR, by using spatial cueing tasks and by comparing peripheral versus central cues (Vecera & Rizzo, 2004, 2006). EVR demonstrated a typical sized cueing effect in response to peripheral cues, suggestive of the ability to reflexively shift attention. However, he showed no cueing effect in response to centrally presented word and eye gaze cues. The authors concluded that gaze is no different from other symbolic cues (e.g. words, arrows).

is subserved by lateralized brain mechanisms involved in face/gaze processing (e.g., Friesen & Kingstone 2003; Kingstone et al. 2004). However, in light of natural variations in the gaze-cueing effect across individuals and the unavailability of prelesional data, these findings must be interpreted with some caution and can hardly be extended to the general population.

To our knowledge, only one behavioral experiment has directly compared the hemispheric lateralization of gaze and arrow cueing effects in normal adults (Greene & Zaidel, 2011). In particular, the authors found a right hemisphere bias for attentional orienting induced by gaze cue, but not for attentional orienting induced by nonsocial stimuli (arrow cues and peripheral cues). However, in our opinion in this study the lateralization of the attentional orienting was manipulated in a way that made difficult the interpretation of the results. First, gaze and arrow cues were presented in the right or left Visual Hemifield (VHF), and the target-stimuli were presented in the upper or lower hemispace of the same VHF. For this reason, cues were 100% informative with regard to the VHF location of the stimulus target, although they were uninformative about the top-bottom location of the target within the same VHF. As underlined by the authors themselves, this experimental choice could have induced a mix of automatic (uninformative regard to up-down location of the stimulus) and controlled (informative regard the VHF) orienting. Furthermore, such lateralized presentation of the cue stimuli (gaze and arrow) could have confounded some hemispheric effects, complicating interpretation of the results. Indeed, the observed evidence of hemispheric differences in attentional orienting induced by gaze and arrow cues may be partly due to the different recruitment of the brain hemispheres for processing gaze and

arrow stimuli, and not necessarily for the subsequent shifts of attention. Instead of being a result of attentional orienting, the different cueing effects for the left and right visual hemifields might rather reflect differences in the processing of the cue itself. For instance, right hemisphere is more highly activated for processing biologically relevant face and gaze stimuli than for processing biologically irrelevant arrows (for a review, see Birmingham & Kingstone, 2009).

Therefore, in the current study we used a central (instead of a peripheral) presentation of cue stimuli (gaze an arrow) in an attempt to neutralize this confounding factor and to investigate the hemispheric lateralization of the attentional shifts induced by arrow and gaze cues, rather than the processing of the cues themselves. Following the neuropsychology data indicating that orienting to gaze cues is subserved by right lateralized brain mechanisms involved in face/gaze processing (e.g., Kingstone et al. 2004; Friesen & Kingstone 2003), we hypothesized that gaze cueing effects would occur for targets presented in the left visual field. Such hemispheric lateralization was predicted not to be present when the spatial cue was an arrow as neuropsychological data showed no lateralization of reflexive orienting to arrow cues, with the arrow cueing effect occurring in both hemispheres (Ristic et al. 2002).

2. Method

2.1. Participants

Forty-eight university students (40 females and 8 males; mean age 23 ± 2.6 years) signed an informed consent before participating as volunteers in the study. The local ethical committee approved the study. All participants were right-handed,

with a hand preference equal or greater than 85%, as assessed by means of a lateral preference questionnaire (Salmaso & Longoni, 1985), had normal or corrected-to-normal vision, and were unaware of the purpose of the experiment.

2.2. *Apparatus*

Stimuli were presented on a 21-inch color VGA monitor. An IBM-compatible PC running E-Prime software controlled the presentation of the stimuli, timing operations, and data collection. Responses were gathered with a standard keyboard.

2.3. *Stimuli*

Stimuli and trial sequences are illustrated in the Figure 1.

In the gaze cueing condition, the fixation was a central face ($3^\circ \times 2.5^\circ$ degree of visual angle) with the pupils straight, while the spatial cue was the same central face with the pupils directed either to the left or to the right. In the arrow cueing condition a horizontal line ($0.5^\circ \times 2^\circ$) was used as fixation. An arrow-head directed either to the left or to the right was used as arrow-cue². The arrowhead was presented at end of the central line in order to ensure that the arrowhead and the eye closest to the target were equidistant from the target in the valid cue condition. Target stimuli were the “X” or “O” ($0.9^\circ \times 0.9^\circ$) letters. All stimuli

² In this study we used a realistic, arrow-like cue to provide ecologically validity to the task (see also Senju, Tojo, Dairoku & Hasegawa, 2004; Marotta, Lupiañez, Martella, Casagrande, 2012). Most studies have used a two arrow cues (Tipples et al., 2002, 2008) or a two arrow heads procedure (heads pointing to the same direction at both ends of a central line; Hietanen et al., 2008; Ristic et al., 2002). Little is known about the impact of this manipulation on arrow-cueing. Kuhn & Benson (2007) speculated that realistic “arrow-like” cues are more effective in triggering reflexive shifts of attention. However, the different types of arrow cues have never directly compared. Further research will be necessary to shed light upon this issue.

were black on a white background.

2.4. Procedure

Participants were seated at the distance of approximately 56 cm in front of a computer monitor, in a dimly lit, sound-attenuated room, and their heads were held steady with a chin/head rest. A trial sequence of the procedure is shown in Figure 1.

Each trial began with a display consisting of a central fixation stimulus that differed depending on the cue types (i.e., the straight looking face or the line respectively for gaze and arrow condition), and was presented for 700 ms. Then the cue was presented as the movement of the eyes randomly to the left or to the right, or the appearance of arrow-heads at one of the sides. Both gaze and arrow cues were not predictive of target location. After 100, 300 or 600 ms, the target appeared for 130ms in the left or in the right visual field (6° from the centre of the screen). The cue display remained until response, or until 1400 ms had elapsed. A blank screen was then presented for 700ms after each trial. Each of the two experimental sessions (one for each cue type) was composed of 25 practice trials followed by an experimental block of 104 trials. Eight catch trials, in which no target was presented, occurred randomly in each experimental session. Cue direction, target location, and cue–target stimulus onset asynchrony (SOA) were randomly selected within each block of trials. The order of blocks with each cue type (gaze/arrow) was counterbalanced across participants.

Participants were instructed to respond to the presentation of the target by pressing either the “C” key (with the left hand) or the “M” key (with the right

hand) on the computer keyboard depending on the target letter that was presented. Half of participants pressed “C” for the letter “X” and “M” for the letter “O”, whereas the other half received the reversed mapping. They were informed that the direction of the central cue did not predict target location, and that they should ignore it, while maintaining central fixation throughout each trial.

[INSERT FIGURE 1 ABOUT HERE]

2.5. *Design*

The experiment had a four-factor repeated measure design. Cue Type had two levels: gaze and arrow. Visual Hemifield (VHF) had two levels: left and right. SOA had three levels: 100, 300, 600 ms. Validity had two levels: valid trials (direction of the cue was congruent with target location) and invalid trials (direction of the cue was incongruent with target location). Planned comparisons were used for the analysis of interactions.

3. Results

Mean response times, standard deviations and error rates are shown in Table 1. RTs faster than 200 ms or slower than 1200 ms (1 % of the trials), as well as incorrect responses (7 % of the trials), were excluded from the RT analysis. The ANOVA showed that the main effect of *Validity* reached significance ($F_{1,47}=16.39$; $p<.001$; partial $\eta^2= 0.26$), with faster responses for valid than invalid trials (494ms vs. 504ms). The effect of *VHF* was significant ($F_{1,47}=7.08$; $p<.01$; partial $\eta^2= 0.13$), showing faster RTs for targets presented in the right visual field than for targets presented in the left visual field (495ms vs. 504ms). The effect of

SOA was also significant ($F_{2,94}=16.89$; $p<.001$; partial $\eta^2= 0.24$), with slower responses at the shortest *SOA* of 150 ms. *Cue type* was not significant ($F<1$). There was also a significant *Validity x Cue type* interaction ($F_{1,47}=9.33$; $p<.004$; partial $\eta^2= 0.17$). RTs were faster on valid trials than on invalid trials when arrows were used as cues ($F_{1,47}=29.17$; $p<.001$; partial $\eta^2= 0.38$), but no significant differences were found between valid and invalid trials when eye-gaze was used ($F_{1,47}=1.46$; $p<.233$; partial $\eta^2= 0.03$). Importantly, this interaction was qualified by the *Validity x Cue Type x VHF* interaction, which was also significant ($F_{1,47}=4.24$; $p=.045$; partial $\eta^2= 0.08$; see figure 2). No other interaction reached significance. Two separate ANOVAs, one for each Cue Type condition, were conducted to examine the *Validity x VHF* interaction in each cue type condition. The analysis for the gaze cue condition revealed significant effects of *VHF* ($F_{1,47}=6.80$; $p=.012$; partial $\eta^2= 0.13$) and *SOA* ($F_{2,94}=10.82$; $p<.001$; partial $\eta^2= 0.30$). Importantly, the critical *Validity x VHF* interaction was also significant ($F_{1,47}=6.50$; $p=.013$; partial $\eta^2= 0.12$). RTs were faster on valid trials than on invalid trials (500ms vs. 513ms; $F_{1,47}=6.58$; $p=.001$; partial $\eta^2= 0.12$) when targets were presented in the left visual field, but no differences were found between valid and invalid trials (Mean=497ms vs. 493ms; $F<1$) when targets were presented in the right visual field. The analysis for the arrow cue condition showed the main effects of both *Validity* ($F_{1,47}=28.18$; $p<.001$; partial $\eta^2= 0.38$) and *SOA* ($F_{2,94}=9.64$; $p<.001$; partial $\eta^2= 0.36$). Of interest, the interaction *Validity x VHF* was not significant ($F<1$): cueing effects were very similar in each visual hemifield (cueing effects: 17 ms vs. 16ms, at the left and the right visual hemifield, respectively), and planned comparisons revealed that they were

significant both in the left ($F_{1,47}=15.13$; $p=.001$; partial $\eta^2= 0.24$) and in the right visual hemifield ($F_{1,47}=15.06$; $p=.001$; partial $\eta^2= 0.24$). Analyses of errors rate showed no significant effects. However, it is important to note that the error data were in the same direction as RT: in the arrow condition, participants made more errors on invalid than on valid trials when targets were presented both in left and in the right visual field; in the gaze condition, participants made more errors on invalid than on valid trials when targets were presented in left visual field; whereas when targets were presented in right visual field participants made more errors on valid than on invalid trials.

[INSERT FIGURE 2 AND TABLE 1 ABOUT HERE]

4. Discussion

The comparison between eye-gaze and arrow cueing effects has been used to evaluate the cognitive mechanisms of social attention (for a review, see Birmingham & Kingstone, 2009). Despite the extensive research on the orienting effects induced by gaze and arrow cues, subtle or no behavioral differences have been observed between the two types of cues. Therefore, the usual findings observed in these behavioral studies seem to run counter the intuition that considers eyes as unique, special social-attention stimuli. However, a different pattern emerges when instead of comparing quantitatively the cueing effects produced by central arrows and gaze-cues, the orienting mechanisms triggered by the two types of cues are dissociated in terms of qualitative differences. In other words, since both types of cue provide directional information (we have a lot of experience with them either due to their biological or social meaning, or to

extensive practice), a fast and strong cueing effect has been generally observed with both arrows and gaze. However, there are differences in how (instead of whether or not, in which extent) attention is oriented in the direction indicated by the cue as a function of the type of cue. In a recent study we have found that qualitatively distinct modes of attentional selection are triggered by eye-gaze and arrow cues (Marotta, Lupiañez, Martella & Casagrande, 2012). In particular, we presented a display with two rectangular objects one of which was cued at one end or another by central non-informative directional arrows or eye gaze cues; targets followed in one of four critical conditions: at the cued direction (and object) indicated by the cue (same-location/same-object trials), in the opposite object and direction to which the cue was directed (opposite-location/opposite-object trials); at uncued location of the same object (same-object trials) or at uncued location in the other object (different-object trials). We found that arrow cues induced object-based selection (i.e., a same-object advantage: RTs were faster on same-object trials than on different-object trials), whereas eye-gaze cues induced space-based selection (i.e., no same-object advantage). Moreover, a series of studies by Kingstone and his colleagues with a split brain patient found that reflexive orienting to eye gaze was lateralized to the right hemisphere (Kingstone, Friesen, & Gazzaniga, 2000), while no such cortical lateralization was found in response to an arrow cue (Ristic et al., 2002).

Using this piece of evidence as the basis for qualitative differences between arrows and gaze as orienting cues, the results of the present study converge with, and support the hypothesis that the mechanisms triggering attentional orienting are different when arrows and gaze cues are used. In healthy participants reflexive

orienting to centrally presented gaze cues was only observed when the target was presented in the left visual field, whereas reflexive orienting to arrow cues occurred for targets presented in both left and right visual fields. This evidence is consistent with the findings from a recent study in which similar hemispheric differences were observed with peripherally presented (in the left or the right visual field) gaze and arrow cues (Green & Zaidel, 2011). Our findings complement those reported by Green and Zaidel (2011) in showing that it is not only the processing of the stimuli that is lateralized, but the actual shift of attention. As both types of cues were centrally presented, both hemispheres processed the cue information, but only one was recruited for the shifts of attention. On other hand, the study by Green and Zaidel (2011) complements our findings in showing that, in the gaze cueing paradigm, what is lateralized to the right hemisphere is not the shift of attention to the left, but the shift of attention within the left hemifield regardless of its direction (right, left, up or down). In fact, in Green and Zaidel's study, the gaze cue was directed up or down and the same lateralization to the right hemisphere was observed.

Therefore, taken together, our findings and those of Green and Zaidel (2010) strongly suggest that although both eye gaze and arrows trigger reflexive orienting, the neural mechanisms engaged in these two tasks are differently lateralized in the brain.

Neuropsychological research has provided abundant evidence for the right hemisphere dominance in spatial orienting of attention. Particularly, hemispatial neglect, a syndrome of one-sided inattention, is a relatively common consequence of right hemisphere lesions (Danckert & Ferber, 2006; Saevarsson, Kristjánsson &

Hjaltason, 2009). In normal participants, imaging data also demonstrate a greater role of the right hemisphere in distribution of attention within the left and right visual hemifields (Corbetta, Miezin, Shulman, & Petersen, 1993; Shulman, Pope, Astafiev, McAvoy, Snyder, & Corbetta, 2010). However, behavioral data in normal participants do not yield a consistent pattern of asymmetries in attentional orienting. While some studies suggest the right hemisphere dominance, showing better left visual field performance (Casagrande, Martella, Di Pace, Pirri, Guadalupi, 2006; Du & Abrams, 2010; Evert, McGlinchey-Berroth, Verfaellie, & Milberg, 2003), others shows no asymmetry (Greene et al., 2008, exp.1; Wainwright & Bryson, 2005), or even a right visual field advantage (Nobre, Sebestyen, & Miniussi, 2000; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990; Rhodes & Robertson, 2002). It seems that at least some of these discrepancies might be explained by the neuroanatomical model proposed by Corbetta, Patel, and Shulman (2008), according to which the bilateral dorsal frontoparietal network controls both voluntary and automatic orienting, while the right-lateralized ventral frontoparietal network subserves reorienting to behaviorally relevant stimuli. Thus, the results of the present experiment might suggest that orienting to eye-gaze cues depend on the right lateralized network, because the gaze represents a behaviorally relevant stimulus.

In the present study we used a short enough target duration (130 ms), suitable to investigate lateralization effects. Eye movement latencies are approximately 200 ms and take approximately 40 ms to complete (Rayner, 1998). Nevertheless, a potential concern may be that there was some delay between the cue and the target. The cues may have triggered saccades in the cued direction, making the

target presentation not lateralized any more. However, it is unlikely that the cue-target delay modulated the pattern of result, as no interaction with SOA was significant in the omnibus analysis ($F < 1$). In addition, we conducted an ANOVA limited to the shortest 150 ms SOA and this analysis revealed again a significant interaction Validity x VHF x Type of Cue ($F_{1,47}=3.96$; $p = .05$), showing a right hemisphere dominance for gaze cueing but not for arrow cueing. It seems therefore more likely that the origin of the present results resides in the existence of a separate system for socially cued orienting of attention.

Ristic et al. (2002) hypothesized that orienting to eyes may activate the right hemisphere STS, according to previous studies suggesting that this region may be specialized for processing gaze information. However, while Sato et al. (2009) have found right lateralized activity in the STS, other studies have found bilateral activity in attention network, including frontoparietal regions and/or extrastriate cortices (Greene et al., 2009; Hietanen et al., 2006; Tipper et al., 2008). As speculated by Green & Zaidel (2011) attentional orienting in response to gaze cues may therefore rely on the interaction between the right STS and these bilateral structures. Future studies will hopefully shed light on this issue.

References

Akiyama, T., Kato, M., Muramatsu, T., Saito, F., Umeda, S., Kashima, H. (2006). Gaze but not arrows: A dissociative impairment after right superior temporal gyrus damage. *Neuropsychologia*, 44, 1804–1810.

Baron-Cohen, S. (1994). How to build a baby that can read minds: Cognitive mechanisms in mindreading. *Current Psychology of Cognition*, 13,

513-552.

Bayliss AP, di Pellegrino G, Tipper SP (2005). Sex differences in eye gaze and symbolic cueing of attention. *The Quarterly journal of experimental psychology. A, Human experimental psychology* 58, 631-650.

Birmingham, E., Kingstone, A. (2009). Human Social Attention: A New Look at Past, Present and Future Investigations. *The Year in Cognitive Neuroscience 2009: Ann. N.Y. Acad. Sci.* 1156:118–140.

Brignani, D., Guzzon, D., Marzi, C. A., Miniussi, C. (2009). Attentional orienting induced by arrows and eye gaze compared with an endogenous cue. *Neuropsychologia*, 47(2), 370-381.

Casagrande, M., Martella, D., Di Pace, E., Pirri, F., Guadalupi, F. (2006). Orienting and alerting: effects of 24 hours of prolonged wakefulness. *Experimental Brain Researc.*, 171(2), 184-193

Corbetta, M., Miezin, F. M., Shulman, G. L., & Petersen, S. E. (1993). A PET study of visuospatial attention. *Journal of Neuroscience*, 13(3), 1202–1226.

Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: From environment to theory of mind. *Neuron*, 58(3), 306–324.

Danckert, J., & Ferber, S. (2006). Revisiting unilateral neglect. *Neuropsychologia*, 44(6), 987–1006.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual*

Cognition, 6(5), 509-540.

Du, F., & Abrams, R. A. (2010). Visual field asymmetry in attentional capture. *Brain and Cognition*, 72(2), 310–316.

Emery, N.J. (2000). The eyes have it: the neuroethnology, function and evolution of social gaze. *Neuroscience and Biobehavioural Reviews*, 24, 581-604.

Engell, A. D., Nummenmaa, L., Oosterhof, N. N., Henson, R. N., Haxby, J. V., & Calder, A. J. (2010). Differential activation of frontoparietal attention networks by social and symbolic spatial cues. *Social Cognitive & Affective Neuroscience*, 5(4), 432-40

Evert, D. L., McGlinchey-Berroth, R., Verfaellie, M., & Milberg, W. P. (2003). Hemispheric asymmetries for selective attention apparent only with increased task demands in healthy participants. *Brain and Cognition*, 53(1), 34–41.

Friesen, C.K., Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, 5(3), 490-495.

Friesen, C.K., Kingstone, A. (2003). Covert and overt orienting to gaze direction cues and the effects of fixation offset. *Neuroreport*, 14(3), 489-93.

Friesen, C.K., Ristic, J., Kingstone, A. (2004). Attentional effects of counterpredictive gaze and arrow cues. *Journal of Experimental Psychology: Human Perception & Performance*, 30(2), 319-329.

Frischen, A., Bayliss, A.P., Tipper, S.P. (2007). Gaze cueing of attention: visual attention, social cognition and individual differences. *Psychological*

Bulletin, 133(4), 694–724.

Greene, D. J., Barnea, A., Herzberg, K., Rassis, A., Neta, M., Raz, A., et al. (2008). Measuring attention in the hemispheres: The lateralized attention network test (LANT). *Brain and Cognition*, 66(1), 21–31.

Greene, D. J., Mooshagian, E., Kaplan, J. T., Zaidel, E., Iacoboni, M. (2009). The neural correlates of social attention: Automatic orienting to social and nonsocial cues. *Psychological Research*, 73(4), 499–511.

Greene, D.J., Zaidel, E. (2011). Hemispheric differences in attentional orienting by social cues. *Neuropsychologia*, 49, 61-68

Guzzon, D., Brignani, D., Miniussi, C., Marzi, C.A. (2010). Orienting of attention with eye and arrow cues and the effect of overtraining. *Acta psychologica*, 134(3), 353-62.

Hietanen, J.K., Leppanen, J.M. (2003). Does facial expression affect attention orienting by gaze direction cues? *Journal of Experimental Psychology: Human Perception & Performance*, 29, 1228–1243.

Hietanen, J. K., Nummenmaa, L., Nyman, M. J., Parkkola, R., Hamalainen, H. (2006). Automatic attention orienting by social and symbolic cues activates different neural networks: An fMRI study. *Neuroimage*, 33(1), 406–413.

Hommel, B., Pratt, J., Colzato, L., Godijn, R. (2001). Symbolic control of visual attention. *Psychological Science*, 12(5), 360-365.

Kanwisher, N., Downing, P., Epstein, R., Kourtzi, Z. (2001). Functional Neuroimaging of Human Visual Recognition. In *The Handbook on Functional Neuroimaging*. Edited by R. Cabeza & A. Kingstone. MIT Press 109-152.

Kingstone, A., Friesen, C.K., Gazzaniga, M.S. (2000). Reflexive joint attention depends on lateralized cortical connections. *Psychological Science, 11*, 159–166.

Kingstone, A., Tipper, C., Ristic, J., Ngan, E. (2004). The eyes have it!: an fMRI investigation. *Brain and Cognition, 55*(2), 269-71.

Kuhn, G. & Benson, V. (2007). The influence of eyegaze and arrow pointing distractor cues on voluntary eye movements. *Perception and Psychophysics, 69*(6), 966–971.

Kuhn, G., Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. *Perception and Psychophysics, 71*, 314-327.

Langton, S.R.H., Bruce, V. (1999). Reflexive social orienting. *Visual Cognition, 6*, 541-567.

Marotta, A., Lupiáñez, J., Martella, D., Casagrande, M. (2011). Eye gaze versus arrows as spatial cues: two qualitatively different modes of attentional selection. *Journal of Experimental Psychology: Human Perception & Performance 38*(2), 326-335..

Nobre, A. C., Sebestyen, G. N., & Miniussi, C. (2000). The dynamics of shifting visuospatial attention revealed by event-related potentials. *Neuropsychologia, 38*(7), 964–974.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32A*, 3-25.

Rayner, K. (1998). Eye movements in reading and information processing—20 years of research. *Psychological Bulletin, 124*, 372-422.

Reuter-Lorenz, P. A., Kinsbourne, M., & Moscovitch, M. (1990). Hemispheric control of spatial attention. *Brain and Cognition*, 12, 240–266.

Rhodes, D. L., & Robertson, L. C. (2002). Visual field asymmetries and allocation of attention in visual scenes. *Brain and Cognition*, 50(1), 95–115.

Ristic, J., Friesen, C.K., Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review*, 9(3), 507-513.

Saevarsson, S., Kristjánsson, Á., & Hjaltason, S. (2009). Unilateral neglect: A review of causes, anatomical localization, theories, and interventions. *Icelandic Medical Journal*, 95, 27-33.

Salmaso, D., Longoni, A.M. (1985). Problems in the assessment of hand preference. *Cortex*, 21, 533-549.

Sato, W., Kochiyama, T., Uono, S., Yoshikawa, S. (2009). Commonalities in the neural mechanisms underlying automatic attentional shifts by gaze, gestures, and symbols. *Neuroimage*, 45(3), 984–992.

Senju, A., Tojo, Y., Dairoku, H., et al. (2004). Reflexive orienting in response to eye gaze and an arrow in children with and without autism. *Journal of Child Psychology and Psychiatry*, 45(3), 445–458.

Shulman GL, Pope DL, Astafiev SV, McAvoy MP, Snyder AZ, Corbetta M (2010). Right hemisphere dominance during spatial attention and target detection occurs outside the dorsal frontoparietal network. *Journal of Neuroscience*. 30(10): 3640-51.

Tipper, C. M., Handy, T. C., Giesbrecht, B., & Kingstone, A. F. (2008). Brain responses to biological relevance. *Journal of Cognitive Neuroscience*,

20(5), 879–891.

Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic Bulletin & Review*, 9(2), 314-318.

Tipples, J. (2008). Orienting to counterpredictive gaze and arrow cues. *Perception and Psychophysics*, 70, 77-87.

Vecera, S. P., & Rizzo, M. (2004). What are you looking at? Impaired 'social attention' following frontal-lobe damage. *Neuropsychologia*, 42(12), 1657–1665.

Vecera, S. P., & Rizzo, M. (2006). Eye gaze does not produce reflexive shifts of attention: Evidence from frontal-lobe damage. *Neuropsychologia*, 44(1), 150–159.

Wainwright, A., & Bryson, S. E. (2005). The development of endogenous orienting: Control over the scope of attention and lateral asymmetries. *Developmental Neuropsychology*, 27(2), 237–255.

Table 1. Mean Reaction Times, Standard Deviations and Percentage of Errors as a Function of Type of Cue, Visual Hemifield, SOA and Validity.

SOA and VALIDITY		GAZE CUE						ARROW CUE					
		LVH			RVH			LVH			RVH		
		M	SD	%E	M	SD	%E	M	SD	%E	M	SD	%E
150ms	Valid	507.88	91.38	4.19	516.81	88.78	11.29	510.71	93.46	5.38	502.04	101.22	5.72
	Invalid	524.38	98.38	8.66	506.28	89.02	4.70	517.47	91.72	6.61	512.79	93.73	6.06
300ms	Valid	497.53	83.25	7.15	481.55	94.65	6.82	478.83	87	4.95	473.92	88.30	4.25
	Invalid	506.42	99.47	5.53	486.61	89.81	7.85	499.31	83.44	7.36	498.64	83.76	7.27
600ms	Valid	486.01	93.25	7.53	493.06	97.63	5.74	487.35	98.43	4.97	482.92	90.99	8.00
	Invalid	508.09	95.68	8.13	486.27	92.57	6.49	511.69	103.70	4.91	495.57	102.86	7.96

LVH: Left Hemifield; RVH: Right Hemifield; M: Mean; SD: Stand Deviation; %E: Percentage of Errors

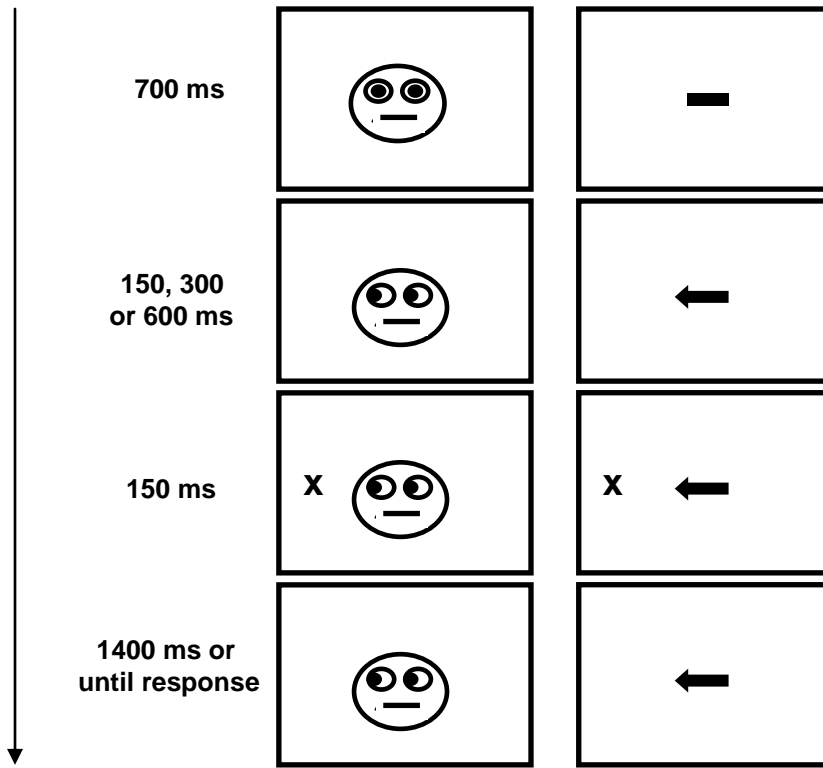


Figure 1. Schematic view of a trial sequence, from top to bottom for either the gaze cue and the arrow cue conditions. The example represents a valid trial.

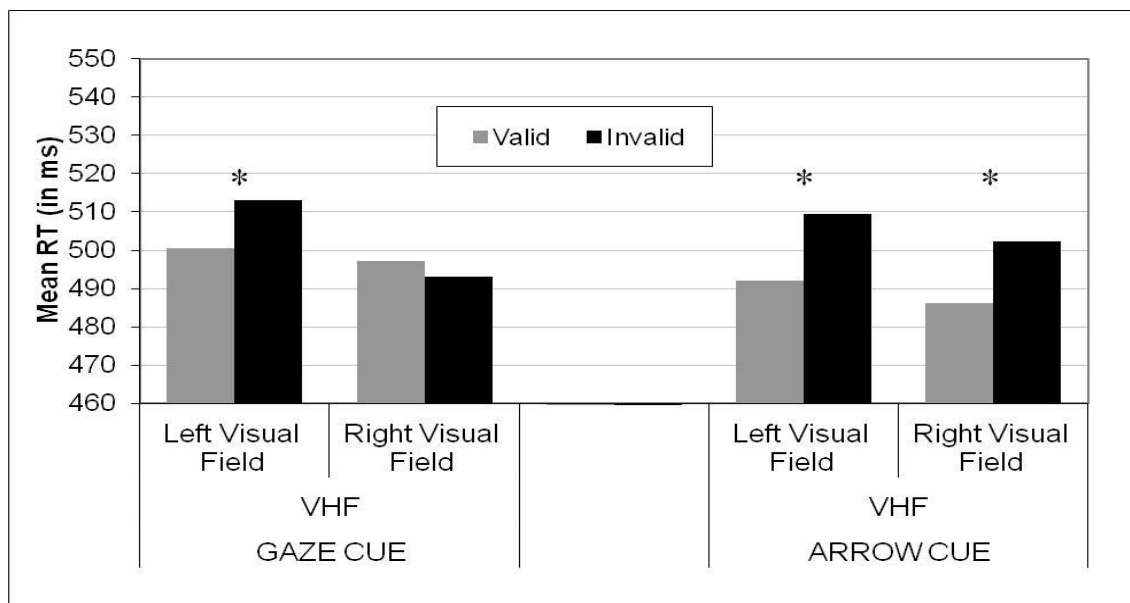


Figure 2. Mean reaction times (RTs) for valid and invalid conditions as a function of Cue type and VHF. The asterisks indicate significant effects ($p < .05$)