Durham University

Durham Research Online

Deposited in DRO:

30 June 2015

Version of attached file:

Accepted Version

Peer-review status of attached file:

Peer-reviewed

Citation for published item:

Cole, G.G. and Smith, D.T. and Atkinson, M.A. (2015) 'Mental state attribution and the gaze cueing effect.', Attention, perception, psychophysics., 77 (4). pp. 1105-1115.

Further information on publisher's website:

https://doi.org/10.3758/s13414-014-0780-6

Publisher's copyright statement:

The final publication is available at Springer via https://doi.org/10.3758/s13414-014-0780-6.

Additional information:

Use policy

The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a link is made to the metadata record in DRO
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

Please consult the full DRO policy for further details.

Durham University Library, Stockton Road, Durham DH1 3LY, United Kingdom
Tel : +44 (0)191 334 3042 | Fax : +44 (0)191 334 2971
http://dro.dur.ac.uk

Mental state attribution and the gaze cueing effect.

Geoff G. Cole[1], Daniel T. Smith[2], Mark Atkinson[1]

1. Centre for Brain Science, University of Essex.
2. Department of Psychology, University of Durham.

Running head: Gaze cueing and ToM.

Key words: Gaze cueing – Vision – Theory of mind – Social attention – Perspective taking

Submitted:

Word count: 7845

Address for correspondence

Geoff G. Cole
Centre for Brain Science
University of Essex
Wivenhoe Park
Colchester
CO4 3 SQ
E-mail: ggcole@essex.ac.uk
Tel: 01206 872331
Fax: 01206 873801

Abstract

Theory of mind is said to be possessed by an individual if they impute mental states to others. Recently, some authors have argued that such mental state attributions mediate the gaze cueing effect in which observation of another individual shifts an observer's attention. Employing a technique commonly used to assess mental state attribution in non-human animals, we assessed whether a gaze cue's ability to see a target is necessary for an attention shift to occur. In three experiments the gazing agent could either see the same thing as the participant (i.e., target) or had their view obstructed by a physical barrier. We found robust gaze cueing effects even when the observed agent in the display could not see the same thing as the participant. These results suggest that the attribution of 'seeing' is not necessary for the gaze cueing effect to occur.

Introduction

In 1978 Premack and Woodruff published a landmark paper in which they introduced the Theory of Mind (ToM) concept. The authors stated that a ToM can be assumed to be possessed by an individual if they are able to impute mental states to themselves and others. Empirically, their paper solely concerned whether the chimpanzee is able to make such mental state attributions. Thus the ToM notion was originally used within an animal context and became a useful way of characterizing animal cognitive ability in a variety of species (e.g., Dally, Emery & Clayton, 2005; Penn & Povinelli, 2007). Soon after Premack and Woodruff's paper appeared a number of developmental psychologists applied the ToM idea to human infants (e.g., Wimmer & Perner, 1983). A central concern was to identify the age at which humans acquire ToM and, more practically, whether ToM tests do indeed index a child's ability to infer the mental states of others. ToM has now been applied within a number of other contexts including, for instance, schizophrenia (Harrington & Siegert, 2005), autism (Baron-Cohen, 2000), altzheimer's disease (Gregory et al. 2002), decision-making (Torralva et al. 2007), and evolutionary psychology (Povinelli & Preuss, 1995).

A number of authors have recently argued that mental state attributions occur during gaze cueing, in which the observation of where another person is looking influences perceptual processing in the observer (Nuku & Bekkering, 2008; Samson, Apperly, Braithwaite, Andrews, & Scott, 2010; Teufel et al., 2009; Teufel, Alexis, Clayton, & Davis, 2010; Teufel, Fletcher, & Davis, 2010). In the paradigm gaze cueing experiment a face is presented in the centre of a display with its eyes and/or head directed to the left or right. A target is then presented either at the gazed-at location or in the opposite hemifield. Results typically show that reaction time (RT) to determine the identity or presence of a target is reduced when presented in the gazed-at position (Friesen & Kingstone, 1998; Langton & Bruce, 1999). This is usually taken as evidence that seeing gaze triggers a shift of attention in the observer.

The basic gaze cueing effect is highly robust, and many variations of this paradigm have been developed all aimed at understanding various aspects of social cognition (e.g., Frischen & Tipper, 2004; Hietanen, 2002; Kuhn, Tatler, & Cole, 2009). However, the cognitive mechanisms underlying the cueing effects remain controversial. The most common explanation suggests that gaze cueing is a reflective/bottom-up process that is driven by mechanics of eye deviation perception (e.g., Baron-Cohen 1995; Bayliss, di Pellegrino, & Tipper, 2004; Driver et al., 1999; Fernandez-Duque & Baird, 2005). According to this view, attention is shifted from the eyes because they deviate towards the gazed location. Contrasting this explanation is the mental state attribution account. Nuku and Bekkering (2008), for instance, have argued that gaze cueing occurs because the observer infers "that the agent is physically able to attend to the target". Indeed, not only does gaze indicate where a person is looking it also suggests that the individual is attending/perceiving something or someone at the gazed location. As Calder et al. (2002) additionally point out, gaze “implies that the person may have some intention or goal towards this particular object. In other words, gaze engages the mechanisms involved in the attribution of intentions and goals to others…”. Nuku and Bekkering based their conclusion on results from two variants of the gaze cueing procedure in which the agent's head was turned to the left or right. Critically, the agent's ability to see was manipulated by having its eyes closed versus open or being blocked out by a dark rectangle versus wearing sunglasses. Results showed larger cueing effects when the agent was able to see the target. This clearly suggests that inferring the agent's mental state (i.e., ‘seeing’ versus ‘not seeing’) influenced the degree to which the agent shifted the observer's attention.

Teufel et al. (2010) and others (e.g., Caron, Butler, & Brooks, 2002) have however pointed out that the kind of design used by Nuku and Bekkering confounds potential mental state attribution and properties of the stimuli. Specifically, Nuku and Bekkering's experiments not only manipulated the agent's perception but also characteristics of the agent's eye region which may have generated the results obtained. Teufel et al. (2010) eliminated this potential confound by presenting agent's who wore mirrored goggles and participants were told that these individuals could either see or not see (i.e., the goggles were either transparent or opaque). Importantly therefore, the inducing stimuli were identical in both seeing conditions with only the participants belief being manipulated. As with Nuku and Bekkering's study, Teufel et al. observed greater gaze cueing when participants were informed that the agent could see. In a second experiment Teufel et al. manipulated the probability with which the face cued the target location such that the target was twice as likely to occur at the uncued location. It is known that gaze cues are able to shift attention even when an observer knows that a target is more likely to appear at a non gazed-at location (e.g., Driver et al., 1999). Teufel et al. found that participants were only able to voluntarily shift their attention away from the gazed location when told the agent could not see through the goggles. As with Nuku and Bekkering’s observations, this again suggests that gaze cueing is modulated according to whether the agent can see or not. In another study using mirrored goggles, Teufel et al. (2009) employed a gaze perception aftereffect in which prolonged exposure to a face gazing in one direction alters subsequent perception of where a face is looking (Jenkins, Beaver, & Calder, 2006). Teufel et al. reported that this effect only occurred when the observer believed the agent could see through the goggles.

Langton (2009) however, has urged caution in concluding that mental state attribution modulates gaze cueing. Langton suggests the possibility that the important attribution may concern whether the agent's perceptual mechanisms are functioning or not rather than their mental state. Langton also makes the point that typical gaze cueing studies present an isolated gazer that is not actually looking at anything. This makes it difficult to attribute a genuine mental state to the agent. Furthermore, as Teufel et al. (2010) also points out, the mental state account does not concur with one of the basic findings from the large body of gaze cueing work; attentional shifts induced by a gazing agent appear to be largely reflexive. For example, gaze-cued shifts of attention are characterized by their rapid time-course and resistance to cognitive control (e.g., Driver et al., 1999). Furthermore, objects that have no mental state (e.g. a glove) but incorporate a pair of eyes are effective in shifting attention to the looked-at direction (e.g., Quadflieg, Mason, & Macrae, 2004) and gaze cueing is unaffected by cognitive load (Law, Langton, & Logie, 2009). These findings suggest that gaze cueing is largely controlled by bottom-up mechanisms with little contribution from higher processes that are responsible for mental state attribution.

~~Clearly, humans often make explicit mental state attributions in social situations. For instance, when one wonders what another individual is looking at. However, the implication of applying ToM mechanisms to gaze cueing is that the attribution of a mental state to others is fast and involuntary. This notion has been made explicit by~~

~~Samson et al. (2010) who argued that humans rapidly and spontaneously compute the perspective of another individual. In their basic experiment an image of a room is shown. In the centre is a human avatar which is looking either towards the left-hand wall or the right-hand wall. The participant is asked to judge the number of discs located on the two walls and is required to do this either from their own perspective or the avatar's perspective. Crucially, the experimenters manipulated consistency of the avatar's and participant's perspective; on some trials the avatar and participant could see the same number of discs whilst on other trials they could see a different number of discs. For example, if the avatar looked to the left-hand wall and one disc was located on each of the two walls, the avatar saw one disc and the participant, by virtue of seeing the whole room, saw two. By contrast, if two discs appeared on the left-hand wall and none of the right, both participant and avatar saw the same number of discs, i.e., two, both located on the left-hand wall. Samson et al.'s central results showed that RT to make the disc number judgment was reduced when the avatar's viewpoint was consistent with the participant's relative to when their viewpoints were inconsistent. Importantly, this occurred even when participants were told to ignore the avatar's perspective. The authors concluded that these results are due to the discs being "*seen by the other person*" (original italics) and that computation of other people's perspective occurs spontaneously.~~

~~In addition to the behavioral work on gaze cueing and perspective taking, evidence for spontaneous ToM processes in social attention has come from neuroimaging studies. Whilst measuring blood flow from a number of brain areas including the medial prefrontal (MPF) cortex, Calder et al. (2002) presented observers with photographs of people whose eyes gazed in various positions. Participants were asked to indicate~~

~~whether the models had thick or thin eyebrows. Importantly therefore, observers were not asked to consider the mental state of the models; they were only asked to make a simple perceptual judgment. Results showed that direct gaze was particularly associated with activity in the fusiform gyrus. This can be expected given this region's well known involvement in face processing (Kanwisher, Mcdermott, & Chun, 1997). More importantly however was the observation that averted gaze lead to greater activity in the MPF cortex. The significance of this is that the MPF region is thought to be concerned with inferring another person's thoughts, goals and intentions (Frith & Frith, 1999). In other words, activity in a brain region associated with ToM was automatically activated when a person viewed averted gaze.~~

Comment [DTS1]: I wonder if this material is still necessary?
The goal of the revised manuscript is to test the claim that the mental state of an avatar is an important in determining whether the avatar will elicit a shift of attention. We argue that previous studies are confounded by obscuring the eyes. We address the confound by manipulating the properties of the scene in such a way as to change the mental state of the avatar (i.e. we change the perspective of the avatar). It seems to me that we could move directly from the issues raised by Langton to the rationale for our study. This way we don't get bogged down in the issue of automaticity of perspective taking.

The principal aim of the present work was to test whether the attribution of seeing is necessary for gaze cueing. To address this issue we conducted three gaze cueing experiments in which we manipulated the agent's perspective by employing a technique commonly used in studies that assess mental state attributions of seeing in non-human animals (e.g., Hare, Call, & Tomasello, 2001). Animal behaviour work often uses a physical barrier positioned such that it either allows a stimulus to be seen or occludes it. For instance, a chimpanzee may be tested to determine whether it knows that another chimpanzee is unable to see a food item due to the position of the occluding barrier. Similarly, in the present work, rather than changing some aspects of the cueing agent we placed a physical barrier either side of the agent. On 'non-seeing' trials these barriers fully occluded targets presented to the left or right. By contrast, on 'seeing' trials the barriers were moved so that they allowed the target to be seen. If the attribution of seeing is necessary for gaze cueing then the effect (as suggested by Teufel and others) should be abolished when the agent's vision is restricted by the barriers. Critically, Our use of physical barriers thus avoids potential confounds that arise when aspects of the gazing agent itself are manipulated such as when goggles are worn or the eyes are blanked out.

Experiment 1

In Experiment 1 the cue was a photograph of a female model whose head and gaze was oriented to the side (see Figure 1). We also varied the interval between the onset of the cue and target to assess whether any mental state attribution effect changed over time.

Method.

Participants. Thirty-eight participants from the University of Essex took part in exchange for course credit.

Stimuli and apparatus. The gaze cue agent was the head of a female aged 30. She looked out from a cardboard box that measured 18.9° in height and 12.8° in width. Door-like structures were incorporated into the sides of the box. When these doors were open the agent could look out to the sides but could not do so when closed. This manipulation therefore generated the seeing and non-seeing conditions. When gazing to the side the model was asked to also turn her head. The targets were black letters, S and H (3.5° high, 3.3° wide), that were placed to the left or right during the photographing. Thus the model was actually looking at the letters. We edited the photographs so that only the cardboard box, the model, and the target letters were visible. The experiment was driven by an eMac computer incorporating a CRT monitor.

Design and procedure. A within-participant, 2 x 2 x 3 factorial design was used. The first factor manipulated cue validity (valid, invalid) and the second factor manipulated visibility (seeing, non-seeing). The third factor manipulated the SOA between the appearance of the cue and target. The three levels were 100 ms, 400 ms, and 800 ms. In order to ensure that any mental state attribution did not need to be computed trial-by-trial the visibility conditions were blocked and their presentation order counterbalanced. The SOA and validity manipulations were presented within block and presented in random order. The two blocks of trials in the experiment presented the (empty) cardboard box as background with a fixation point located in its middle. Participants were explicitly told that the face could either see or not see the target letter depending of which barrier was presented. They were informed of this at the beginning of each visibility block. Each trial began with the presentation of the model for 100, 400, or 800 ms then the target. This display remained until response and the beginning of a trial was initiated by the participant’s response on the previous trial. Thirty-six valid and 36 invalid trials were presented in both visibility blocks for each SOA, thus generating 432 trials in total. The numbers of different trial types were balanced such that the number of target types and target locations were equated. The face validly cued the target location on 50% of trials. Twenty four practice trials were included.

Results and discussion

Data from two participants were excluded because their error rate was greater than 20%. 3.4% of responses were defined as outliers using the same criterion described previously and omitted from further analysis. Figure 2 shows mean RTs for each condition. An ANOVA with validity, visibility and SOA as within-participants factors revealed a significant main effect of validity, F(1, 35) = 19.4, $p < 0.001$, $\eta^2 = .36$, and SOA, F(2, 70) = 51.1, $p < 0.0001$, $\eta^2 = .59$, but no significant main effect of visibility, F(1, 35) < 1. The interaction between validity and visibility was not reliable, F(1, 35) = 2.6, $p > 0.11$, neither was the three-way interaction, F(1, 35) <1. The interaction between validity and SOA was however significant, F(2, 70) = 13.1, p

Comment [DTS2]: We need to describe the criterion here

< 0.001, $\eta^2 = .27$. With respect to the error rates, no effects were significant, all Fs < 2.9, all ps > 0.05.

The first notable aspect of these results is the presence of an overall gaze cueing effect. Participants were faster to identify the target when it appeared in the cued location. This replicates the many previous reports of eye gaze triggering a shift in an observer's attention (e.g., Friesen & Kingstone, 1998; Langton & Bruce, 1999). The significant validity x SOA interaction is also in line with other gaze cueing studies demonstrating that the gaze cueing effect builds up over time (e.g., Driver et al. 1999). Indeed, Figure 2 shows no cueing effect occurred at 100 ms SOA. Importantly however is the absence of any visibility effect on gaze cueing; this is demonstrated by the lack of visibility x validity interaction. The demonstration that the face cued attention despite having its vision restricted suggests that the mental state attribution of 'seeing' is not necessary for the gaze cueing effect. Given the lack of a gaze effect at 100 ms SOA we performed additional analyses to assess any influence of visibility on the gaze effect in the 400 ms SOA condition. This condition may be the important condition to examine whether mental state influences gaze cueing because Teufel et al. (2010) observed modulation of gaze cueing at 400 ms SOA. Results however showed no significant interaction between validity and visibility, F(1, 35) = 1.9, p > 0.17. Indeed, if one looks at the means only (see Figure 2) there is a larger cueing effect in the non-visible condition. This is also apparent in the 800 ms SOA condition. In sum, the results from Experiment 1 reveal a robust cueing effect but one that was not modulated according to whether the agent could see the target or not. These data are not consistent with the claim that gaze cueing is contingent on the mental state of the avatar.

Experiment 2

The purpose of Experiment 2 was to assess our central question concerning mental state attribution and gaze cueing using a different behavioural measure to that used previously. In Experiment 1 we employed speeded motor responses to measure the gaze cueing effect. However, processes indexed by RT may be adversely affected by response noise. As Milliken and Tipper (1998) point out, “the act of measurement may contaminate the measurement itself’’ (p. 216). An alternative to measuring processes that involve response end mechanisms is to present stimuli under degraded conditions (e.g., brief displays) and measure accuracy of perception. Because such measurements involve participants making a purely perceptual decision, rather than emitting a speeded motor response, such measurements are less contaminated by response noise. The use of accuracy as a potentially more sensitive measurement compared with RT has previously been noted by many authors. For instance, Santee and Egeth (1982) suggested that under the ‘‘data limited’’ conditions (Norman & Bobrow, 1975) of briefly presented displays accuracy measures are more sensitive to perceptual processes (see also, Gellatly, Cole, Fox, & Johnson, 2003; Milliken & Tipper 1998; Rafal, Smith, Krantz, Cohen, & Brennan, 1990). Empirical support for this has come from Cole, Kuhn, Heywood, and Kentridge (2009) who showed that although colour “singletons” do not automatically attract attention when RT is used to index capture they do so when a ‘one-shot’ change detection method is used.

In Experiment 2 therefore we employed a change detection task in which so-called change blindness is induced. Change blindness is the phenomenon whereby observers often fail to notice a change to a visual scene if the change is masked by simultaneous visual transients (e.g., Simons & Rensink, 2005). The rationale for our use of the procedure is based on the link between attention and the degree to which change blindness is induced (e.g. Rensink, O' Regan, & Clark, 1997; Smith & Schenk, 2008). If a stimulus has attentional priority one should expect it to be less susceptible to change blindness relative to a stimulus that does not receive attentional priority (Cole, Kentridge, & Heywood, 2004; Cole, & Kuhn, 2009; Cole, & Kuhn, 2010; Pisella, Berberovic, & Mattingly 2004; Ro, Russell, & Lavie, 2001; Scholl, 2000; Smith & Schenk, 2008, 2010). Experiment 2 used the one-shot variant of the procedure in which the changed item occurred once only. Crucially, the change was either at a gazed-at location or elsewhere in the display. As with Experiment 1 the gazing agent could either see the same stimuli as the participant or not.

Method.

Participants. Eighteen undergraduate participants were recruited from Durham University.

Stimuli and apparatus. The stimuli were based on those described for Experiment 1 with the following exceptions. The agent gazed at one of four positions (top-right, top-left, bottom-right, bottom-left). For non-seeing trials the barriers were green that obscured the agent’s vision of the probe stimuli. For the seeing trials windows appeared in the barriers which allowed the agent a clear view of the targets presented at the bottom and top positions. The stimulus letters were drawn from the set E, U, O, P, S, F, H, L, and A. Stimuli were generated using a Cambridge Research Systems ViSaGe graphics card and displayed on a 17-inch Sony Trinitron CRT monitor with a refresh rate of 100Hz. Responses were collected using a button-box with two response buttons. Participants were seated 57 cm from the monitor and the head was supported by a chin rest.

Design and procedure. A within-participant, 2 x 2 factorial design was used. The first factor manipulated cue validity (valid, invalid). The second factor manipulated visibility (seeing, non-seeing). Trials began with the appearance of the environment and a fixation point at the centre of the monitor for 1000 ms. The letter stimuli then appeared for 1000 ms, followed by the gaze cue, which was present for 100 ms. The entire stimulus array was then occluded by a black mask for 50 ms. This mask was replaced by the changed stimulus array and gaze cue, which was present until the participant responded. There was a 2000 ms inter-trial interval during which a fixation point was presented on a blank grey screen. Seeing and non-seeing trials were randomly interleaved. A total of 200 trials were presented with 20% of these being no-change trials. When the target was present the agent validly cued the target location on 25% of trials. Participants were instructed to report seeing a change only when they were confident that one of the letters had changed. In practice, this meant the participant had to know either the location or the identity of the change. If they were unsure whether a change had occurred they were instructed to report that they had not detected a change.

Results and discussion

The overall false alarm rate was 6.2%. Figure 3 shows mean accuracy for the four conditions. An ANOVA with validity and visibility as within-participants factors revealed a significant main effect of validity, $F(1, 17) = 16.9$, $p < 0.01$, $\eta^2 = .5$, but no significant main effect of visibility, $F(1, 17) < 1$. The interaction was not significant, $F(1, 17) < 1$. As with Experiment 1, these data again show a robust gaze cueing effect. However, as was also observed in Experiment 1, the effect was not influenced by what the agent could see.

Experiment 3

A growing number of studies have begun to examine visual cognition during real social interaction. Such studies have lead to some revisions of what is known about visual attention (see Skarratt, Cole, & Kuhn, 2012, for an extensive review). For instance, gaze cues were for a long time assumed to be unable to induce inhibition of return (IOR; Posner & Cohen, 1984). However, attention shifts generated by observing the eyes of a real person sat opposite produce large and robust IOR (e.g., Cole, Skarratt, & Billing, 2012; Skarratt, Cole, & Kingstone, 2009; Welsh et al., 2005). One can argue that issues concerning mental state attributions will particularly benefit from experiments that involve interactions with real people. This is based on the assumption that it should be easier to compute the mental state of a real person compared with a schematic or even photographed representation. In Experiment 3 therefore we used a real person as the cue who sat facing the participant before looking towards one of the two possible target locations (see Figure 4). Physical barriers were located either side of the gazer that either allowed the targets to be seen or not. This experimental set up also controlled for a possible confound that may have existed in Experiments 1 and 2. Although participants in those experiments were informed that the barriers either allowed the targets to be visible or not, it is not entirely evident that this was inferred. Participants may not have actually believed that the barriers rendered the targets non-visible in the occluded conditions. This could have been for many reasons including poor depth clues which may not have adequately conveyed the intended positions of the targets. Presenting a real person adjacent to real barriers ensured no ambiguity as to what the cue person could see.

Method.

Participants. Sixteen participants from the University of Essex took part in exchange for course credit.

Stimuli and apparatus. The gaze cue person was the third author. He sat approximately 160 cms from the participant with his back to a projector screen lit from behind. The visible part of the screen measured 98 cms in height and 175 cms in length. The targets could appear 65 cm to either the left or right of the cue person’s nose. Time was taken to ensure that the cue’s nose was always located centrally between the target locations. The occluding barriers were extendable screens that measured 85 cms in height and were extended to be 40 cms wide. They were positioned on two tables located on either side of the cue person. The targets were black letters presented on a uniform white screen. Targets were S and H that measured 13 cms in height and 11 cms in width. The experiment was driven by a Mac Book Pro and responses made via a Cedrus Button Box. A standard LCD monitor was additionally located behind the participants head (see below).

Design and procedure. A within-participant, 2 x 2 factorial design was employed. As reported previously the two factors were validity (valid, invalid) and visibility (seeing, non-seeing). Each trial effectively began with the cue-person returning their head/gaze from the side to look straight ahead and directly into the eyes of the participant. Approximately 500 ms after this head return was completed a 3-2-1 visual countdown (each 500 ms) was presented to the cue-person via a computer monitor located behind the participant (and above their head) and was only visible to the cue-person. This countdown occurred at the top of the monitor on either the left or right and informed the person-cue which side he should look towards when the countdown was completed. The position of the monitor enabled this information to be seen peripherally by the cue-person, i.e., without the need to look away from the participant. This countdown procedure ensured that the person-cue moved his head at almost the same moment on each trial. The target appeared exactly 600 ms after the countdown was completed. This exact timing was achieved via the use of a video splitter; a single computer presented identical information to both the cue-person's monitor and participant's screen. The countdown information was of course hidden from the participant (by a black cloth hung over the top of the screen). We estimated that the total head movement time was approximately 600 ms. Thus the target appeared at about the same time as cue-person finished turning their head, or to put another way, 600 ms after the cue person began their head movement.

The visibility condition was blocked and presentation order counterbalanced. Manipulating visibility was achieved by placing the barriers such that they either touched the presentation screen (non-seeing) or they were moved forward by 25 cms allowing the person-cue to see the targets. Although it was clearly evident that this barrier positioning rendered the targets visible or not, each participant was asked to confirm that this was the case. All agreed. Every other aspects of the experiment were as reported previously.

Results and discussion

Using the same definition as described previously, 2.2% of responses were deemed to be outliers and omitted from further analysis. Figure 5 shows mean RTs for each of the four conditions. An ANOVA revealed a significant main effect of validity, F(1, 15) = 34.6, $p < 0.001$, $\eta^2 = .7$, but no significant main effect of visibility, F(1, 15) = 1.8, $p > .19$. The interaction was not significant, F(1, 15) < 1[1]. With respect to errors, there were no significant main effects of validity, F(1, 15) < 1, nor visibility, F(1, 15) = 2.1, $p > .17$, and the interaction were also not significant, F(1, 15) = 1.4, $p > 0.24$. Overall, these results concur with those reported in Experiments 1 and 2. A cueing effect was observed but was not dependent on what the cueing agent could see.

General discussion

The ability to infer mental states of other individuals is one of the central tenets of social cognition. Furthermore, the orienting of one's attention around a visual scene based on the behaviour of another individual (i.e., social attention) can clearly occur as a result of a mental state attribution; as when we orient gaze because we would like to know what another person is looking at. Across three experiments, we have assessed whether an observer needs to attribute 'seeing' to a gazer in order for the gaze cueing effect to occur. Results have shown robust cueing effect independent of whether the gaze cue could see that target or not. These results are clearly discrepant with previous studies that observed apparently robust effects of mental state on gaze cueing (Nuku & Bekkering, 2008; C. Teufel, Alexis, Clayton, & Davis, 2010; Christoph Teufel, Fletcher, & Davis, 2010). In the following section we propose a new theoretical model of gaze cueing that explains why mental state attribution effects vary across different experimental designs, and makes new predictions about the conditions required in order to observe mental state effects on gaze cueing.

A Schema Theory of Gaze Cueing

To understand the boundary conditions of gaze cueing, we propose that gaze cueing can be considered within the theory of action control proposed by Norman and Shallice (1986) and Cooper and Shallice (2000; in this context 'actions' can refer to cognitive operations and motor outputs). Central to this view is the idea that action control is achieved by the activation of program-like representations called schemas. These schemas specify highly learned sequences of actions required to achieve a specific goal. Schemas are activated in a bottom-up fashion in response to the properties of the external environment. However, the threshold for activation of a schema can be modulated in a top-down manner by ~~using top-down executive control~~a number of factors, including the goals and intentions of the observer~~ (this corresponds to an ‘attentional resource’)~~. Once activated, the operations specified by the schema are executed automatically (i.e. they are fast, difficult to suppress and do not require attention). With respect to social attention, we propose that repeated association between observed gaze direction and relevant stimuli leads to the formation of a gaze cueing schema that allows very rapid allocation of processing resources to the gazed-at location. This idea is a more formal expression of the view that social attention is the consequence of learned associations, rather than an innate response to biological stimuli (e.g. Brignani, Guzzon, Marzi, & Miniussi, 2009).

The advantage of placing gaze cueing in this framework is that the factors that mediate the selection/deselection of schemas have been precisely specified by Cooper and Shallice (2000). Specifically, Cooper and Shallice argue that schemas have an activation value, which is the threshold incoming excitatory influences must surpass in order to activate the schema. The activation value can be influenced by experience such that repeatedly activating a schema lowers is activation value and top-down ~~executive~~ control process, which can raise or lower thresholds. The level of excitation is determined by the presence of stimuli that match the trigger properties of the schema and lateral influences from competing schemas. The probability of a schema becoming activated therefore depends on an interaction between the excitatory power of incoming sensory stimulation, practice and level of excitatory/inhibitory influence being exercised by the ~~central executive.~~top-down influences

The schema theory of gaze cueing suggests a number of predictions about the conditions in which gaze cueing should be observed. First, the probability of engaging the gaze cueing schema will depend on ~~the~~ the interaction between ~~strength of the~~ bottom-up sensory information regarding gaze direction and the ~~availability of executive resources~~top-down influences relating to the goals and beliefs of the observer. ~~.~~ If cue information is powerful (e.g., it contains unambiguous information about gaze direction), it should be very difficult to prevent schema activation, regardless of ~~availability of executive resources~~the top-down influences, so one would predict rapid gaze cueing even under conditions where the observer is motivated to attend to an uncued location. ~~Second~~However,~~,~~ when cue information is weaker (e.g., when the cue could be eyes or could be something else, or when gaze direction is ambiguous), schema activation is more sensitive to the influences of ~~executive~~ top-down control. In this case, cueing effect should be reduced or ~~-~~absent.~~ if the observer is motivated to inhibit schema activation~~.~~–~~ Secondly, top down modulation of the cueing schema should be possible if the observer is sufficiently motivated to inhibit schema activation, even when the cue information is unambiguous.

Activation is probabilistic- i.e. on some trial the schema will be activated, leading to a fast RT whereas on other trials it will not. If the schema is activated on the majority of trials a large and consistent advantage at the cued location will emerge. If it is activated on a small number of trials there will be fewer valid trials with a fast RT, leading to a smaller mean difference. So, we do propose a threshold model,

These two predictions are consistent with the majority of the empirical data. Specifically, studies that use unambiguous eye-gaze cues tend to produce rapid, involuntary gaze cueing even when participants know that gaze direction is non-predictive (e.g. Driver et al., 1999), and there is contextual information suggesting that gaze-direction is irrelevant. However, when some ambiguity regarding gaze direction is introduced by obscuring the eyes and using head-gaze as a cue (e.g., Nuku & Bekkering 2008; Teufel et al., 2009; Samson, et al. 2010), or making the cues status as eyes ambiguous (Ristic & Kingstone, 2005) gaze cueing effects are modulated by top-down knowledge that the cue can or cannot 'see'.

Third, the reflexive gaze cueing effect should follow a developmental trajectory, such that gaze cueing in infants and young children should be slow and under conscious control, but that as the schema becomes established the cueing effect should become increasing fast but resistant to cognitive control. Thus, young children should show weak cueing effects, particularly under conditions of high cognitive load, whereas older children and adults should be unaffected by cognitive load (this second prediction is consistent with recent data from Law et al., 2009). There should also be a systematic reduction in the latency at which cueing effects can be observed as age increases. Fourth,

modulation of the gaze cueing schema depends on the availability of executive resources, so reducing the availability of these resources by imposing cognitive load or engaging in ego-depletion (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Muraven, & Tice, 2000) should limit the capacity for schema control. The model therefore predicts that the *modulation* of gaze cueing by mental state attribution will be reduced or abolished under conditions of high cognitive load (see Schneider, Lam, Bayliss, & Dux, 2012, for support). Fifth, the usual response to seeing averted gaze is to orient the eyes to the gazed-at location so a gaze cueing schema may produce concurrent activation of the oculomotor system, ~~and the usual response to seeing averted gaze is to orient the eyes to the gaze-at location~~. ~~However, this activation does not have a functional role in the shift of attention~~. This prediction is consistent with recent evidence that gaze-cues engage the oculomotor system (Grosbras, Laird, & Paus, 2005; Kuhn & Kingstone, 2009; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002), but that this activation is not required for gaze cueing (Friesen & Kingstone, 2003). Additionally, there is nothing special about the social aspect of gaze-cues. The model predicts that any over learned cue-target association can become encoded as a schema and thus show the same pattern of results as gaze cueing. This prediction is consistent with the well established finding that arrow cues trigger attention shifts that are behaviourally similar to those triggered by gaze cues (Ristic, Friesen, and Kingstone 2002; Stevens et al., 2008; Tipples 2002), and recent evidence that overtraining any arbitrary association between stimulus property and spatial location can produce rapid, involuntary shifts of attention (Guzzon, Brignani, Miniussi, & Marzi, 2010)).

Finally, the schema theory of gaze cueing explains why the phenomenon is observed in persons with autism (Leekam, Hunnisett, & Moore, 1998), a finding hard to explain from a mental state perspective. Specifically, as the cueing effect is the product of learning stimulus-response associations, and this process is intact in autism, people with autism should show reflexive cueing, assuming they have been exposed to associations between gaze and relevant stimuli during development. However, these participants should experience problems with the modulation of gaze cueing in response to the mental states of an avatar, because they do not attribute mental states to the avatar (they assume it sees what they see), so are not motivated to exert control over schema activation.

In summary, we have found that the attribution of ‘seeing’ is not necessary for gaze cueing to occur. The irrelevance of an observed agent’s point-of-view was maintained for both depicted and real life faces, and in tasks that index attention using both RT and response accuracy. We have proposed a Schema Theory of Gaze cueing, which argues that mental state attribution can only influence reflexive gaze cueing when the information about gaze-direction is ambiguous. This approach accounts for the failure to observe effects of mental state attribution in the current study, the positive results of previous studies, and makes clear predictions about the results of future empirical studies.

Footnote

1) In the mental attribution studies of Teufel et al. (2010), data was analysed via an "inverse efficiency" index first proposed by Townsend and Ashby (1978). In this analysis RT is divided by accuracy. For all our RT experiments we present results based on conventional analysis in which RT is not dependent on accuracy. We did however reanalyse our two RT gaze cueing experiments (i.e., Experiments 1 and 3) with respect to inverse efficiency. The results were largely the same. Importantly, all validity/visibility interactions were non-significant (all ps > .2)

Acknowledgements.

We would like to thank Dr Keira Ball and Ms Emma Morgan for additional data collection, Rebeccah-Claire Billing and Damien Wright for assistance during the development of this work, and Roger Deeble for technical help.

References

Baron-Cohen, S. (2000). Theory of mind and autism: A review. *International Review of Research in Mental Retardation, 23,* 169-184.

Baron-Cohen S. (1995). The eye direction detector (EDD) and the shared attention mechanism (SAM): Two cases for evolutionary psychology. In: Moore C, Dunham PJ, editors. Joint attention: Its origins and role in development. Hillsdale, NJ: Erlbaum; 41–59.

Baylis, G. C. and Driver, J. (1992). Visual parsing and response competition: The effect of grouping factors. *Perception and Psychophysics, 51,* 145-162.

Bayliss, A. P., di Pellegrino, G., & Tipper, S. P. (2004). Orienting of attention via observed eye gaze is head-centred. *Cognition, 94,* B1-B10.

Baumeister, R. F., Muraven, M., & Tice, D. M. (2000). Ego depletion: A resource model of volition, self-regulation, and controlled processing. *Social Cognition, 18,* 130-150.

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

Calder, A. J., Lawrence, A. D., Keane, J., Scott, S. K., Owen, A. M., Christoffels, I., & Young, A.W. (2002). Reading the mind from eye gaze. *Neuropsychologia, 40,* 1129–1138.

Caron, A. J., Butler, S. C., & Brooks, R. (2002). Gaze following at 12 and 14 months: Do eyes matter. *British Journal of Developmental Psychology, 20,* 225-239.

Cole, G. G., Kentridge, R. W., Gellatly, A.R.H., & Heywood, C. A. (2003). Detectability of onsets versus offsets in the change detection paradigm. *Journal of Vision, 3,* 22-31.

Cole, G. G., Kentridge, R. W., & Heywood, C. A. (2004). Visual salience in the change detection paradigm: The special role of object onset. *Journal of Experimental Psychology: Human Perception and Performance, 30,* 464-477.

Cole, G. G., & Kuhn, G. (2009). Appearance matters: Attentional orienting by new objects in the precueing paradigm. Visual Cognition, 17, 755-776.

Cole, G. G., & Kuhn, G. (2010). Attentional capture by object appearance and disappearance. Quarterly Journal of Experimental Psychology, 63, 147-159.

Cole, G. G., Kuhn, G., Heywood, C. A., & Kentridge, R. W. (2009). The prioritization of feature singletons in the allocation of visual attention. *Experimental Psychology, 56,* 134-146.

Cooper, R., & Shallice, T. (2000). Contention scheduling and the control of routine activities. *Cognitive Neuropsychology, 17,* 297-338.

Dally, J. M., Emery, N. J., & Clayton, N. S. (2005). Cache protection strategies by western scrub-jays (Aphelocoma californica): implications for social cognition. *Animal Behaviour, 70,* 1251-1263.

Driver, J., Davis, G., Kidd, P., Maxwell, E., Ricciardelli, P., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition, 6,* 509-540.

Frischen, A. P., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition and individual differences. *Psychological Bulletin, 133,* 694-724.

Frischen, A., & Tipper, S. P. (2004). Orienting attention via observed gaze shift evokes longer term inhibitory effects: Implications for social interactions, attention and memory. *Journal of Experimental Psychology: General, 133,* 516-533.

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

Frith, C. D. & Frith, U. (1999). Interacting minds--a biological basis. *Science, 286,* 5445, 1692-1695.

Gellatly, A.R.H., Cole, G. G., Fox, C., & Johnson, M. (2003). Motor inhibition may determine the relative duration of reaction times to abrupt onset displays. *Perception, 32,* 1377-1391.

Gregory, C., Lough, S., Stone, V., Baron-Cohen, S., & Hodges, J. (2002). Theory of mind in patients with frontal variant frontotemporal dementia and Alzheimer's disease: theoretical and practical implications. *Brain, 125,* 752-674.

Hare, B., Call, J., & Tomasello, M. (2001). Do chimpanzees know what conspecifics know? *Animal Behaviour, 61,* 139-151.

Hietanen, J. K. (2002). Social attention orienting integrates visual information from the head and body orientation. *Psychological Research, 66,* 174-179.

Jenkins, R., Beaver, J.D., and Calder, A.J. (2006) I thought you were looking at me! Direction-specific aftereffects in gaze perception. *Psychological Science, 17,* 506-514.

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

Law, A. S., Langton, S. R. H., & Logie, R. H. (2009). Assessing the impact of verbal and visuospatial working memory load on eye-gaze cueing. *Visual Cognition, 18,* 1420-1438.

Leekam, S. R., Hunnisett, and Moore, C. (1998). Targets and cues: gaze-following in children with autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 39,* 951–962.

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

Kuhn, G, Tatler, B. W., & Cole, G. G. (2009). You look where I look! Effect of gaze cues on overt and covert attention in misdirection. *Visual Cognition, 17,* 925-944.

Langton, S., & Bruce, V. (1999). Reflexive orienting to social attention signals. *Visual Cognition, 6*, 541–568.

Langton, S. R. H. (2009). Gaze perception: is seeing influenced by believing? *Current Biology, 19,* R651–R652.

Milliken, B., & Tipper, S. P. (1998). Attention and inhibition. In H. Pashler (Ed.), *Attention* (pp. 191-221). East Sussex: Psychology Press Ltd.

Müller, H. J., & Rabbitt, P. M. A. (1989). Reflexive and voluntary orienting of visual attention: Time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance, 15,* 315 330.

Norman, D. A., & Bobrow, D. J. (1975). On data-limited and resource-limited processes. *Cognitive Psychology, 7,* 44-64.

Nuku, P., & Bekkering, H. (2008). Joint attention: Inferring what others perceive (and don't perceive). *Consciousness and Cognition, 17,* 339-349.

Penn, D. C., & Povinelli, D. J. (2007). On the lack of evidence that chimpanzees possess anything remotely resembling a 'theory of mind'. *Philosophical Transactions of the Royal Society, B, 362,* 731-744.

Pisella, L., Berberovic, N. & Mattingley, J.B. (2004). Impaired working memory for location but not for colour or shape in visual neglect: a comparison of parietal and non-parietal lesions. *Cortex, 40,* 379-390.

Povinelli, D. J., & Preuss, T. M. (1995). Theory of mind: Evolutionary history of a cognitive specialization. *Trends in Neuroscience, 18,* 418-424.

Premack, D., & Woodruff, G. (1978). Does the Chimpanzee Have a Theory of Mind. *Behavioral and Brain Sciences, 1,* 515-526.

Quadflieg, S., Mason, M. F., & Macrae, C. N., (2004) The owl and the pussycat: gaze cues and visuospatial orienting. *Psychonomic Bulletin & Review. 11,* 826–831.

Rafal, R.D., Smith, J., Krantz, J., Cohen, A., & Brennan, C. (1990). Extrageniculate vision in hemianopic humans: Saccade inhibition by signals in the blind field. *Science, 250,* 118-121.

Rensink, R. A., O'Regan, J. K., & Clark, J. J. (1997). To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science, 8,* 368-373.

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

Ristic, J., & Kingstone, A. (2005). Taking control of reflexive social attention. *Cognition,* 94, 55-65.

Ro, T. Russell, C., & Lavie, N. (2001). Changing faces: a detection advantage in the flicker paradigm. *Psychological Science, 12,* 94-99.

Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., Bodley Scott, S. E. (2010). Seeing it their way: Evidence for rapid and involuntary computation of what other people see. *Journal of Experimental Psychology: Human Perception and Performance, 36,* 1255-1266.

Santee, J. L., & Egeth, H. E. (1982). Do reaction time and accuracy measure the same aspects of letter recognition? *Journal of Experimental Psychology: Human Perception and Performance, 8,* 489-501.

Scholl, B. J. (2000). Attenuated change blindness for exogenously attended items in a flicker paradigm. *Visual Cognition, 7,* 377-396.

Schneider, D., Lam, R.,. Bayliss, A. P., & Dux, P. E. (2012). Cognitive load disrupts implicit Theory-of-Mind processing. *Psychological Science, 23,* 842–847.

Simons, D. J., & Rensink, R. A. (2005). Change blindness: Past, present, and future. *Trends in Cognitive Sciences, 9,* 6-20.

Smith, D. T., & Schenk, T. (2008). Reflexive attention attenuates change blindness (but only briefly) *Perception & Psychophysics, 70,* 489-495.

Smith, D. T., & Schenk, T. (2010). Inhibition of Return exaggerates change blindness. *Quarterly Journal of Experimental Psychology, 63),* 2231-2238.

Teufel, C., Alexis, D.M., Todd, H., Lawrance-Owen, A.J., Clayton, N.S., Davis, G. (2009). Social cognition modulates the sensory coding of observed gaze direction. *Current Biology, 19,* 1274-7.

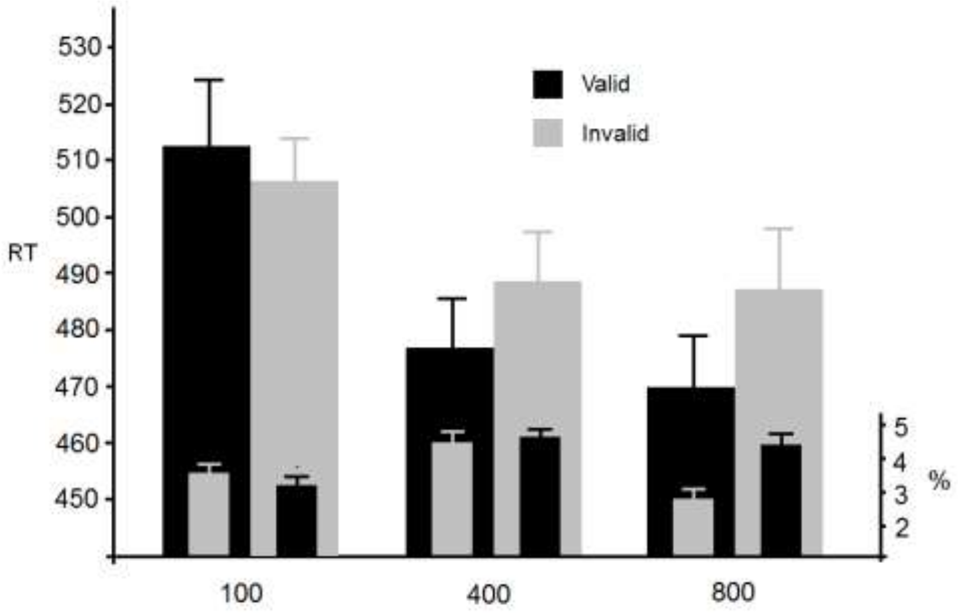
Teufel, C., Alexis, D. M., Clayton, N. S., & Davis, G. (2010). Mental-state attribution drives rapid, reflexive gaze following. *Attention, Perception & Psychophysics, 72,* 695-705.

Teufel, C., Fletcher, P.C., & Davis, G. (2010). Seeing other minds: attributed mental states influence perception. *Trends in Cognitive Science, 14,* 376-382.

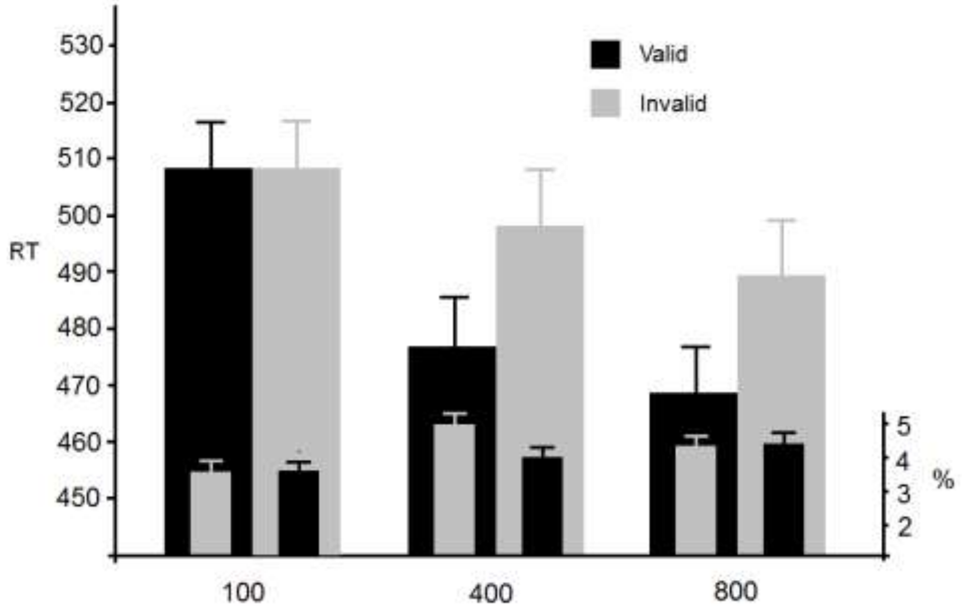
Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic Bulletin & Review*, 9, 314-318.

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition, 13,* 103-28.

Figure 1



Visible



Non-visible

Figure 2

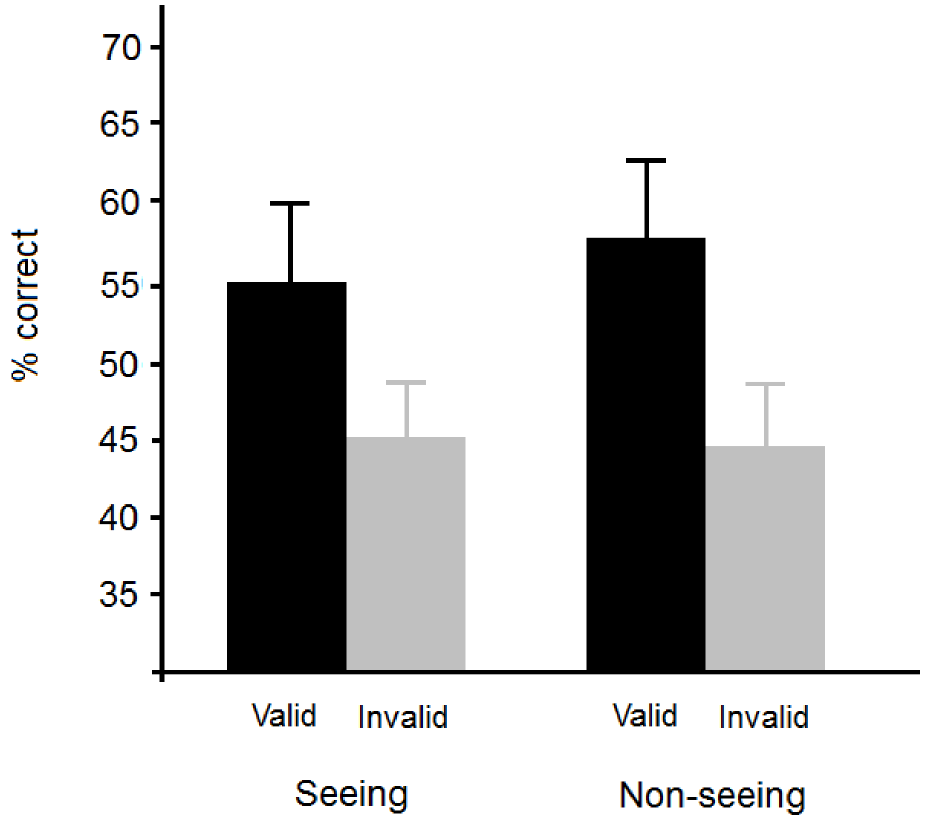

% correct
70
65
60
55
50
45
40
35
Valid
Invalid
Valid
Invalid
Seeing
Non-seeing

Figure 3

Figure 4

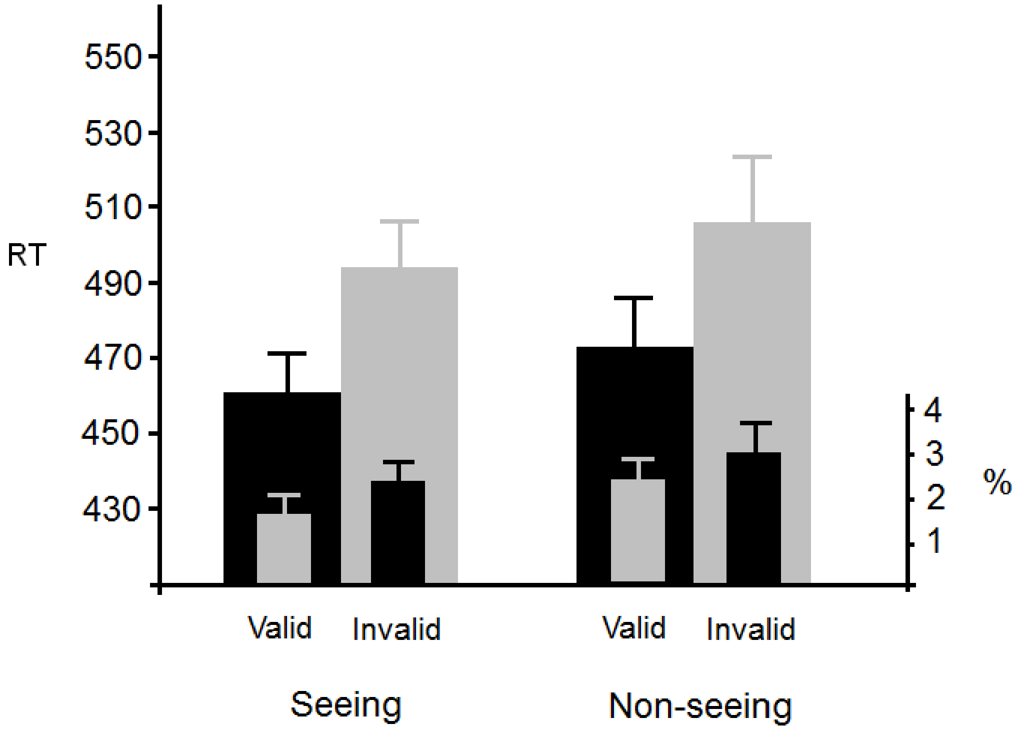

550
530
510
RT
490
470
450
430
4
3
2
1
%
Valid
Invalid
Valid
Invalid
Seeing
Non-seeing

Figure 5.

Figure Legends

Figure 1. Stimuli used in Experiment 1. The example shows a valid trial in the 'seeing' condition.

Figure 2. Mean RT and error rates from Experiment 1 together with standard error bars.

Figure 3. Results from Experiment 2. Standard error bars are also shown.

Figure 4. The set-up for Experiment 4. The image shows a valid trial in which the barrier occludes the cue's visibility of the target. The inset image shows what the person-cue saw during the first part of each trial.

Figure 5. Mean RT and error rates from Experiment 3. Standard error bars are also shown.

END

Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology*, *74*(5), 1252-1265. doi: 10.1037/0022-3514.74.5.1252

Baumeister, R. F., Muraven, M., & Tice, D. M. (2000). Ego depletion: A resource model of volition, self-regulation, and controlled processing. *Social Cognition*, *18*(2), 130-150. doi: 10.1521/soco.2000.18.2.130

Brignani, D., Guzzon, D., Marzi, C. A., & Miniussi, C. (2009). Attentional orienting induced by arrows and eye-gaze compared with an endogenous cue. [Review]. *Neuropsychologia*, *47*(2), 370-381. doi: 10.1016/j.neuropsychologia.2008.09.011

Friesen, C. K., & Kingstone, A. (2003). Covert and overt orienting to gaze direction cues and the effects of fixation offset. [Article]. *Neuroreport*, *14*(3), 489-493. doi: 10.1097/01.wnr.0000058776.36017.5d

Grosbras, M. N., Laird, A. R., & Paus, T. (2005). Cortical regions involved in eye movements, shifts of attention, and gaze perception. *Human Brain Mapping*, *25*(1), 140-154. doi: 10.1002/hbm.20145

Guzzon, D., Brignani, D., Miniussi, C., & Marzi, C. A. (2010). Orienting of attention with eye and arrow cues and the effect of overtraining. *Acta Psychologica*, *134*(3), 353-362. doi: http://dx.doi.org/10.1016/j.actpsy.2010.03.008

Kuhn, G., & Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. [Article]. *Attention Perception & Psychophysics*, *71*(2), 314-327. doi: 10.3758/app.71.2.314

Nuku, P., & Bekkering, H. (2008). Joint attention: Inferring what others perceive (and don't perceive). *Consciousness and Cognition, 17*(1), 339-349.

Rensink, R. A., O' Regan, J. K., & Clark, J. J. (1997). To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science, 8*(5), 368-373.

Ricciardelli, P., Bricolo, E., Aglioti, S. M., & Chelazzi, L. (2002). My eyes want to look where your eyes are looking: Exploring the tendency to imitate another individual's gaze. *Neuroreport, 13*(17), 2259-2264. doi: 10.1097/00001756-200212030-00018

Ristic, J., & Kingstone, A. (2005). Taking control of reflexive social attention. *Cognition, 94*(3), B55-B65.

Smith, D. T., & Schenk, T. (2008). Reflexive attention attenuates change blindness (but only briefly) *Perception & Psychophysics, 70*(3), 489-495.

Teufel, C., Alexis, D. M., Clayton, N. S., & Davis, G. (2010). Mental-state attribution drives rapid, reflexive gaze following. [Article]. *Attention Perception & Psychophysics, 72*(3), 695-705. doi: 10.3758/app.72.3.695

Teufel, C., Fletcher, P. C., & Davis, G. (2010). Seeing other minds: attributed mental states influence perception. *Trends in Cognitive Sciences, 14*(8), 376-382.