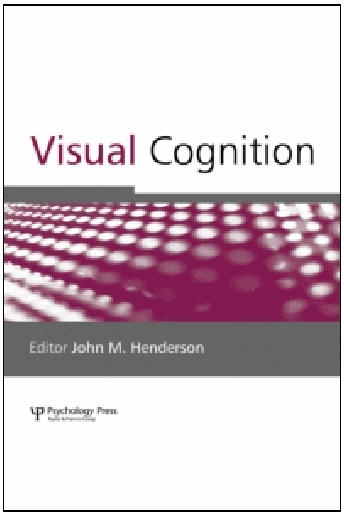

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Get real! Resolving the debate about equivalent social stimuli

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Get real! Resolving the debate about equivalent social stimuli

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Gaze and arrow studies of spatial orienting have shown that eyes and arrows produce nearly identical effects on shifts of spatial attention. This has led some researchers to suggest that the human attention system considers eyes and arrows as equivalent social stimuli. However, this view does not fit with the general intuition that eyes are unique social stimuli nor does it agree with a large body of work indicating that humans possess a neural system that is preferentially biased to process information regarding human gaze. To shed light on this discrepancy we entertained the idea that the model cueing task may fail to measure some of the ways that eyes are special. Thus rather than measuring the orienting of attention to a location cued by eyes and arrows, we measured the selection of eyes and arrows embedded in complex real-world scenes. The results were unequivocal: People prefer to look at other people and their eyes; they rarely attend to arrows. This outcome was not predicted by visual saliency but it was predicted by the idea that eyes are social stimuli that are prioritized by the attention system. These data, and the paradigm from which they were derived, shed new light on past cueing studies of social attention, and they suggest a new direction for future investigations of social attention.

Keywords: Social attention; Gaze perception; Attentional selection; Cuing paradigm; Scene perception.

Our everyday knowledge suggests that we are very interested in the attention of other people. Indeed, experience suggests that as social beings we are

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quick to notice when people are looking at us; and when they are not looking at us we are quick to determine what they are looking at. This intuition, that we care about where other people are attending, has led to the birth of research in *social attention*.

Although there are several cues to the direction of another person's attention (e.g., gaze direction, head position, body position, pointing 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 equipped to promote fast discrimination of gaze direction, having the highest dark iris-to-white sclera contrast of all the primate eyes (Kobayashi & Koshima, 1997). Humans are not only very accurate at discriminating gaze direction (Cline, 1967; Gibson & Pick, 1963; Lord & Haith, 1974), but we also appear to have neural structures that are preferentially biased for processing gaze information. For instance, single cell recordings in monkeys show that the superior temporal sulcus (STS) has cells that are selective for different gaze directions, independent of head orientation (Perrett et al., 1985); and neuroimaging studies (e.g., Hoffman & Haxby, 2000; Pelphrey, Viola, & McCarthy, 2004) have similarly shown that the human STS seems to be especially activated by changes in gaze direction. 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, & Benson, 1992).

Perhaps what makes eyes so unique is that in addition to implying where someone's attention is directed, they can be used to infer a wealth of other social information that we use on an everyday basis. For instance, eyes can help us determine what someone is feeling, thinking, or wanting (Baron-Cohen, Baldwin, & Crowson, 1997). Eyes are also used to modulate social interactions, by facilitating conversation turn-taking, exerting social dominance, and signalling 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, both intuition and empirical evidence suggest that eyes are extremely important and unique social-communicative stimuli.

To measure the unique social importance of eyes, an abundance of research has examined the extent to which gaze direction can trigger an attention shift in others (what is sometimes called "joint attention"). Using the model gaze cueing task it is well-established that infants (Farroni, Johnson, Brockbank, & Simion, 2000; Hood, Willen, & Driver, 1998), preschool children (Ristic, Friesen, & Kingstone, 2002), and adults alike (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999) will shift attention automatically to where others are looking. In the typical gaze cueing paradigm a participant is first shown a picture of a real or schematic face with the eyes looking either to the left or to the right. A target is then presented either at the gazed-at location or at the opposite location. The usual finding is that response time (RT) to detect a target is fastest when the target appears at the gazed-at (cued) location, consistent with the notion that attention was shifted there in response to where the gaze cue was looking. Because this effect emerges rapidly and occurs even when gaze direction does not predict where a target is going to appear, it is considered to measure *reflexive* orienting of attention to gaze direction.

This automatic gaze cueing effect was initially thought to be an effect that was unique to gaze, with other, well-learned directional stimuli, like arrows, failing to produce a reflexive attention effect (Jonides, 1981). It was therefore somewhat surprising when Ristic, Friesen and Kingstone (2002) and Tipples (2002) reported in separate investigations that central, spatially nonpredictive arrow cues produce a robust reflexive orienting effect; and Ristic et al. mapped out the time course of this attention effect for eyes and arrows and showed that they were very similar.

A number of subsequent studies have confirmed that the arrow cueing effect is very similar to the gaze cueing effect (e.g., Gibson & Bryant, 2005; Gibson & Kingstone, 2006; Hommel, Pratt, Colzato, & Godijn, 2001; Ristic, Wright, & Kingstone, 2007; see also Eimer, 1997). Indeed, even some of the more subtle attention effects that were initially thought to be unique to gaze cues have now been shown to occur for arrow cues as well. For instance, it was initially thought that only gaze cues produce reflexive orienting to a location despite observers' intention to shift attention volitionally somewhere else (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004). However, Tipples (2008) has shown convincingly that arrows, too, can produce this reflexive attention effect.

Similarly, brain lesion and neuroimaging studies are equivocal as to whether gaze and arrow cues engage different underlying neural systems. Specifically, although some neuropsychological studies suggest that there are different neural systems for gaze and arrow cueing (Kingstone, Friesen, & Gazzaniga, 2000; Ristic et al., 2002; Vuilleumier, 2002), the neuroimaging findings comparing gaze and arrow cueing are less clear. For instance, there is recent 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, Parkkola, & Hämäläinen, 2006; Tipper, Handy, Giesbrecht, & Kingstone, 2008). That is, when physical differences between the cues are controlled, gaze and arrow cues appear to engage the same brain systems (Tipper et al., 2008).

This convergence between gaze and arrow cues extends to overt shifts of attention. Ricciardelli, Bricolo, Aglioti, and Chelazzi (2002) found that when participants were asked to make a speeded eye movement to the left or right of fixation, as indicated by a central square stimulus, correct saccade latencies were fastest when an irrelevant central face gazed in the signalled saccade direction (congruent gaze). A similar effect occurred when an arrow replaced the gaze stimulus. In contrast, although *incongruent gaze* produced unwanted saccades in the incorrect direction, *incongruent arrows* did not. In a follow-up study, Kuhn and Benson (2007) implemented the same saccade paradigm as Ricciardelli et al., but used more traditional, "arrow-like" cues than did Ricciardelli et al. (who used simple arrowheads, e.g., $< >$). Kuhn and Benson now found that both incongruent gaze and arrow stimuli triggered incorrect saccades; although the response latency for incorrect saccades appeared to be somewhat shorter for gaze than arrow stimuli. Recently, however, this error latency difference between eyes and arrows was found to be unreliable (Kuhn & Kingstone, 2009).

Collectively, the extant data are equivocal with regard to the unique effects of gaze cueing. On the one hand, there are some studies that find subtle differences between gaze cueing and arrow cueing, but on the other hand often these differences are not observed. Overall, the evidence that gaze cueing is unique from arrow cueing is weak. Thus, even though we have an intuition that eye gaze is a special attentional stimulus, behavioural and neural evidence indicates that humans shift their attention in response to eyes and arrows in similar ways, and that this applies to both covert and overt orienting.

The broader implications of this conclusion are not altogether clear. Certainly, the finding that arrow cues produce near identical effects to gaze cues runs counter to our intuition that eyes are unique, special social attention stimuli. However, it could be simply that arrows are also important social stimuli, which explains why they, too, have the same effect on attention as eyes. This potential status of arrows has not been overlooked. For example, Kingstone, Smilek, Ristic, Friesen, and Eastwood (2003) wrote "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).

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 from other stimuli, like 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. The cueing paradigm may be merely measuring eyes and arrows on a dimension that they share strongly—their ability to communicate directional information such as left and right (Gibson & Kingstone, 2006). 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. To demonstrate that, however, one would need a different way to measure the person and the rock, i.e., 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): "[A]lthough arrows and eye gaze may be of equal relevance when they are presented to the participant in isolation, key differences between social and nonsocial cues may only become apparent when they are embedded within a richer environment."

AN ALTERNATIVE RESEARCH 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 in response to 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 given equal priority by the attention system. Does this 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 aim of the present study was to examine whether this equivalence between eyes and arrows will hold when the *selection* component of social attention is measured. Specifically, will eyes and arrows be given equal priority when participants are provided with the opportunity to freely select stimuli from a complex real-world visual scene?

The fact that no studies have compared the selection of eyes versus arrows in complex settings 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). Research on scene perception has consistently shown that when presented with a complex scene, observers tend to select (fixate) items that are informative (Buswell, 1935; Henderson, Weeks, & Hollingworth, 1999; Loftus & Mackworth, 1978; Yarbus, 1965/1967). When people are absent from visual scenes, this means that observers will look primarily at objects that add semantic meaning to the scene and scene regions with high amounts of visual information (Antes, 1974; Buswell, 1935; Henderson et al., 1999; Loftus & Mackworth, 1978). When people are present in a scene, observers look primarily at the eyes and faces of the people and devote less attention to the rest of the scene (Birmingham, Bischof, & Kingstone, 2007, 2008a, 2008b; Yarbus, 1965/1967). This suggests that when a person is presented in a scene, their eyes become important to understanding the scene. We have interpreted these findings as indicating that people fixate the eyes of others because they perceive the eyes to contain important social information. In support of this, observers' preference for eyes is enhanced by social tasks (e.g., describe where people in the scene are directing their attention) and by increasing the social content and activity of a scene (e.g., increasing the number of people actively doing something (Birmingham et al., 2008b). Thus, there is evidence suggesting that observers preferentially select gaze information from a complex scene, and that this reflects the fact that eyes are perceived to be informative social stimuli.

However, no studies have tested whether gaze would be preferentially selected if an arrow were also placed in the scene. Research using the cueing paradigm indicates that eyes and arrows are equivalent attentional cues, and that this reflects the fact that arrows, like eyes, are socially significant. One possible outcome then is that eyes and arrows will be selected to the same extent. An alternative possibility is that eyes will be preferentially selected over arrows. This finding would suggest that eyes and arrows do not have equal social relevance, and would dovetail with the general intuition that while eyes and arrows are both directional, eyes are unique in that they can communicate other social information, such as the emotion, intention, state of mind, and ages of other people. As such, eyes may be prioritized by the attention system. This outcome is not predicted by past gaze and arrow cueing studies.

METHOD

The present study examined the extent to which eyes and arrows are selected from complex scenes. We presented a variety of photographs of real-world scenes containing both people and arrows, and monitored observers' eye movements while they freely viewed the scenes. This allowed us to determine how often, and how quickly, observers select eyes and arrows.

Participants

Fifteen undergraduate students from the University of British Columbia participated in this experiment. All had normal or corrected to normal vision, and were naïve to the purpose of the experiment. Each participant received course credit for participation in a 1-hour session.

Apparatus

Eye movements were monitored using an Eyelink II tracking system. The online saccade detector of the eyetracker was set to detect saccades with an amplitude of at least 0.5°, using an acceleration threshold of $9500°/s^2$ and a velocity threshold of 30°/s.

Stimuli

Full colour photographs were collected from various sites on the World Wide Web.

Each picture was presented on a white 800 × 600 pixel canvas. Thus, in some cases, a picture that was slightly smaller than 800 × 600 pixels was surrounded by the white borders of the canvas. Image (canvas) size was 36.5 × 27.5 cm, corresponding to 40.1° × 30.8° at the viewing distance of

Figure 1 (opposite). Left: The scenes used in the experiment. A–C: Scenes with eyes and arrows; D–F: Scenes with large arrows; G: Scene without people. Middle: Overlays from all observers' fixations. There was a clear preference for the people in the scene, particularly their faces and eyes. Fewer fixations went to the arrows. Right: Saliency maps for each scene, with first fixations from all observers. First fixations tended to land on the nonsalient areas of the scene (black in the saliency map). To view this figure in colour, please see the online issue of the Journal.

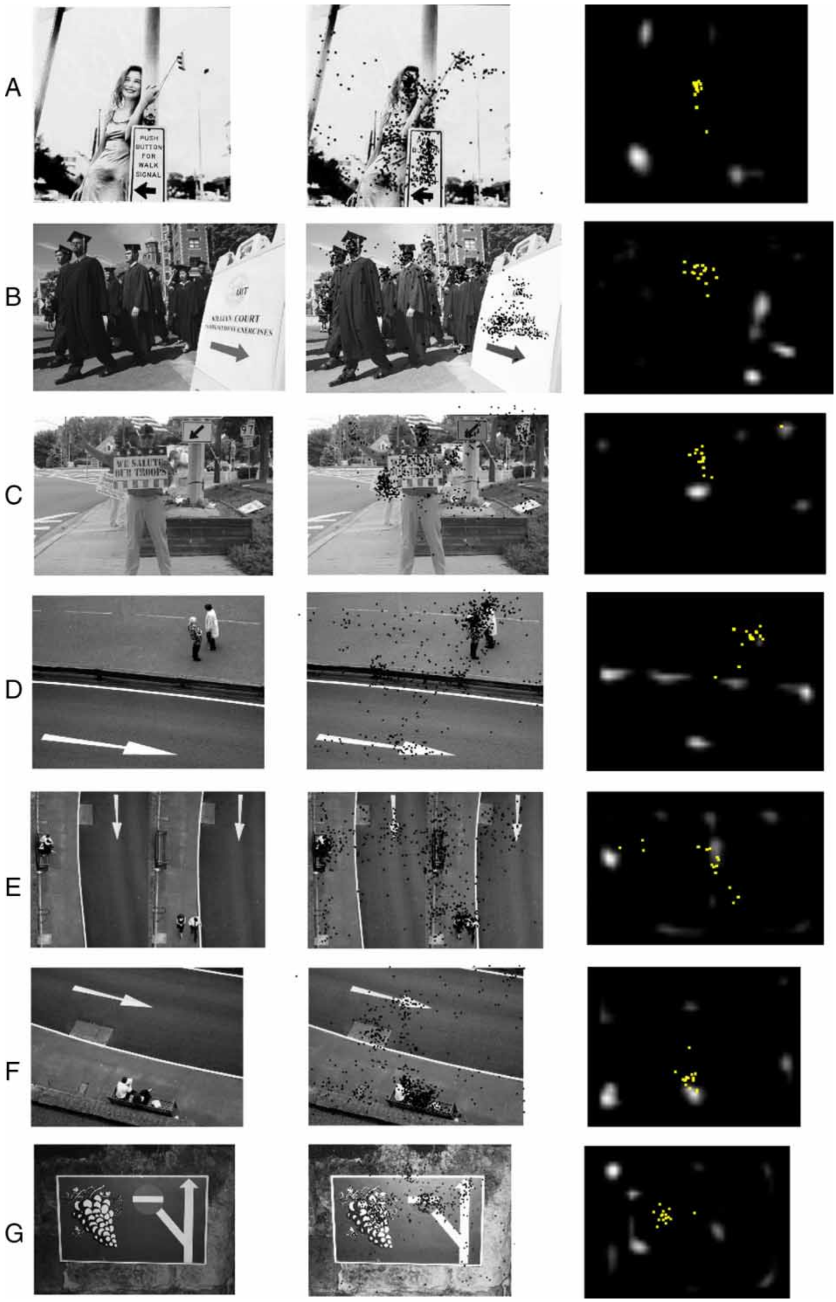

Figure 1 (*see caption opposite*)

50 cm. Twenty-three images were used in the present experiment: Six images contained both people and arrows, one image contained arrows but no people, and 16 remaining "filler" images were displayed (containing photographs of people, faces, and paintings). The critical seven arrow images analysed in the present experiment are shown in Figure 1 (left column).

Procedure

Participants were seated in a brightly lit room, and were placed in a chinrest so that they sat approximately 50 cm from the display computer screen. Participants were told that they would be shown several images, each one appearing for 15 s, and that they were to simply look at these images.

Before beginning the experiment, a calibration procedure was conducted. Participants were instructed to fixate a central black dot, and to follow this dot as it appeared at nine fixed locations on the screen in a random order. This calibration was then validated, a procedure that calculates the difference between the calibrated gaze position and target position and corrects for this error in future gaze position computations. After successful calibration and validation, the scene trials began.

At the beginning of each trial, a fixation point was displayed in the centre of the computer screen in order to correct for drift in gaze position. Participants were instructed to fixate this point and then press the spacebar to start a trial. The 23 pictures were shown in random order. Each picture was shown in the centre of the screen and remained visible until 15 s had passed, after which the picture was replaced with the drift correction screen.

RESULTS

Data handling

In keeping with previous reports (e.g., Birmingham et al., 2008a, 2008b; Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006) the data were handled in the following manner. For each image, an outline was drawn around each region of interest (e.g., "eyes", "arrow") and each region's pixel coordinates and area were recorded. We defined the following regions in this manner: Eyes, heads, bodies (including arms, torso, and legs), arrows,[1] and "other".

[1] We also conducted an analysis using just the heads of the arrows, which some might argue contain the most information. The pattern of results remained the same as what is reported here.

To determine what regions were of most interest to observers we computed *fixation proportions* by dividing the number of fixations for a region by the total number of fixations over the whole display. We corrected for area differences between regions and across scenes to control for the fact that large regions would, by chance alone, receive more fixations than small regions. This was accomplished by dividing the proportion score for each region by its area. These area-normalized data are shown in Table 1. Table 1 also shows the raw fixation proportions (not area-corrected). Note that although we analyse the area-normalized data, all the key significant effects are replicated when the uncorrected data are analysed, i.e., the significant preference to select eyes over arrows in people scenes, and to select other objects rather than arrows in the nonpeople scene.

To determine where observers' initial saccades landed in the visual scene, we computed the number of first fixations that landed in a region (*initial fixations*). The initial fixation was the first fixation made after the experimenter-controlled fixation at screen centre. These data were not area-corrected and are shown in Table 1.

To determine whether low-level properties of the scene—that is, *visual saliency*—could account for where observers committed their first fixation to the scene, we computed saliency maps according to Itti and Koch's (2000) model. Itti and Koch measure visual saliency of an image by identifying strong changes in intensity, colour, and local orientation. We used the Saliency Toolbox (Walther & Koch, 2005, 2006). As visual saliency has been hypothesized to have its greatest impact on the first saccade (Henderson et al., 1999; Parkhurst, Law, & Niebur, 2002; although see Tatler, Baddeley, & Gilchrist, 2005, for evidence that this is not the case), we focused our analysis on initial fixations.

We computed the average saliency of fixated scene locations and compared this to the average saliency of random locations sampled from the smoothed probability distribution of all first-fixation locations from participants' eye movement data across all scenes. This control value was chosen to account for the known bias to fixate the lower central regions of scenes (see Tatler, 2007, for more on the central fixation bias). This comparison allowed us to determine whether the saliency model accounted for first fixation position above what would be expected by chance.

Fixation proportions

Scenes with eyes and arrows. Our main question of interest was whether eyes and arrows would be fixated to the same extent. Thus, we analysed the images containing both eyes and arrows, i.e., images with people who were large enough for the observer to see the eye region (Figure 1, A–C). The middle column of Figure 1(A–C) shows fixation plots for all subjects for

TABLE 1
Proportion of all fixations landing in each region (fixation proportions: area-normalized and nonnormalized), and proportion of all first fixations landing in each region (initial fixations)

Scene type	*Region*	*Fixation proportion (area-normalized)*	*Fixation proportion (nonnormalized)*	*Initial fixations (nonnormalized)*
Eyes and arrows	Eyes	0.45	0.09	0.20
	Heads	0.23	0.14	0.20
	Bodies	0.05	0.19	0.13
	Text	0.21	0.32	0.22
	Arrow	0.05	0.01	0.00
	Other	0.01	0.25	0.24
Large arrows	Heads	0.51	0.09	0.07
	Bodies	0.33	0.20	0.40
	Bench	0.09	0.09	0.13
	Arrow	0.05	0.08	0.00
	Other	0.02	0.54	0.40
No people	No-entry	0.53	0.26	0.07
	Grapes	0.27	0.37	0.93
	Arrow	0.17	0.11	0.00
	Other	0.03	0.26	0.00

these three images. Immediately noticeable from these plots is that observers concentrated their fixations primarily on the people, particularly their eyes. Observers rarely fixated the arrows.

To confirm these impressions, we conducted a repeated measures ANOVA on the area-normalized fixation proportions (see Table 1) with region (eyes, heads, bodies, text, arrows, and "other"—the remainder of the scene) as a factor. This analysis revealed a highly significant effect of region, $F(5, 70) = 50.98$, $p < .0001$. Pairwise comparisons (Tukey-Kramer multiple comparisons test) revealed that observers fixated the eyes more than any other region ($p < .05$). The next most frequently fixated regions were heads and text, which were fixated more than bodies and arrows, and the rest of the scene, ps $< .05$. Confirming our impression from Figure 1, arrows were not fixated often in these scenes. Thus, to answer the main question of our study, eyes were fixated more frequently than arrows, which were hardly fixated at all.

Scenes with larger arrows. One might wonder if observers failed to show a preference for arrows in the previous analysis because they were relatively inconspicuous given that they were smaller than the people in the scene (Figure 1, scenes A–C). To address this issue we analysed three other scenes in which the arrows were large and the people were small (indeed, their eyes were not clearly visible, Figure 1, D–F). Fixation plots for these images are shown in Figure 1 (D–F, middle column). Again, it is immediately noticeable that observers focused mostly on the people, particularly the heads of the people, and that few fixations were committed to the arrows. Even the empty bench in Scene E, where people would be expected, seemed to receive more fixations than the arrows in the scene. For these scenes, we analysed fixation proportions as a function of region (heads, bodies, bench, arrows, other). Note that the eyes were not visible because the people were small (also because of the viewing angle) and thus eyes were not analysed. The ANOVA revealed an effect of region, $F(4, 56) = 83.62$, $p < .00001$, with heads being fixated more than any other region (Tukey Kramer, $p < .05$). Bodies were the next most fixated, and more so than benches, arrows, and other items, all ps $< .05$ (see Table 1). Thus, despite their very large size, arrows were again fixated infrequently relative to the people. Note that as the data are *proportions* of fixations as a function of region, one cannot directly compare the data for Scenes D–F to Scenes A–C, as the content of the scenes (and thus the regions of interest) are not constant; however, it is unequivocal that in all cases fixations were committed preferentially to eyes when they were available, and frequently to heads when eyes were not available; and in all cases fixations were rarely committed to arrows.

Scenes with no people. The results thus far have demonstrated that observers care very little about arrows placed in scenes containing people. It appears that as social beings, observers allocate their attention primarily to other people, particularly their eyes and heads. What happens when no people are in the scene? Given that arrows have been thought of as socially relevant objects (Kingstone et al., 2003; Tipples, 2002), would they receive preferential attention when placed among other objects when there are no people present? We analysed the data for the scene in Figure 1(G). For the analysis the scene was parsed into four regions: The “no-entry” sign, the drawing of grapes, the arrow, and other (remaining items of the scene). The fixation plot in Figure 1(G) shows that relative to the no-entry sign and the grapes, the arrow was fixated infrequently. The data are summarized in Table 1. An ANOVA on the fixation proportions revealed an effect of region, $F(3, 42) = 135.78$, $p < .00001$, with pairwise comparisons revealing that observers looked more at the no-entry sign than any other region (Tukey-Kramer, $p < .05$). The next most fixated region was “grapes”, which was fixated more than the arrow, $p < .05$. All three of these regions were fixated more often than the remainder of the image (other), $p < .05$ when area-normalized. These data suggest that observers show little interest in the arrow relative to other main scene items.

Initial fixations

Scenes with eyes and arrows. Although the fixation proportions showed that eyes were fixated more frequently than arrows, these were computed over the entire viewing period. Thus, the analyses of fixation proportions might reflect more voluntary or strategic viewing patterns that developed over time. The very first fixation, on the other hand, reveals which regions attract attention immediately upon the appearance of the scene. We reasoned that if arrows capture attention as strongly as eyes, then this would be reflected in the first fixation being just as likely to land on an arrow as an eye region. Thus, we analysed the proportion of first fixations (the first fixation after the experimenter-controlled fixation at centre) that landed on eyes, heads, bodies, arrows, or other (see Table 1). These data were not area normalized. There was a significant effect of region, $F(5, 70) = 3.61$, $p < .01$, with eyes, heads, text, and the remainder of the scene all equally likely to receive the first fixation, and all more likely than the arrow, which never received the first fixation (Tukey-Kramer, $p < .05$).

Scenes with larger arrows. Larger arrows were also never fixated first (Table 1). An ANOVA revealed an effect of region, $F(4, 56) = 9.33$, $p < .0001$. Bodies and other were both most likely to get the first fixation, more so than any other region, (Tukey-Kramer, $p < .05$). As with scenes containing smaller arrows, larger arrows never received the first fixation.

Scenes with no people. An ANOVA revealed an effect of region (no-entry, grapes, arrow, other), $F(3, 42) = 70.38$, $p < .0001$. The grapes were highly likely to be fixated first, and more so than the no-entry sign (Tukey-Kramer, $p < .05$). The arrow and the rest of the scene were never fixated first.

Visual saliency

Saliency of the location of subjects' first fixations was compared to a chance-based estimate (called *biased-random*) that takes into account the bias to fixate the lower central regions of the scene. Figure 1 (right column) shows all observers' first fixations overlaid on the saliency maps of each image. To determine whether the saliency model accounted for first fixation position above what would be expected by chance, nonparametric statistics (Mann-Whitney U tests) were performed to compare the medians of *fixated* saliency and *biased-random* saliency.

The fixated saliency was very low (0.0022), and was no different from biased-random saliency (0.0027, $p > .50$). Thus, saliency at fixated locations was no higher than would be expected by chance. In fact, observers generally fixated nonsalient regions in the scenes. Figure 1 demonstrates this nicely, showing that fixations tended to land on the black parts of the saliency map.

DISCUSSION

The aim of present study was to determine whether eyes and arrows are selected to the same extent within complex scenes. Although cueing studies have found that observers orient in response to central directional gaze and arrow cues in similar ways, these studies do not inform us whether the attentional system *selects* eyes and arrows to the same extent.

One possibility was that observers might select arrows as often as eyes. This would be consistent with research using the cueing paradigm showing that gaze and arrows are equivalent attentional cues, suggesting that they may be of equal social relevance. An alternative possibility was that eyes would be preferentially selected over arrows. This finding would suggest that eyes and arrows do not have equal social relevance, and would be in line with the general intuition that while eyes and arrows are equivalent at conveying directional information, eyes are special social stimuli because, for example, unlike arrows, they can communicate other important social information about people such as their age, identity, emotions, and inner attentional states. As such, one would expect humans to prioritize information from eyes over arrows.

The results of the present study were clear. When both eyes and arrows were visible in a scene, the majority of fixations went to the eyes, and very few went to the arrows (Table 1). Furthermore, an analysis of the first fixations made in the scenes revealed that observers never fixated an arrow first. Instead, participants were equally likely to fixate the eyes, heads, and text on the first fixation. This finding suggests that when people are presented with scenes containing eyes and arrows, eyes (and heads and text) capture attention but arrows do not. Moreover, we found that when observers are provided with extended periods of time to view natural scenes, they continue to show interest in the people, particularly their eyes, and continue to essentially ignore the arrows.

A general preference for people persisted in scenes in which the arrow was large and the people were small. We were interested in whether making the arrow large in comparison to the people, and reducing the eye information in the scene, would enable arrows to be prioritized. However, in those images, the arrows were again rarely fixated. Instead, the heads were fixated the most frequently overall. Again, the arrows were never fixated first. Thus, even when arrows were large, and eyes were unavailable, arrows did not receive many fixations overall relative to the people in the scene.

We were also interested in exploring whether an arrow would be preferentially selected when placed in a scene without people. Given that arrows have been thought of as social tools (Kingstone et al., 2003), one might expect them to receive more attention than other, presumably less social objects (as intuited, for instance, from the gaze/arrow cueing literature). Thus, we showed an image of a road sign with other graphic components (a "no-entry" symbol and a bunch of grapes). However, the data revealed that observers again fixated the arrow less often than the other elements of the scene. In addition, the arrow was never fixated first, but the grapes often were. Thus, although this is a single scene, the initial data suggest that even when arrows are placed within a scene without people, they do not receive much attention,

Finally, we analysed the contribution of visual saliency to observers' fixation placement. The saliency at fixated locations was remarkably low, and no higher than what would be expected by chance. This agrees with other recent studies suggesting that visual saliency provides a poor account of eye fixation patterns in complex visual scenes (Cerf, Harel, Einhäuser, & Koch, 2008; Henderson, Brockmole, Castelhano, & Mack, 2007; Nystrom & Holmqvist, 2008; Tatler, 2007; Torralba, Oliva, Castelhano, & Henderson, 2006), particularly when the task is active. In fact, it appears that task demands can completely override the effects of visual saliency in complex visual displays (Einhauser, Rutishauser, & Koch, 2008; Foulsham & Underwood, 2008; Nystrom & Holmqvist, 2008; Rothkopf, Ballard, & Hayhoe, 2007).

Before we move onto the implications of these findings, we must note some of the limitations of our study that warrant future investigation. For instance, the small number of test images along with our choice of filler images, which all contained at least one person but no arrows, could have biased observers' viewing behaviour to look at the people. However, we do not believe that this was driving observers' fixations, as we have shown in previous work that observers show a strong bias to look at the eyes when people and nonpeople images are interleaved (Birmingham, Bischof, & Kingstone, 2007). It is also noteworthy that in the real world one is repeatedly exposed to images of people and real people alike. Indeed, if anything one might reasonably make the argument that by repeatedly presenting images containing arrows to our participants we risked over-estimating how often observers normally select arrows. While that concern does not seem to have manifested itself in the present study, the traditional model cueing paradigm, which normally preselects and presents an arrow stimulus to observers for hundreds of trials, does seem vulnerable to concerns of this nature.

There are several important implications of the present findings. First, to answer the main question of the study, when eyes and arrows are presented within complex scenes and observers are allowed to select items for further processing, observers show a profound preference to select eyes rather than arrows. This is consistent with the neural evidence that humans possess brain mechanisms that are preferentially biased to processing eyes (e.g., Hoffman & Haxby, 2000; Pelphrey et al., 2004; Perrett et al., 1985). Thus, although eyes and arrows are equally good at conveying directional information, and hence produce equivalent effects on shifts of spatial attention within the cueing paradigm, they are not given equal priority by the attention system via selection within complex scenes. On the contrary, observers show a bias to select information from people's eyes.

Second, arrows were not only selected less often than eyes, they were typically selected less often than most other scene regions. This was true even when the arrows were large, and when people were absent from the scene. What makes this finding interesting is that even though it is clear that an arrow will produce reflexive shifts of attention within the context of the cueing paradigm, observers show very little interest in arrows within the context of complex scenes. One interpretation of these findings is that the importance of arrows as social communicative tools may be restricted to situations in which direction or location information is task-relevant (e.g., following an exit sign on the highway; determining which lane is the turning lane, etc.). Indeed, the cueing paradigm is just that—a situation in which the task is to detect a target at a location on the screen. There, even though arrow direction is not spatially informative about where the target will appear, spatial location is a task-relevant dimension, i.e., the only factor over which the target may vary is its spatial position, and the only factor over which the cue may vary is whether it is spatially congruent or incongruent with the target. That said, it may be worthwhile for future studies to map out fixation performance to eyes and arrows within complex scenes under task instructions that emphasize either gaze or arrows in order to determine if, when, and for how long, observers demonstrate a selection bias for arrows. Based on previous work that has shown that people have a profound bias to look at eyes and heads regardless of task instruction (Birmingham et al., 2008b; Cerf et al., 2008), it is possible that any selection bias for arrows may be fleeting.

A third implication of the present study is that despite a general preference to select people from complex scenes, there appears to be a hierarchy to the selection of "people parts". If the people are large enough so that the eyes are visible, observers will concentrate their fixations on the eyes, followed by the heads, and then the bodies. If the people are too small for the eyes to be discriminated, then observers will concentrate their fixations on the heads, followed by the bodies. Thus, although there is a general preference for people, observers preferentially fixate the eyes if they are available, then heads, then bodies. This is consistent with Perrett et al.'s (1992) model of social attention, in which gaze is at the top of a hierarchy of social attention cues, followed by head position, and then body position.

Fourth, in light of the data indicating an enormous preference to select eyes over arrows, we can return to our initial consideration of the cueing literature, which indicates that eyes and arrows are equivalent social cues. This position must be rejected. We favour the alternative view that the similarity between gaze and arrow cues within the cueing paradigm occurs because the cueing paradigm is not measuring much of what makes eyes and arrows different. Indeed, because similar cueing effects are found for gaze, arrows, words (Hommel et al., 2001), wagging tongues (Downing, Dodds, & Bray, 2004), and even eyes and arrows drawn within a gloved hand (Quadflieg, Mason, & Macrae, 2004), it appears that the cueing paradigm may measure how well different cues convey directional information. 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 rather than the social equivalence of eyes and arrows.

We do not mean to suggest that using the cueing paradigm to study the orienting of attention in response to gaze direction is necessarily unimportant. However, it may be the case that the cueing paradigm is not measuring how this process occurs in the real world, where different stimuli are embedded in rich social contexts and compete for selection. We propose that a more favourable research approach is one that tries to measure social attention in more real-world settings. For instance, Kuhn and Land (2006) showed that the vanishing ball illusion, in which a ball is perceived to have vanished in mid-air, relies strongly on social attention cues from the magician performing the trick. That is, when the magician pretends to toss a ball upwards but secretly conceals the ball in the palm of his hand, observers are much more likely to perceive the ball travelling upward and vanishing when the magician looks upwards 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 example of how social attention, both with regard to *orienting to (selecting) social cues* and *orienting in response to social cues*, can be studied successfully using rich, complex stimuli.

Furthermore, it would certainly be advantageous to move from eye monitoring people while they view *images* of people to eye monitoring people while they view *real* people. By definition, 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. There is some intriguing initial research that has begun to examine the effects of social attention in real-world settings (e.g., Gullberg, 2002; Kuhn & Tatler, 2005; Tatler & Kuhn, 2007). For example, recent work has shown that the effect of misdirection in a cigarette magic trick (occurring when the magician looks at one hand while secretly dropping a cigarette with the other, giving the impression that the cigarette has "vanished") is stronger in live demonstrations than in videotaped demonstrations (Kuhn, Tatler, Findlay, & Cole, 2008). Such findings suggest that eye gaze is a more powerful social attention stimulus in the real world than in images of the real world. This possibility opens up an enormous range of questions that investigations of social attention will most certainly begin to explore.

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