

Human Social Attention

A New Look at Past, Present, and Future Investigations

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The present review examines the neural-behavioral correlates of human social attention, with special regard to the neural mechanisms involved in processing gaze information and the functional impact of gaze direction on the spatial orienting of attention. Our review suggests that there is strong evidence that specific brain systems are preferentially biased toward processing gaze information, yet this specificity is not mirrored by the behavioral data as measured in highly controlled model attention tasks such as the Posner cueing paradigm. In less controlled tasks, however, such as when observers are left free to select what they want to attend, they focus on people and their eyes, consistent with one's intuition and with the neural evidence that eyes are special. We discuss a range of implications of these data, including that much is to be gained by examining brain and behavioral processes to social stimuli as they occur in complex real-world settings.

Key words: social attention; gaze perception; attentional selection; eye movements; cueing paradigm; scene perception

Introduction

Imagine the following scenario. You are walking down a busy city street and you notice that there is a woman who has stopped walking and is gazing upward. Using her gaze direction, you move your eyes to see what she is looking at. As this simple example illustrates, folk knowledge suggests that we are very interested in where other people are directing their attention, and that we use their eyes to infer where, and to what, they are attending. The intuition that we care about the attentional states of others has led to the birth of research in *social attention*.

While there are several cues to the direction of another person's attention (gaze direction, head position, body position, point-

ing gestures), the above description suggests that gaze direction has a special status as an attentional cue (Emery 2000; Langton, Watt, & Bruce 2000). Morphologically, the human eye is uniquely equipped to promote fast discrimination of gaze direction, having a much higher dark-iris-to-white-sclera contrast compared with all nonhuman primate eyes (Kobayashi & Koshima 1997). Perhaps though, what makes gaze so special is that in addition to typically providing an excellent indication of someone's direction of attention, it can be used to infer a wealth of other social information that we use on an everyday basis. For instance, gaze is used to modulate social interactions, by facilitating conversation turn-taking, exerting social dominance, or signaling social defeat or appeasement (Argyle & Cook 1976; Dovidio & Ellyson 1982; Ellsworth 1975; Exline 1971; Exline, Ellyson & Long 1975; Kendon 1967; Kleinke 1986; Lochman & Allen 1981). Thus, intuition and empirical evidence suggest that

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the eyes are extremely important and possibly unique social-communicative stimuli. Indeed, eye gaze is thought to be so important that it has been placed as the primary social attention cue in prominent models of social attention (Baron-Cohen 1995; Perrett, Hietanen, Oram, et al. 1992).

Given the special status held by eye gaze as a social attention cue, one might predict both that (1) the human brain has a neural system that is preferentially biased for the processing of gaze direction, and (2) humans are predisposed to use eye gaze to attend to where others are looking. Both proposals are considered in turn. We begin by reviewing the evidence that a neural system biased toward the processing of gaze direction exists. We suggest that while there is considerable support for the existence of such a neural system, it is also clear that context influences how the system is engaged. We then turn to discuss the data suggesting that humans readily use eye gaze to determine where others are directing their attention. We note that while there is good evidence derived from naturalistic gaze following and lab-based attention-cueing studies (e.g., Posner 1980) that people automatically shift their attention to where other people are looking (e.g., Friesen & Kingstone 1998), the lab-based evidence using the cueing paradigm indicates that people also shift their attention automatically in response to a number of other directional cues, most notably arrows (Eimer 1997; Ristic, Friesen, & Kingstone 2002; Tipples 2002). A number of recent studies have been dedicated to determining whether the effects of gaze cueing are truly different from the effects of arrow cueing, and whether gaze and arrow cueing arise from the same underlying neural system. We propose that while some differences do occasionally emerge between gaze and arrow cueing, their general convergence suggests that the cueing paradigm may be failing to capture many key aspects of eyes that distinguish them from other stimuli, like arrows. In other words, the general intuition that eyes are very special is correct, but the cueing paradigm measures eyes and arrows on

a dimension in which they share a great deal of similarity—their ability to communicate directional information (Gibson & Kingstone 2006). The implication is that researchers may benefit by considering alternative approaches for studying the uniqueness of eyes relative to other stimuli.

In our final section we present a new approach that emphasizes the selection of gaze information rather than the orienting of attention to where gaze is directed. To return to our initial example of a woman gazing upward, our final section examines the selection of the woman's gaze rather than subsequent orienting of attention to where she is looking. When gaze information is examined in the lab in this way, the evidence indicates that people have a fundamental interest in eye information that far exceeds other information in the environment, including arrows. These data dovetail with the evidence that attentional selection is being driven by neural systems that give weight to the unique social information provided the eyes, and hence they suggest fruitful direction for future investigations.

Section 1. An Expert Gaze-Processing System

One line of evidence that converges with the notion that eye gaze is a special social attention cue stems from research indicating that humans are especially accurate at discriminating different directions of eye gaze. Early studies reported that people are particularly adept at detecting when another person is looking directly at them (Cline 1967; Gibson & Pick 1963; Lord & Haith 1974). More recent research has demonstrated a remarkably high visual acuity for judging averted gaze as well (e.g., 30 sec of arc; Symons, Lee, Cedrone, et al. 2004). Consistent with the notion that these judgments of gaze direction reflect an expert system, investigations have revealed that when the contrast polarity between a white sclera and dark iris is reversed, the direction of the perceived gaze



Figure 1. Example of how perception of gaze direction is strongly influenced by the dark and light elements of the eye. When contrast polarity is reversed (right), observers incorrectly report that the eyes are looking to the left.

may reverse as well (see Figure 1), suggesting that gaze direction involves a specialized system that perceives the dark part of the eye as that which does the looking (e.g., Ricciardelli, Baylis & Driver 2000; Sinha 2000). This stands in contrast to previous accounts (Anstis, Mayhew & Morley 1969) that have emphasized the importance of geometric properties of the eye for determining gaze direction (i.e., the position of the circular iris relative to the surrounding sclera). More recent work suggests that contrast and geometric information work together in the computation of gaze direction (Olk, Symons & Kingstone 2008).

Considerable research has been conducted on the neural mechanisms that are critical to processing gaze information, with much of this research suggesting that a key role is played by a region of cortex called the superior temporal sulcus (STS). It seems that one of the many functions of the STS, including biological motion processing, audiovisual integration, and face processing (see Allison, Puce & McCarthy 2000; Hein & Knight 2008, for reviews), is to process gaze direction. Single-cell studies with macaque monkeys have found populations of cells in the anterior STS that are selective for specific gaze directions (Perrett et al. 1985). Neuropsychological and lesion studies have found evidence for deficits in judging gaze direction associated with damage to the STS

(e.g., Akiyama et al. 2006; Heywood, Cowey & Rolls 1992). Some neuroimaging studies of human posterior STS activity have also found stronger activation for faces with averted gaze than for faces with direct gaze (e.g., Hoffman & Haxby 2000), although in some cases the opposite effect was found (e.g., Pelphrey, Viola & McCarthy 2004) or no significant difference between direct and averted gaze was found at all (e.g., Calder et al. 2002; George, Driver & Dolan 2001; Wicker, Michel, Henaff, et al. 1998). Most recently, researchers have looked at neural adaptation to demonstrate the presence of neurons in anterior STS that are finely tuned for processing left and right gaze directions (Calder et al. 2007).

While more extensive reviews of the neural mechanisms of gaze processing have been provided elsewhere (Allison et al. 2000; Emery 2000; Frischen, Bayliss & Tipper 2007; Grosbras, Laird & Paus 2005; Jellema, Baker, Wicker, et al. 2000), we will provide a brief review of this literature pertaining to what brain mechanisms may be subserving gaze processing, with special emphasis on the STS. These data are drawn from studies ranging from single-cell investigations with monkeys to human neuropsychological, lesion, and neuroimaging research. It is important to note that while we focus on the STS it would be a gross oversimplification to conclude that the STS is the only critical region to gaze processing. On the contrary, the evidence suggests that other brain regions are also intimately involved in computing gaze direction, including areas of the amygdala (e.g., Kawashima et al. 1999), fusiform gyrus (e.g., George et al. 2001), parietal cortex (e.g., Hoffman & Haxby 2000), and medial prefrontal cortex (e.g., Calder et al. 2002). We then turn to the role that context plays in how the gaze-processing system is engaged.

Single-Cell Studies with Monkeys

One of the earliest studies of selectivity for gaze direction was conducted by Perrett

et al. (1985). These researchers took single-cell recordings in the anterior STS while macaque monkeys viewed faces that varied on head direction in both the horizontal and vertical plane. Full and half-profile faces also varied on gaze direction, with gaze directed either at the monkey or averted to the side. The authors found selectivity both for head and for gaze direction; however, the selectivity for gaze was in some cases totally independent of selectivity for head orientation. In addition, some cells fired just as strongly to their preferred gaze direction when the eyes were presented alone as when they were presented in the context of a face. Perrett et al. also found selectivity for *conjunctions* of gaze and head directions. For instance, one group of cells fired maximally when gaze direction was congruent with head direction (e.g., full face with direct eye contact). For these cells, any deviations in head direction or gaze direction led to a reduction in firing rate.

Importantly, Perrett et al. (1985) found evidence that gaze direction information overrides head direction information. For example, a cell that was tuned to fire maximally when both head and gaze were pointed downward also fired strongly when gaze pointed downward but the head was at the full-face position. Thus, in this case, the cell responded strongly to the downward gaze cue and was not dampened by the nonpreferred full-face view. The authors concluded that this special selectivity for gaze direction in the STS reflects the importance of gaze information for determining the social attention of others (Perrett et al. 1992).

Neuropsychological and Lesion Studies

The notion of an expert gaze-processing system involving the STS has also received support from lesion studies with monkeys and humans. For instance, Campbell, Heywood, Cowey, et al. (1990) removed the banks and floor of the STS in macaque monkeys after training them to discriminate the gaze direction of photographed human faces. There was a significant drop in gaze discrimination perfor-

mance after STS ablation. Similarly, Heywood et al. (1992) removed face-sensitive cells in macaque STS and found that discrimination of gaze direction was impaired relative to before surgery, whereas performance on other face-processing tasks was unaffected (e.g., face matching and face identification).

In humans, Akiyama et al. (2006) reported that a patient with damage to the right superior temporal gyrus showed impaired gaze discrimination that was manifested as a rightward bias (a tendency to report left gaze as direct and direct gaze as right). Analogously, Pourtois et al. (2004) used transcranial magnetic stimulation (TMS) to show that temporary disruption to the posterior STS in healthy subjects slowed (but did not reduce the accuracy of) the discrimination of direct and averted gaze, relative to when TMS was applied to somatosensory cortex.

Gaze discrimination deficits have also been reported in human patients with prosopagnosia. Prosopagnosia is a condition in which brain damage to ventral temporal cortex is associated with deficits in recognizing familiar faces while being unimpaired on other visually demanding tasks (Damasio, Damasio & Van Hoesen 1982; Farah 1996; Sergent & Signoret 1992). Patients with prosopagnosia, for example, have been found to be accurate at recognizing different facial expressions, while at the same time being unable to recognize the identity of a face (Bruyer et al. 1983; Kurucz & Feldmar 1979). Some studies have also reported striking impairments for these patients in discriminating gaze direction (Campbell et al. 1990; Heywood et al. 1992; Perrett et al. 1988). Importantly, evidence from patient studies points to the possibility of a dissociation between gaze discrimination and other face-processing tasks. For example, while some patients are impaired at gaze discrimination and face recognition (Heywood et al. 1992), others are impaired at face recognition but show normal gaze discrimination performance (e.g., Campbell et al. 1990). This complements the STS ablation studies showing the

converse effect, with monkeys showing impairments in gaze discrimination but spared ability to recognize faces. Taken together, these results suggest a neural basis for the distinct representation of gaze processing and face recognition.

Neuroimaging Studies with Humans

Additional and converging evidence for an expert gaze-processing system comes from brain imaging investigations of human participants. In a now classic fMRI study by Hoffman and Haxby (2000), observers were given a repetition detection task in which a series of static faces were shown, one-by-one, and the task was to indicate whether the current face matched the previously presented face. When observers were asked to look for repetitions in face identity, there was more activity in the inferior occipital gyri (IOG) and lateral fusiform gyri (LFG); when they were asked to look for repetitions in gaze direction, there was more activity in the posterior STS of the left hemisphere. In a second experiment, the left STS and bilateral intraparietal sulcus (IPS) were activated more strongly when observers passively viewed faces with averted gaze relative to faces with direct gaze. In contrast, viewing averted gaze had no effect on activity in the IOG or LFG. These results suggest that eye-gaze direction has distinct representations involving the STS.

Recent work by Calder et al. (2007) suggests that anterior STS, in particular, is involved in the separate coding of different gaze directions. Using fMRI adaptation, Calder et al. (2007) adapted participants to a particular gaze direction by presenting a series of photographed faces all with the same direction of gaze. Subjects were then asked to judge the gaze direction of a series of test faces with variable gaze positions. The results showed both behavioral and neural evidence of adaptation. Behaviorally, subjects often judged an averted gaze as direct after being adapted to that averted gaze direction. At the neural level, adapting to leftward gaze led to a reduction in blood oxy-

genation level-dependent (BOLD) response in the anterior STS for left gaze probes relative to right and direct gaze probes; the converse effect occurred after rightward gaze adaptation. Importantly, this adaptation effect was not due to low-level visual processes because it occurred across a variety of different face identities, sizes, and orientations. These findings support the notion of distinct neural populations in anterior STS that are tuned to different directions of gaze.

Is it possible that the STS is involved in processing any directional cue, and not gaze per se? Hooker et al. (2003) addressed this question by measuring STS activity in response to a “growing” arrow as the directional stimulus. Subjects were asked to determine whether the directional stimulus was pointing at a peripheral target. Other conditions included a face with changing gaze directions, a face superimposed with an arrow, and a face with meaningless, nondirectional eye movements. The results showed that the right STS was most responsive for the face with directional gaze information, suggesting that the STS is especially selective for meaningful gaze direction. However, since the authors only reported the activations in the directional gaze condition once the control activations were subtracted away (e.g., directional gaze minus arrow), it is possible that STS was activated for the control conditions, albeit to a lesser extent. For instance, a later study by Tipper, Handy, Giesbrecht, et al. (2008) found that the superior temporal gyrus (an area of cortex close to the STS and often included in the “STS region”; Allison et al. 2000) was equally activated for gaze and arrow cues.

Other Brain Regions Involved in Gaze Perception

Although studies of gaze perception have focused primarily on the STS and nearby cortex, the results indicate that a much wider network is involved. For instance, a handful of neuroimaging studies have implicated the amygdala in processing direct gaze. In a positron emission

tomography (PET) experiment, Kawashima et al. (1999) found that while the left amygdala responded equally to direct- and averted-gaze faces, the right amygdala was activated only by direct-gaze faces. This selectivity of the right amygdala for direct gaze is consistent with the notion that the amygdala is involved in processing social signals from the face. Interestingly, no STS activation was found in either task relative to the control condition.

Somewhat contradictory evidence for the amygdala's selectivity for direct gaze comes from Hooker et al. (2003). In their Experiment 2, Hooker et al. showed a series of faces and asked subjects to detect when the eyes of the face were looking directly at them. In one block, all faces had averted gaze; in another block, 60% of faces had averted gaze and 40% had direct gaze. Interestingly, the authors found stronger amygdala activation when all the faces had averted gaze than when only 60% of faces had averted gaze. The authors interpreted this effect as indicating that the amygdala is involved in monitoring for direct gaze, and that the heightened amygdala activation reflects the anticipation of socially salient information, and not the actual stimulation from direct gaze. However, their results might also be easily interpreted as indicating the importance of the amygdala for processing averted gaze and not direct gaze.

The amygdala's role in gaze perception is also supported by evidence that the ability to judge gaze direction is impaired after damage to the amygdala (although see Broks et al. 1998 for conflicting evidence). Young et al. (1995) tested a patient after a partial bilateral amygdalotomy and found severe impairments in processing the emotional expression of faces, as well as deficits in judging gaze direction. At the same time, the patient was able to match faces with respect to identity. Finally, there is accruing evidence that the amygdala is normally involved in orienting attention to other people's eyes, as bilateral amygdala damage leads to drastically reduced fixations to the eye region of a face (Adolphs et al. 2005). It is possible that

this deficit in selecting eyes is fundamental to, and possibly underlies, the gaze discrimination impairments seen in amygdala patients. This is complemented by evidence that increased activation of the amygdala is correlated with fixations to the eyes for individuals with autism (Dalton et al. 2005).

Yet other studies have implicated the fusiform gyrus, an area known to be responsive to face stimuli, in processing gaze direction. George et al. (2001) found increased fusiform gyrus activation in response to faces with direct gaze compared to faces with averted gaze, regardless of head orientation (frontal or deviated). These authors interpreted the increased fusiform activation as reflecting enhanced attention and deeper encoding of faces with direct gaze.

George et al. (2001) also found stronger correlation between fusiform and amygdala activity for faces with direct gaze relative to averted gaze and a stronger correlation between fusiform and intraparietal sulcus (IPS) activity for faces with averted gaze relative to direct gaze. The IPS is a brain area linked to shifts in covert spatial attention (e.g., Corbetta, Shulman, Miezin, et al. 1995; Corbetta 1998; Nobre et al. 1997). These results are consistent with the idea that the amygdala is involved in processing socially engaging stimuli such as direct gaze and the possibility that IPS is involved in shifts in spatial attention associated with averted gaze. Interestingly, the STS was not differentially activated by direct and averted gaze in George et al. study. Providing further support for the involvement of IPS in gaze perception, Hoffman and Haxby (2000) found that relative to attending to identity, attending to gaze was associated with stronger activity in the left IPS. This latter result suggested that observers were processing the directional content of the gaze stimuli, and may have shifted their attention in line with this directional information. However, no behavioral measures of shifts of attention were actually collected by Hoffman and Haxby (2000), and so this role for IPS is fairly speculative.

Finally, it is noteworthy that there is accruing evidence that the medial prefrontal cortex (MPFC), which has been implicated in theory of mind (ToM) tasks (i.e., attributing mental states to others), is recruited during gaze processing. Calder et al. (2002) found that the MPFC was particularly activated for faces with averted gaze, suggesting that there may be a tendency to attribute intentions to a face with averted gaze (e.g., “why is that person looking away from me?”). Furthermore, the MPFC is anatomically linked to posterior STS, which has also been found to be activated during ToM tasks (Gallagher & Frith 2003).

Conflicting Findings: Context Matters

Our brief survey indicates considerable evidence supporting the existence of a functional network preferentially biased toward processing gaze information, with the STS region playing a critical role in this network. However, not all of the research data agrees with this position. For instance, some neuroimaging studies have found no evidence for selectivity within the STS for different gaze directions. Wicker and collaborators (1998) used PET imaging to determine what brain regions were activated by faces with direct or averted gaze as compared to downward gaze (the “no-gaze” condition). While all three gaze conditions activated areas known to be involved in face processing, and both the averted and direct gaze conditions activated areas adjacent to the posterior STS relative to the no-gaze condition, no differences were found between the averted and direct gaze conditions. This is consistent with other studies finding no STS selectivity for different gaze directions (e.g., Kawashima et al. 1999; George et al. 2001).

Furthermore, and in contrast to Hoffman and Haxby’s (2000) finding of greater STS activation for averted than direct gaze, Pelphrey et al. (2004) found the opposite effect, that is, greater STS activation for direct than averted gaze. The authors noted that in Hoffman and

Haxby’s study (as well as in studies showing no STS activation difference between direct and averted gaze such as Calder et al. 2002; George et al. 2001; and Wicker et al. 1998), faces and gaze were static and were presented within a highly artificial context. Thus, it is possible that these studies do not “scale up” to real-world situations in which gaze is dynamic, and in which natural social situations afford special meaning to mutual (direct) gaze. To address this issue, Pelphrey et al. (2004) created virtual-reality simulations of a man walking toward the subject in a hallway and then shifting his gaze from a neutral position either toward (mutual gaze) or away from (averted gaze) the subject. Subjects were simply asked to indicate whether the person was looking toward or away from them. The fMRI data revealed stronger STS activation for mutual gaze than for averted gaze. In contrast, activity in the fusiform gyrus was strong but unaffected by gaze direction. These results suggest that the STS is involved in the analysis of social information conveyed by gaze direction, with mutual gaze eliciting a stronger response from the STS because of its potential for meaningful social communication.

Note that whether mutual gaze is “more meaningful” than averted gaze, and leads to stronger STS activation, may be highly situation-specific. A person walking down an empty hallway toward you has the potential for a social interaction vis-à-vis mutual gaze, and thus mutual gaze may be more meaningful than averted gaze. However, if your task is to look for an object in your environment, then a shift in the direction of someone’s gaze away from you may be more meaningful. This idea is supported by a study showing that the context in which gaze is placed influences STS activity (Pelphrey, Singerman, Allison, et al. 2003). Pelphrey et al. manipulated whether averted gaze correctly acquired a target that had appeared in the visual field. Similar to previous studies, the STS was more strongly activated by shifts of gaze than by no gaze shift. However, the authors found a strong effect of context:

the gaze-evoked response in STS was significantly delayed when the eyes failed to look toward the target. This result illustrates that situational context influences the meaning of gaze information, which in turn is reflected in STS activity.

In general, these contextual effects provide support for the role of the STS in gaze processing, and suggest that the brain processes gaze in a flexible way that changes with the social situation. However, given the influence of situational meaning on how the STS is engaged in gaze processing, it is possible that the results from studies using simple images of faces removed from their natural social context will not generalize to the real world. While much has been learned about how the brain processes gaze from pictures of faces, these findings may be specific to those particular experimental situations. It will be important to conduct future studies of gaze processing across a variety of real-world social contexts.

Section 2: Behavioral Consequences of Gaze Processing: Gaze Cueing of Attention

Social attention is a term that has been used to describe humans' interest in where other people are directing their attention. We have a strong intuition that eye gaze is a special social attention cue, in that it tells us with a reasonable degree of reliability where someone is attending. As such, we would expect that (1) the brain is particularly selective for eye gaze, and (2) humans readily use eye gaze to determine where others are directing their attention. Thus far, we have reviewed evidence regarding point (1) that there is a neural system for processing gaze direction.

There is also a recent literature regarding point (2), that humans readily use eye gaze to determine where others are directing their attention. For instance, infants have been found to spontaneously follow the gaze of adults from around the age of 10 months

(Butterworth & Cochran 1980; Butterworth & Grover 1990; Butterworth & Jarrett 1991; Corkum & Moore 1995; Deák, Flom & Pick 2000; D'Entremont 2000; Morissette, Ricard & Decarie 1995; Scaife & Bruner 1975). This gaze-following response has been studied using a prototypical paradigm: the adult initiates eye contact with the infant and then directs her head and/or gaze to one of two locations in space. This process is repeated for a small number of trials, and the measure of interest is the number of trials on which the infant makes an overt shift in gaze in the direction of the adult's gaze. Prior to 12 months, infants appear to follow head orientation and ignore gaze information (Corkum & Moore 1995; Lempers 1979), whereas after this (at 14 months: Caron, Butler & Brooks 2002, and at 18 months: Corkum & Moore 1995), the impact of gaze information is pronounced. Thus, infants appear to develop a strong tendency to orient to gaze direction somewhere in the second year of life.

At the same time as these infants studies, researchers were beginning to study how adults orient their attention in response to someone else's gaze direction. To study this, researchers modified a model task popularized by Posner (1980) and used it to investigate whether people are preferentially biased to attend to where someone else is looking.

Using the Posner Cueing Paradigm to Measure Social Attention

In the model cueing paradigm, participants are presented with a central fixation dot that is flanked by two squares. The task is to make a key press as quickly as possible when a target item appears inside one of the squares. This target event is preceded by a cue, such as the flashing of one of the squares or the appearance of a central arrowhead pointing toward one of the squares. The standard finding is that the target is detected faster when it appears in the cued square than when it appears in the uncued square. Because the brain processes attended

items more quickly than unattended items, it is concluded that target detection time is speeded because attention is committed to the square that was cued. Note that there are two different ways attention can be directed in the cueing task. One way is to flash one of the squares. In this case, attention is directed to the cued square that flashed. This attention shift is considered exogenous (automatic) because people are quicker to detect a target in the cued square even when the flashing does not predict where the target will occur (that is, the target appears in the cued location 50% of the time and in the uncued location 50% of the time). The other way to direct attention in this paradigm is to present a central arrowhead pointing left or right. In this case, attention is directed to the cued square that the arrowhead pointed toward. Since the early 1980s (Jonides 1981; Posner 1980) it had been assumed that this orienting happens only when the arrowhead predicts where the target will appear (e.g., the target appears in the cued location 80% of the time and in the uncued location 20% of the time). In other words, orienting to a central directional stimulus cue, like an arrow, does not occur when the cue is spatially nonpredictive. Thus, the attention shift associated with a central directional cue is considered endogenous (voluntary).

However, Friesen and Kingstone (1998) hypothesized that in light of our intuition that eye gaze is a special social attention stimulus, perceived shifts in eye direction might automatically trigger attention shifts to gazed-at locations. This idea was tested by modifying the model cueing task in two significant ways (see Fig. 2). First, arrows pointing to the left and right were replaced by a schematic face that looked left or right. Second, the predictive value of the central cue was eliminated; that is, gaze direction did not predict where a target item would appear. Note that because the eyes were centrally located and spatially nonpredictive, the traditional line of thinking predicted that gaze would not lead to shifts of attention; in other words, a central directional

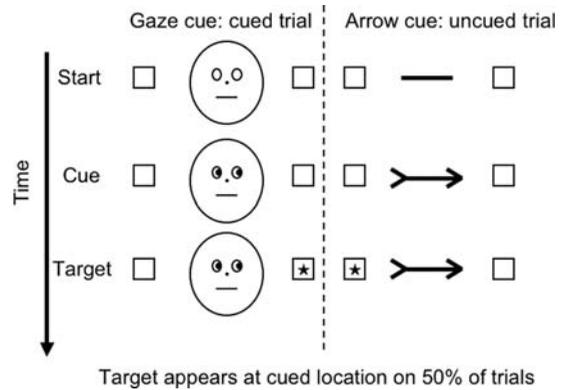


Figure 2. The gaze cueing paradigm (left) and the arrow cueing paradigm (right).

cue should only produce a shift in attention if it reliably predicts where a target is likely to appear. Remarkably, and contrary to traditional thought, spatially nonpredictive eye gaze triggered shifts of attention; target detection was faster for items at the gazed-at location than for items at the other location. This result led to the proposal that the attention shift was automatic because it emerged rapidly and in response to gaze that was spatially nonpredictive. Most importantly, this effect was proposed to occur because the human brain may be specialized to shift attention in response to where other people are attending/looking. The brain mechanisms for this “gaze cueing” effect were hypothesized to involve parietal cortex, which is involved in spatial orienting, and the STS, with which parietal cortex is reciprocally connected (e.g., Harries & Perrett 1991).

In agreement with this initial report, a number of other studies at a similar time reported a similar result and reached the same conclusion: gaze direction triggers an automatic shift in attention to the gazed-at location. For instance, Langton and Bruce (1999) reported that when people are presented a picture of a head turned to the left or right, attention is shifted very quickly in the direction that the eyes and head are pointed. Driver et al. (1999) reported that a picture of a face looking to the left or to the right will trigger a shift of attention to the gazed-at location even if people are correctly

informed that a target is most likely to appear at a location opposite to where the eyes are directed. Furthermore, Hood, Willen and Driver (1998) adapted the gaze-cueing paradigm to assess infant gaze-following and found evidence that babies as young as 3 months are sensitive to adult gaze shifts. They found that infants were faster at making a saccade to a peripheral target probe and made fewer errors (i.e., saccades in the direction opposite to the target) when the target was congruent with the gaze direction of a central face. However, later studies suggested that for very young infants the gaze following response is driven mostly by lateral motion cues provided by the eyes (Farroni, Johnson, Brockbank, et al. 2000; Farroni, Massaccesi, Pividori, et al. 2004). That is, once apparent motion cues are removed from the gaze cues, young infants no longer show the cueing effect (see also Frischen et al. 2007 for a review).

As researchers moved into the 21st century, there was a strong sense of agreement and excitement that this gaze-cueing paradigm promised to tap into social attention and the fundamental importance that humans place on the eyes of others. Furthermore, it suggested a “meeting of fields,” in that mainstream attention-research methods could be used to study questions in the field of social cognition, and that social cognition could enrich our understanding of human attention. Reflecting this, the gaze-cueing paradigm was quickly adapted and applied to study social attention in populations with typical and atypical social development. The effect of gaze direction, however, was somewhat more robust than one would have predicted, with almost everyone, most notably individuals with autism, orienting in response to gaze direction (e.g., Chawarska, Klin & Volkmar 2003; Kylliäinen & Hietanen 2004; Okada, Sato, Murai, et al. 2003; Rutherford & Krysko 2008; Senju, Tojo, Dairoku, et al. 2004; Swettenham, Condie, Campbell, et al. 2003). This was surprising because it conflicted with a common understanding that individuals with autism do not

spontaneously engage in joint attention behaviors, such as following someone’s eye gaze (Baron-Cohen 1995). Although there was the occasional report that individuals with autism may not orient in response to gaze direction (Ristic et al. 2005), many more reports have suggested that eye gaze in the cueing paradigm triggers individuals with autism to shift their attention automatically to the gazed-at location (Chawarska et al. 2003; Kylliäinen & Hietanen 2004; Okada et al. 2002; Rutherford & Krysko 2008; Senju et al. 2004; Swettenham et al. 2003). Furthermore, while initial studies confounded eye motion with gaze direction (Chawarska et al. 2003; Swettenham et al. 2003), making it unclear whether motion signals or gaze direction was cueing attention, Kylliäinen and Hietanen (2004) eliminated motion cues from their design and reported normal shifts of attention to gazed-at locations in an autistic sample.

Concurrent with the development of this research with special populations, there was a parallel line of research examining whether other familiar directional cues, like arrows, produce an automatic shift of attention to the cued location. It is very important to recall here that the endogenous (volitional) attention-cueing task that set the standard for all other cueing tasks that followed was founded on the principle that central arrow cues do not produce an orienting effect when they are spatially uninformative (Jonides 1981; Posner 1980). After all, if they did, then there would be little credibility to researchers’ long-standing claim that informative central arrow cues tap into endogenous mechanisms (e.g., Berger, Henik & Rafal 2005; Jonides 1981; Kingstone 1992; Mueller & Rabbitt 1989; Posner 1980 to name but a small handful of what are literally hundreds of studies). It was therefore surprising when Ristic et al. (2002) and Tipples (2002) reported in separate investigations that central, spatially nonpredictive arrow cues produce a robust reflexive orienting effect that is very similar to what is observed for gaze cues. (How the field could have missed the

fact that nonpredictive arrows produce reflexive orienting is not the focus of the present article; however, the interested reader will find one possible explanation in Kingstone, Smilek, Ristic, et al. [2003] and Kingstone, Smilek & Eastwood [2008]; see also Gibson & Bryant [2005]).

These findings raise the possibility that gaze cueing is not a unique or special effect. Understandably, this doubt has led to a flurry of research seeking to determine whether gaze cueing is different from arrow cueing, either at a behavioral or neural level. Below we review some of these studies.

Is Gaze Cueing Unique?

One possibility is that while both gaze and arrows can orient attention automatically, and therefore are both important attentional cues, gaze cueing may be more strongly reflexive than arrow cueing, reflecting that eyes are biological stimuli with strong social meaning. This is the stance taken in a recent review by Frischen et al. (2007, p. 715):

It is possible that both gaze cueing and orienting of attention via arrow cues have evolved from similar mirror system mechanisms. Directional arrows may have emerged as schematic representations of gaze direction or pointing gestures, both of which are coded in the STS. Of course, at present, such considerations remain speculative because too little is known about the precise role of the STS and other brain areas in orienting attention to gaze and other symbolic cues, and even less is known about the neural architecture of a mirror system for gaze. The STS is more strongly activated during gaze cueing than arrow cueing, which is in line with the behavioral observation that orienting of attention is "more reflexive" in response to gaze cues than to arrows (Friesen et al. 2004; Hooker et al. 2003). Could this be because gaze observation directly activates the hypothetical mirror system, whereas arrow cueing recruits only the attention-orienting system that has evolved from it? After all, gaze cues are biological stimuli that carry social meaning, a dimension that arrow cues are lacking. Further studies into the neural basis of gaze- and arrow-evoked attention shifts are needed to clarify the role of the STS in each.

Indeed, some research suggests a behavioral distinction between gaze and arrow cueing. Friesen, Ristic and Kingstone (2004) found that counterpredictive gaze cues, but not counterpredictive arrow cues, produced reflexive orienting to the cued location. This suggests that gaze cues are prioritized by the brain because of their social significance, leading to more reflexive shifts of attention than do arrow cues. Certainly, this is consistent with the findings that gaze direction is processed by a specialized neural system (Section 1). Indeed, Downing, Dodds and Bray (2004) suggested that while almost any nonpredictive cue carrying spatial compatibility with the target will produce reflexive orienting, it is this more complex influence of gaze cues, that is, the resistance to top-down biases, that sets gaze cues apart from other directional cues. In support of this, Ristic, Wright, and Kingstone (2007) showed that while arrow cueing is sensitive to arbitrary cue-target color contingencies (i.e., it only occurs when the cue and target share the same color), gaze cueing is not sensitive to arbitrary cue-target color contingencies and therefore can be considered to be more reflexive than arrow cueing.

Further evidence comes from studies testing adults' *overt orienting* (involving eye movements) of attention in response to gaze cues. Ricciardelli, Bricolo, Aglioti, et al. (2002) found different overt orienting signatures for central gaze cues and arrow cues. Subjects were asked to make a speeded saccade to the left or right of fixation, as indicated by a central square stimulus. In concert with studies of covert orienting to gaze direction, correct saccade latencies were faster on trials on which a face also gazed at the correct location, relative to when the face gazed at the incorrect location. The same effect occurred for a central arrow stimulus. However, only the *incongruent gaze* stimulus produced unwanted saccades toward the incorrect location; *incongruent arrows* failed in this respect. This is consistent with covert-attention studies showing that orienting to gaze cues is more strongly reflexive than to arrow

cues and persists despite instructions to orient elsewhere.

One possibility is that the reflexive congruency advantage triggered by a nonpredictive arrow may be driven more by automatic (nonattentional) priming than by reflexive attentional shifts, whereas the reflexive congruency advantage triggered by nonpredictive gaze cues is due more to attention (Langdon & Smith 2005). Langdon and Smith (2005) found that nonpredictive gaze cues produced the signature facilitation-plus-cost effect seen for reflexive orienting to traditional peripheral onset cues. That is, a cost-benefit analysis showed that response times were faster when gaze was congruent with the target location (relative to neutral trials) and slower when gaze was incongruent with the target location (relative to neutral trials), reflecting a need to disengage attention from the invalidly cued location and shift attention to the target location. Nonpredictive arrows, on the other hand, produced facilitation-without-cost, suggesting that automatic priming (not involving attention) underlies the reflexive congruency effect for arrows.

Finally, Ristic and Kingstone (2005) demonstrated the uniqueness of gaze cueing relative to, not an arrow, but a stimulus that was physically identical to the gaze cue but could be perceived as the wheels on a car. They found that when an ambiguous stimulus was first perceived as eyes it produced reflexive orienting, even in a later block in which subjects were told the stimulus could be perceived as a car. However, when the stimulus was first perceived described as a car, it did not produce reflexive orienting. Reflexive orienting only occurred when subjects were later informed that it could be perceived as containing eyes. This suggests that the stimulus had to be perceived as having eyes before it could trigger orienting, and that once this percept was activated it triggered reflexive orienting even when an alternative percept was suggested. However, later results by the same authors suggest limits to this finding, showing that when the ambiguous stimulus was back-

projected onto a screen during fMRI scanning, the enlarged image that now filled much of the viewer's visual field triggered orienting regardless of the percept that was adopted (Kingstone, Tipper, Ristic, et al. 2004).

Despite the collection of research showing that gaze cueing may yield relatively subtle differences when compared to arrow cueing, other behavioral research has shown that gaze and arrow cues produce nearly identical shifts of attention (Hommel, Pratt, Colzato, et al. 2001; Tipples 2002). In contrast to Driver et al. (1999) and Friesen et al. (2004), Hommel et al. (2001) found that arrows do produce reflexive shifts in attention despite observers' knowledge that another location was more likely to receive the target. Similarly, Tipples (2008) replicated the conditions of Friesen et al. (2004) counterpredictive gaze cue study and reported reflexive orienting to the location cued by arrows and gaze even when a target was far more likely to appear elsewhere (like Friesen et al., this reflexive attention effect occurred concurrently with the volitional attention effect to the predicted target location). Furthermore, in contrast to Ricciardelli and collaborators (2002), Kuhn and Benson (2007) did not find different reflexive overt orienting signatures for gaze and arrow cues. The authors used a similar voluntary saccade paradigm to Ricciardelli et al., but used more traditional, "arrow-like," cues than did Ricciardelli et al., who used simple arrowheads (e.g., < and >). Using these more effective arrow stimuli, the authors found that the interference effect for arrow cues was of equal magnitude to that for gaze cues. The only difference Kuhn and Benson found between the two types of cues was in the response latency for erroneous saccades, finding shorter error latencies for gaze cues than for arrow cues. However, a later study found no difference between errors elicited by arrows and gaze stimuli (Kuhn & Kingstone 2009).

Furthermore, Friesen and Kingstone (1998) found evidence that gaze cues produce facilitation without costs, which conflicts with Langdon and Smith's (2005) finding that only

arrow cues produce these effects. Similarly, using a voluntary saccade paradigm (instead of the nonpredictive covert attention-cueing paradigm of Langdon and Smith 2005), Kuhn and Benson (2007) found that regardless of cue type (gaze or arrow) saccade latencies for congruent trials were significantly faster than for neutral and incongruent trials (facilitation) but that that saccade latencies were no different for incongruent and neutral trials (i.e., no costs). This is consistent with Koval, Thomas and Everling's (2005) finding of facilitation-without-costs for gaze cues in a prosaccade task. In that study, subjects were instructed to make a saccade toward the onset of a target location. Koval et al. found that saccade latencies were faster on congruent trials than incongruent and neutral trials, but there was no significant cost on incongruent trials relative to neutral trials. Thus, when taken together, a conclusion from these studies is that gaze cues do not appear to produce behavioral effects that differ substantially from those produced by arrow cues.

Because the behavioral research has generally failed to reveal robust differences between gaze and arrow cueing, one possibility is that these differences are only detectable by digging into the neural mechanisms underlying each type of cueing. Some neuropsychological studies suggest that there are different neural systems for gaze and arrow cueing (Akiyama et al. 2006; Kingstone, Friesen, & Gazzaniga 2000; Ristic et al. 2002). For instance, there is evidence from a study with split-brain patients that the reflexive gaze-cueing effect is lateralized to the hemisphere specialized for face processing (Kingstone et al. 2000). In contrast, in a later study this same split-brain patient showed no lateralization of reflexive orienting to nonpredictive arrows, with the cueing effect occurring in both hemispheres (Ristic et al. 2002). In addition, Akiyama and collaborators (2006) found that a patient with damage to her right superior temporal gyrus (STG) showed no orienting in response to gaze cues but preserved orienting to arrow cues. These findings are consistent

with the idea that reflexive orienting to nonbiological cues is underpinned by subcortical brain mechanisms that are shared between the two hemispheres, whereas reflexive orienting to gaze cues is subserved by lateralized cortical mechanisms involved in face/gaze processing (e.g., Kingstone et al. 2004; Friesen & Kingstone 2003).

However compelling these findings are, they must be interpreted with some caution. In particular, lesion studies (e.g., Akiyama et al. 2006) testing one participant are difficult to interpret because of natural variation in the gaze-cueing effect across individuals. As Frischen et al. (2007) point out, some people do not show gaze cueing, and because it is not known how Akiyama et al. patient responded to gaze cues before her lesion, it is difficult to know whether the lesion interfered with gaze cueing or whether she never showed gaze cueing. Furthermore, it is important to consider the influence of low-level differences between gaze and arrow stimuli when interpreting results with single-patient case studies. For instance, the arrow cues in Akiyama et al. (2006) study may have conveyed direction more effectively than did the gaze cues: whereas the arrow cues had clear directionality, the gaze cues were only partially averted (off-center by 11%). A similar concern may be applied to the split-brain studies of Kingstone and colleagues (e.g., Kingstone et al. 2000; Ristic et al. 2002).

Neuroimaging studies with healthy populations have also been conducted in hopes shedding light on whether gaze cueing is unique in some way. For example, Kingstone et al. (2004) showed observers the same eyes/car stimulus that Ristic and Kingstone (2005) used. One group of participants was told that the stimulus was a face with eyes, and the other group was told that the stimulus was a car. While both percepts produced a reflexive orienting effect, the STS was only activated by the gaze cue. This finding suggests that while the gaze and car cues were indistinguishable behaviorally, holding the gaze percept may have engaged a unique brain region; although this does not

necessarily mean that this region was involved in the act of orienting attention.

The neuroimaging findings comparing gaze and arrow cueing, on the other hand, are less clear. Indeed, there is evidence that brain activation differences produced for gaze and arrow cueing may be partly due to the recruitment of different brain areas for visually analyzing gaze and arrow cues, and not necessarily for the subsequent shifts of attention (Hietanen, Nummenmaa, Nyman, et al. 2006). For instance, as reviewed earlier, the STS is more highly activated for basic visual discriminations of gaze direction than for discriminations of arrow direction (e.g., Hooker et al. 2003). Once these basic visual processing differences are removed, and only the subsequent orienting of attention is examined, it is less obvious that gaze and arrow cues are subserved by distinct attentional mechanisms (Hietanen et al. 2006; Tipper et al. 2008). For instance, Hietanen et al. (2006) found that reflexive orienting was supported by partially different mechanisms for gaze cues and arrow cues, with the main difference being that orienting in response to arrow cues activated a more distributed network than orienting in response to gaze cues, and that some of these additional brain areas for arrow cueing (e.g., frontal eye fields) are thought to be involved in voluntary orienting. This might suggest that gaze cueing is slightly more reflexive than arrow cueing, even though behaviorally this distinction is not apparent. This would support the idea that gaze cueing is distinct from arrow cueing at the neural level. However, note that Tipper et al. (2008) did not find this neural distinction between gaze and arrow orienting when the stimulus differences between gaze and arrow cues were removed. They studied gaze and arrow cueing using an ambiguous stimulus that could be perceived as either an eye or an arrow, thus removing the physical stimulus differences normally present in comparisons of gaze and arrow cueing. Very few differences between the neural activations underlying gaze and arrow cueing were found, save for a bigger sensory gain at the cued location for gaze

cues than for arrow cues. Interestingly, the STG was equally activated for gaze and arrow cueing.

However, even these studies must be interpreted with caution, as both suffer from methodological limitations. For instance, the analysis of the Heitanen and collaborators (2006) study may have underestimated the unique contributions of social information. In particular, the analysis collapsed across valid and invalid trials, which is the critical comparison for the attention effect. Moreover, the relatively small number of participants in Tipper et al. (2008) fMRI experiment is a potential limitation given that the critical finding was a null difference in STG activity between gaze and arrow cueing.

As a final line of inquiry, Frischen et al. (2007) point out that if gaze and arrow cueing are subserved by separate neural systems, then one might expect that gaze- and arrow-cueing effects may not correlate strongly within an individual. Although little research has been committed to determining whether individuals who show strong gaze cueing also show strong arrow cueing, there is some evidence from studies of gender differences that suggests that gaze and arrow cueing are related. Bayliss, di Pellegrino and Tipper (2005) found that males show a weaker orienting effect for gaze cues than do females, consistent with previous findings that male infants make less eye contact than do female infants (Lutchmaya, Baron-Cohen, & Raggatt 2002) and therefore may be less sensitive to social cues. However, Bayliss et al. found the same gender difference for arrow cueing, suggesting that gaze and arrow cueing are not distinct. That is, Bayliss et al. findings run counter to what would have been found if gaze and arrow cueing were distinct: "If orienting to the direction of another person's eye gaze is functionally different to the symbolic cueing seen with arrows, for example, then no gender difference would be obtained with arrow cues: Males and females should display attention shifts of equivalent magnitude" (p. 642).

What Can We Conclude from These Studies?

When taken together, the results are rather equivocal with regard to the uniqueness of gaze cueing. On the one hand, some studies have found subtle differences between gaze cueing and arrow cueing, but on the other hand, these differences often are not observed. Overall, the evidence that gaze cueing is distinct from arrow cueing is weak.

What are the implications of this conclusion? Certainly, the finding that arrow cues produce nearly identical effects to gaze cues runs counter to one's intuition that eyes are unique, special social-attention stimuli. However, it could be that arrows are also important social stimuli, which explains why they, too, produce reflexive shifts in attention. This potential status of arrows has not been overlooked. Kingstone et al. (2003) have written that "arrows are obviously very directional in nature, and, like eyes, they have a great deal of social significance. Indeed, it is a challenge to move through one's day without encountering any number of arrows on signs and postings" (p. 178). Thus, perhaps eyes and arrows produce identical effects on attention in the cueing paradigm because they are both important social cues.

An alternative explanation of the data is that the cueing paradigm may be failing to capture key aspects about eyes that distinguish them as special social stimuli that are unlike other stimuli, such as arrows. In other words, the general intuition that eyes are special is correct but the cueing paradigm may not be measuring what makes eyes distinct from arrows. Indeed, the cueing paradigm appears to be measuring eyes and arrows on a dimension in which they share a great deal of similarity, namely their ability to communicate directional information (Gibson & Kingstone 2006). In other words, working from the basic intuition that eyes are very different social stimuli from arrows, one may conclude that the similarity found between eyes and arrows in the cueing paradigm

tells us about the limitations of the cueing paradigm.

This interpretation is supported by the growing evidence that cueing effects similar to gaze cueing are found for a variety of biological and nonbiological cues that convey direction. For instance, Downing et al. (2004, Experiment 1) found that a central face with its tongue pointing randomly left or right produced reflexive attention effects that were indistinguishable from gaze-cueing effects. Hommel et al. (2001) found reflexive orienting both for nonpredictive arrows and for nonpredictive directional words (e.g., "left," and "right") presented centrally. Even more striking, Quadflieg, Mason and Macrae (2004) found equivalent cueing effects for drawings of averted eyes within human faces, within animal faces (e.g., tiger, owl), or within an apple or a gloved hand. The same cueing effect was found for a gloved hand containing two arrows instead of eyes.

The results of this growing collection of studies suggest that any cue with a directional component, or more specifically, any cue carrying the potential for spatial compatibility with the target (e.g., arrow points left, target appears left) may produce reflexive orienting of attention. From this perspective, behavioral differences found between cues could be reattributed to the differences in the cues' ability to convey left/right information. It is like taking a 150-pound person and a 150-pound rock, weighing them, and concluding that they are the same. They are the same, in terms of weight, but there is the intuition that they are not the same in many other ways. For instance, for various reasons people would be much more interested in attending to the person than the rock. To demonstrate that, however, one would need a different way to measure the person and the rock, that is, a different research approach would be called for. In much the same way, what may be needed in the area of social attention is a different research approach—one that better reflects our intuition that the human attention system cares about eyes in a way that is distinct from other stimuli in the environment.

One possible avenue has recently been suggested by Kuhn and Kingstone (2009) “Thus although arrows and eye gaze may be of equal relevance when they are presented to the participant in isolation, key differences between social and non social cues may only become apparent when they are embedded within a richer environment.” (p. 41).

Section 3. A New Approach

An alternative approach for studying social attention is provided by considering the different components of attention that can be measured in experiments involving social stimuli. Rather than examining the orienting of attention in response to a cue (i.e., orienting from the cue to where the cue is pointing), we propose to study the selection of the cue itself (i.e., orienting to the cue). Consider a real-world example of social attention: You are riding a bicycle on campus and notice that your colleague is standing on the sidewalk and looking at something on the ground. Using her gaze direction, you orient your attention to see what she is looking at. It is clear from this example that there are at least two distinct stages of social attention: first, you select (orient to) your colleague’s eyes as a key social stimulus, and second, you orient your attention from her eyes to select the location/object that she is looking at. Importantly, cueing studies with central symbolic cues are specifically designed to test only one of these attentional components: orienting from the cue. The selection of the cue is relatively trivial within the context of the cueing paradigm because the cue, that is, a gaze, arrow, word, or number stimulus, is presented at central fixation and typically in advance of the target object (Gibson & Kingstone 2006). That is, the experimenter essentially preselects the cue and places it at fixation (the current focus of attention). As we found in the preceding section, when this selection process is omitted, the prevailing literature indicates that eyes and arrows are generally given equal pri-

ority by the attention system. Does this general equivalence hold, however, when the selection of social cues is measured? In other words, will eyes and arrows be given equal priority when participants are provided with the opportunity to select them from a complex visual scene?

The fact that no studies have compared the selection of eyes versus arrows is noteworthy given the strong tradition of research on selective attention (e.g., Broadbent 1958, 1972; Deutsch & Deutsch 1963; James 1890; Moray 1959; Neisser 1967; Treisman 1960). The basic assumption behind all these conceptualizations of selective attention is that humans possess a capacity limitation when it comes to handling information in the world. The implication of this capacity limitation is that we must select some items for processing at the expense of others (hence the term *selective* attention).

Before using measures of selection to compare the social relevance of eyes and arrows, one would want to verify that these measures tap into social attention mechanisms. Some of our own most recent work has done just that. We have used the selection approach to demonstrate that observers select (by looking at) the eyes of people within complex scenes because they are interested in the social information provided by the eyes (Birmingham, Bischof & Kingstone 2008a,b). We presented real-world photographs of scenes with people and a variety of objects that depicted a range of different natural social situations. The results of our work showed that, indeed, observers do look mostly at eyes, and they look relatively infrequently at the rest of the scene (e.g., bodies, foreground objects, background objects). Importantly, we also found that this general interest in the eyes of others can be modulated by social factors. For instance, observers in our investigations selected the eyes more frequently in highly social scenes, that is, scenes containing multiple people doing something together. Additionally, attention to the eyes of others increased when observers were reporting on the social attention within the scenes relative to when performing

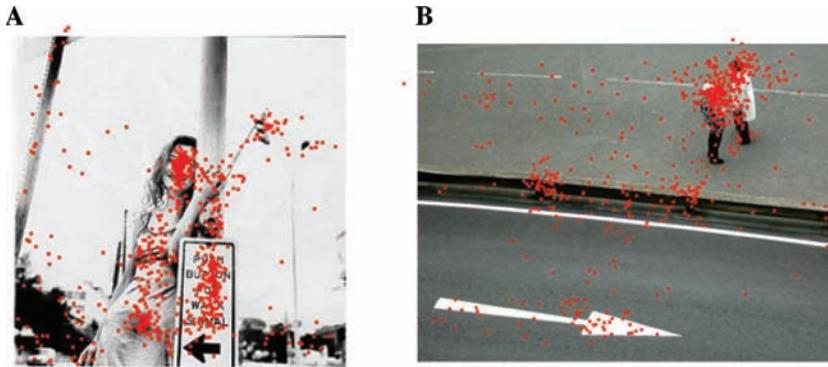


Figure 3. Fixations (dots) overlaid on an image with eyes and arrow (**A**) and an image with a larger arrow (**B**).

other less socially focused tasks, such as describing the scenes (Birmingham et al. 2008b; see also Smilek, Birmingham, Cameron, et al. 2006). These findings led us to conclude that our methodology captures social attention processes, revealing a preferential selection of gaze information that is enhanced by a social attention task and by the social content of the scene. Importantly, our findings reflect the everyday intuition that eyes are unique social stimuli that are prioritized by the human attention system.

With the confidence that our basic approach taps into social attention, we adapted it in a recent study to determine whether observers select eyes and arrows to the same extent (Birmingham, Bischof & Kingstone, in press). We did this by presenting gaze and arrows within complex scenes and studying what people select to fixate. Scenes were shown for 15 sec, during which observers simply looked at the images. A representative illustration of the data is shown in Figure 3. What we found is that observers demonstrate a strong bias to fixate the eyes in the scene, with fewer fixations committed to the arrows (Fig. 3A). Furthermore, while eyes and heads were likely to be prioritized, that is, looked at first, arrows were never fixated first. This general interest in people, and lack of interest in arrows, persists even when we make the arrow much larger than the people in the scene (Fig. 3B). Note also that these findings cannot be explained by low-level visual characteristics of the eyes or arrows, such as visual

saliency (Itti & Koch 2000), as we computed the saliency at fixated locations and found that it was no higher than what would be expected by chance. Overall, our data show that when one examines attentional selection, rather than orienting to a preselected centrally positioned stimulus (as in the cueing paradigm), what one finds is that people care about people, especially their eyes and faces. They rarely look at the arrows when they are small or large; and they rarely look at them when they are large. These findings indicate that in general, the human attention system does not treat eyes and arrows equivalently. When people are free to look at what they find important, they choose to look at people and their eyes. This profound and clear-cut difference between eyes and arrows has never been observed within the context of the cueing paradigm.

The implications of these preliminary data are both broad and deep. First, they suggest that when one takes a different approach to measuring the impact of eyes and arrows on the spatial attention system—one that moves away from the orienting of attention in response to a directional cue that the observer is forced to select (because it is presented at fixation in an otherwise uncluttered field), and moves toward the selection of items in a complex scene—one finds that observers tend to select people and eyes rather than arrows.

Second, finding a profound difference between eyes and arrows would appear to lend

support to the suggestion raised in the previous section that the cueing paradigm may not pick up on basic differences in the social relevance of eyes and arrows, differences that appear to be captured when selection is measured. This dovetails with the finding that when eyes and arrows are inserted as cues into the cueing paradigm, they tend to be treated the same way behaviorally (e.g., Tipples 2008) and engage the same brain mechanisms (e.g., Tipper et al. 2008). The most reasonable explanation for this is that the factor of interest in the cueing paradigm is cue/target location information, and eyes and arrows are well matched in their ability to deliver this type of information. On the other hand, the many features that make eyes and arrows different types of stimuli are not typically important to the cueing paradigm.

Third, the present data raise the possibility that when researchers place a face stimulus in isolation, as they do in the cueing paradigm, they may be bypassing a critical aspect of attention, namely, the selection process. As we saw in the study above, the selection process allows one to assess the importance that observers place on different stimuli. When this selection opportunity is bypassed by the experimenter preselecting and presenting the stimulus to the observer in relative isolation, it is very difficult to gain a sense of the relative importance placed on each stimulus. Additionally, by preselecting and isolating different stimuli, one may change the context in which the stimuli are normally embedded, and in doing so, change the meaning that is normally attached to those stimuli.

Fourth, the data and above considerations suggest that it would be wise to move from eye monitoring people while they view static images of people to eye monitoring people while they view moving images of people, and then ultimately, real people. It is worth noting that to date, virtually all of the research in social attention (including the data presented here) has been confined to situations involving static images of people. By definition, these images of people cannot attend to the observer while the observer is attending to them. This stands in

sharp contrast to many situations in real life. Interestingly, while one might be tempted to predict that observers would look even more often at the eyes in real social situations than in images of social situations, the opposite could just as easily be true. For instance, while eye contact is a functional part of everyday social interactions, social norms indicate that it is often rude to make excessive eye contact or to spend too much time looking at another person. Indeed, in some situations (e.g., being approached by a hostile person) it may be appropriate to avoid eye contact altogether.

Summary and Future Directions

The present review began by examining the brain mechanisms that are involved in processing gaze information and found that there is good evidence (although by no means evidence without some contradictions) that there are brain systems that are preferentially biased toward gaze information. We then considered a large body of behavioral evidence that sought to examine the functional impact of gaze direction on the spatial orienting of attention, and found that, contrary to what had been expected from the neural evidence, a range of cues from eyes to arrows have a similar effect on attention. In our final section, we showed that when observers are left free to select what they want to attend to, they focus on people and their eyes, consistent with one's intuition and the neural evidence that eyes are special. We discussed a range of implications of this finding, including that when researchers preselect a stimulus and simplify the setting it is normally embedded in, they may profoundly change the way that stimulus is processed in more complex real-world settings.

Interestingly, this brings us full circle and raises some questions regarding the initial studies examined in Section 1, which by and large have examined the neural mechanisms in face and gaze processing by presenting these stimuli in relative isolation. While the majority

of this research suggests that there is a network of brain areas involved in processing gaze direction, there are inconsistencies in how this network is engaged. As we described, there are studies that strongly suggest that context matters to how STS responds to gaze direction. For instance, we reviewed the finding of Pelphrey et al. (2004) that when eye gaze is presented in a more social context (a person walking down the hall, pausing, and either looking at you or away from you) it activates STS more strongly when it is directed at the observer. This stands in contrast to other studies finding stronger STS activity for averted gaze in the context of free viewing and gaze discrimination tasks (e.g., Hoffman & Haxby 2000). The finding that context clearly influences how the STS is activated points to the possibility that the results from imaging studies of gaze perception may be specific to the context that they were tested in. If so, the implication is that our understanding of how the brain processes gaze in a very different context—the real world—may be much less than originally thought.

Thus, an exciting direction for future research is to measure social attention in more real-world settings, in which gaze direction is one of several stimuli that make up a rich social context. For instance, Kuhn and Land (2006) showed that the vanishing ball illusion, in which a ball is perceived to have vanished in midair, relies strongly on social attention cues from the magician performing the trick. That is, when the magician pretends to toss a ball upward but secretly conceals the ball in the palm of his hand, observers are much more likely to perceive the ball traveling upward and vanishing when the magician looks upward with the fake toss than when he looks down at his hand. Furthermore, on real throws on which the ball is physically present, instead of simply tracking the ball with their eyes, observers often make fixations to the magician's face before looking at the ball. This suggests that observers select information about the magician's attention in order to predict the position of the ball. Kuhn and Land's study thus provides an excellent ex-

ample of how social attention, both with regard to the selection and orienting components of attention, can be studied successfully using rich, complex stimuli.

Conflicts of Interest

The authors declare no conflicts of interest.

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