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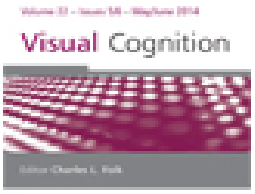

Visual Cognition

ISSN: 1350-6285 (Print) 1464-0716 (Online) Journal homepage: http://www.tandfonline.com/loi/pvis20

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VISUAL COGNITION, 2009, 17 (6/7), 925–944

Psychology Press
Taylor & Francis Group

You look where I look! Effect of gaze cues on overt and covert attention in misdirection

Gustav Kuhn
Durham University, Durham, UK

Benjamin W. Tatler
Dundee University, Dundee, UK

Geoff G. Cole
Durham University, Durham, UK

We designed a magic trick in which misdirection was used to orchestrate observers' attention in order to prevent them from detecting the to-be-concealed event. By experimentally manipulating the magician's gaze direction we investigated the role that gaze cues have in attentional orienting, independently of any low level features. Participants were significantly less likely to detect the to-be-concealed event if the misdirection was supported by the magician's gaze, thus demonstrating that the gaze plays an important role in orienting people's attention. Moreover, participants spent less time looking at the critical hand when the magician's gaze was used to misdirect their attention away from the hand. Overall, the magician's face, and in particular the eyes, accounted for a large proportion of the fixations. The eyes were popular when the magician was looking towards the observer; once he looked towards the actions and objects being manipulated, participants typically fixated the gazed-at areas. Using a highly naturalistic paradigm using a dynamic display we demonstrate gaze following that is independent of the low level features of the scene.

Keywords: Covert attention; Eye movements; Gaze cueing; Gaze following; Overt attention; Social attention.

Our subjective perception of the world is one of full coherence, yet our conscious representation is rather limited (Rensink, 2002). Rather than

Please address all correspondence to Gustav Kuhn, Department of Psychology, University of Durham, South Road, Durham DH1 3LE, UK. E-mail: Gustav.Kuhn@Durham.ac.uk

This research was funded by the Wolfson Research Institute, University of Durham. We also thank Daniel Smilek, Greg Zelinsky, and James Brockmole for their helpful comments.

http://www.psypress.com/viscog DOI: 10.1080/13506280902826775

processing all of the sensory information, the visual system selects the information that is of importance through the systematic orientation of both covert and overt attention. The latter process is achieved by directing the fovea, capable of encoding high acuity visual information, to spatial locations that are of importance. Enhanced processing can also occur in the absence of eye movements, namely through the deployment of covert attention (Posner, 1980).

Over the past years much research has been conducted identifying the mechanism behind attentional orienting. In the covert attention literature it has become apparent that people automatically orient their attention towards certain stimulus features (e.g., Wolfe & Horowitz, 2004). For example, events such as the onset of an object (e.g., Cole, Kuhn, & Liversedge, 2007; Yantis & Jonides, 1990), onset of motion (Abrams & Christ, 2003), or objects looming towards the observer capture our attention (Cole & Liversedge, 2006; Franconeri & Simons, 2003). Although certain events, such as the onset of new objects are capable of capturing attention in the absence of a unique visual transient (Cole & Kuhn, 2009) attentional orienting in response to these stimulus properties is largely driven by luminance transients (Franconeri, Hollingworth, & Simons, 2005).

A key component of attentional orientation is the overt orientation of the eyes. A large volume of research has been aimed at exploring the factors that underlie and influence what locations we select as the targets of fixation in complex scenes (since Buswell, 1935). Traditionally, the debate about the factors responsible for fixation selection has centred on the bottom-up/top-down dichotomy (see Henderson, 2003), mirroring the issues that have been explored in visual search literature (see Wolfe & Horowitz, 2004). While people no longer argue for selection being *either* bottom-up *or* top-down, the debate continues about the relative influence of these two orienting processes (as reflected throughout this Special Issue).

Current models, derived mainly from static scene viewing, favour a view in which higher level factors such as behavioural task (Einhauser, Rutishauser, & Koch, 2008), expertise with similar scenes (Underwood, Foulsham, & Humphrey, 2009, this issue), spatial expectation for object location (Ehinger, Hidalgo-Sotelo, Torralba, & Oliva, 2009, this issue), and object appearance (Kanan, Kanan, Zhang, & Cottrell, 2009, this issue) modulate or even override a basic low-level form of attentional capture based on image conspicuity or salience (Itti & Koch, 2000). Other behavioural biases such as the general tendency to look near the centre of monitor displays (Tatler, 2007) and the tendency to make particular eye movements more frequently than others (Tatler & Vincent, 2009, this issue) have also been shown to influence where observers fixate.

A surprising omission from the high-level cues so far investigated in the context of emerging models of eye guidance when viewing complex scenes is gaze cueing. Where an individual attends can be strongly influenced (perhaps event automatically) by where another individual is attending (Driver et al., 1999; Friesen & Kingstone, 1998). Using a Posner (1980) type precueing task it has been shown that participants detect targets occurring in the gazed-at location more rapidly than when they occur at a non-gazed-at location, even when the gaze is nonpredictive of the target location, thus suggesting that gaze direction results in automatic orienting of covert attention. Similarly, gaze cues also affect people's overt attentional deployment (Kuhn & Benson, 2007; Kuhn & Kingstone, 2009; Mansfield, Farroni, & Johnson, 2003; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). For example, if participants are required to look at targets presented either to the left or the right of a centrally presented face whose gaze is either congruent or incongruent to the intended saccade direction, participants often followed the distractor gaze even though the gaze direction was nonpredictive (Kuhn & Benson, 2007; Ricciardelli et al., 2002) or counterpredictive of the intended saccade direction (Kuhn & Kingstone, 2009), thus arguing that this type of gaze following may even be automatic.

Presenting faces in isolation and at the centre of the observer's gaze means not only is the face's gaze the only directional cue available, but also that it is preselected as the fixation target for the observer (they do not need to initially orient to the face to infer gaze direction). Numerous studies have shown that nonsocially relevant directional cues such as arrows trigger automatic shifts in both overt (Friesen, Ristic, & Kingstone, 2004; Hommel, Pratt, Colzato, & Godijn, 2001; Tipples, 2002) and covert attention (Kuhn & Benson, 2007; Kuhn & Kingstone, 2009). It is therefore likely that any directional cue presented in isolation will result in attentional orienting. The true influence of social attention may therefore only be understood if we examine the role of gaze cueing in a richer context, i.e., in natural scenes.

To date, few studies have investigated attentional orienting in response to gaze cues when the face is presented in a more natural environment (Birmingham, Bischof, & Kingstone, 2009, this issue). Results from the social attention literature predict attention should be directed towards areas that are being looked at by the central figure in the display. Indeed, Fletcher-Watson, Findlay, Leekam, and Benson (2008) showed that that participants spent more time looking at the object being fixated by the scene character than would be predicted by chance. Similarly, Castelhano, Wieth, and Henderson (2007) measured participants' eye movements whilst they were looking at sequences of scene photographs that told a story. Their results showed that the actor's face was highly likely to be fixated and participants' next saccade was often directed towards the object that was the focus of the actor's gaze direction.

One problem in interpreting studies using naturalistic displays, as the results cited earlier, is that we cannot be sure that the location cued by the gaze of the central figure in the display is not also cued by other factors. For example, the cued location may have different or conspicuous low-level feature properties and thus be favoured by a salience-type selection mechanism. Alternatively (or additionally) the gaze-cued location may be of central importance to the higher level interpretation of the scene, this being the target of any high-level selection mechanism. This is particularly problematic in natural scenes: Indeed the question could be raised about why the central figure is looking at that location in the first place. Is it to do with the visual or semantic prominence of the location? In the extreme we could suggest that the cooccurrence of attention at the mutually gazed location is not a reflection of a tendency to follow another's gaze, but a common mechanism underlying fixation selection (such as the latest modifications to Itti's salience framework; Itti & Koch, 2001).

There are two ways in which the above concern about whether gaze cueing really influences fixation selection in social scenes can be addressed. First, we can artificially manipulate where the depicted characters in the scene are looking. Dukewich and Klein (2008) did exactly this: They measured participants' eye movements whilst looking at art and digitally manipulated the gaze direction of the central figure. By manipulating the gaze direction, this approach allowed for the independent assessment of the degree to which attentional orienting is influenced by the gaze direction of the central figure. Rather surprisingly, their results demonstrated that participants viewing behaviour was only weekly influenced by the central character's gaze direction. The images used by Dukewich and Klein consisted of rather abstract artistic paintings, which may have been too artificial to engage full social processing, and thus reduced the effectiveness of the gaze manipulation. Furthermore, by digitally changing gaze direction all other directional cues in the paintings, such as the character's head and body direction and the location of other objects in the scenes, were no longer consistent with the character's manipulated gaze direction.

Alternatively, we can find a situation in which a component of the natural behaviour is to decouple gaze direction and conspicuous events. Magic offers an ideal opportunity for this (see Kuhn, Amlani, & Rensink, 2008; Macknik et al., 2008) because some tricks explicitly use the magician's gaze direction to misorient the observer attention at the crucial moments (Lamont & Wiseman, 1999). We have developed magic tricks that allow us to consider the extent to which an observer's gaze is misdirected by the magician's gaze (Kuhn & Tatler, 2005; Kuhn, Tatler, Findlay, & Cole, 2008). In these magic tricks misdirection is used to prevent participants from detecting a visually salient event. By measuring participants' eye movements whilst watching this misdirection trick we can evaluate the extent to which overt attention has been manipulated. Moreover, analogous to approaches that use change detection and inattentional blindness as measures of covert attention

(Tse, 2004), the detection of the to-be-concealed event provides us with an index of covert attention (see Kuhn & Findlay, in press, for a full discussion on how detection provides an index of covert attention rather than inference). Previous studies using misdirection tricks have demonstrated that detection of the event was independent of where people were looking, thus demonstrating that misdirection may involve misdirecting covert rather than overt attention. Similarly, in the vanishing ball illusion, Kuhn and Land (2006) demonstrated that although social cues could be used to deceive participants' expectations and as such what they saw, participants' eye movements were not fooled the magician's gaze. Based on these previous results it therefore remains to be seen whether social cues effectively misdirect overt attention, when used in isolation.

Using a combination of both live performances and video presentations of performances, we have shown that participants' eye movements were strongly driven by the magician's social cues, i.e., where he was looking (Kuhn & Land, 2006; Tatler & Kuhn, 2007). However, the magician's gaze cues are rarely used in isolation. Instead magicians typically employ a combination of additional attentional cues such as movement or changes in contrast so as to maximize the misdirection's propensity. The extent to which gaze cues are responsible for this attentional misdirection above all of the other cues, remains unclear. For example, in Tatler and Kuhn (2007) the cigarette "disappearance" (i.e., dropping the cigarette into his lap) is concealed by the magician gazing at his other (empty) hand, whilst at the same time waving this empty hand so providing strong motion cues at this location. It is therefore unclear whether the observer's fixation of the empty hand is driven primarily by motion or gaze cues.

Within the context of the magic trick it is possible to disentangle gaze-cueing effects from the effects of other cues. That is, there can be situations in which the magician's gaze cues are effectively in conflict with both the low-level cues in the scene (e.g., both the waving empty hand and the white cigarette dropping against a black background provide what must be visually salient events) and the behavioural goals of the observer (when instructed to work out how the magician made the cigarette disappear the hand in which the cigarette is held is central to the high level goals of the observer). Thus, in the case of the dropping object, gaze can be used to cue either the waving, empty hand (the normal situation for misdirecting the viewer; here referred to as the misdirection condition) or the hand dropping the object (here referred to as the nonmisdirection condition). By comparing the gaze allocation and detection probabilities in these two situations, we can effectively disentangle the influence of gaze and low-level motion cues in misdirection. Not only does this approach offer new insights into how a magician achieves successful misdirection of his audience, but also it allows insights into the relationship between gaze cues and other cues in the allocation of attention in natural, social settings.

METHOD

Participants

Thirty-two students from Durham University took part in the study (mean age = 25.3; 19 female, 13 male). Participants were either paid or received course credits.

Material

Two versions of the misdirection trick were recorded. The effect[1] in this magic trick was the disappearance of a lighter (see Figure 1 for a description of the trick; video can be downloaded from http://www.dur.ac.uk/gustav.kuhn/papers/KuhnetalVisCog2009/Material.htm). In this trick the magician picks up a lighter with his left hand and lights it. He then pretends to take the flame with his right hand, and gradually moves it away from the hand that is holding the lighter. In the misdirection condition the magician looks at the right hand throughout the manoeuvre. Once the right hand has reached the other side, whilst still looking at it, he snaps his fingers, waves his hand and reveals that it is empty. The misdirection employed involves a combination of cues in particular the waving hand and the magician's gaze direction, which is directed towards the right hand. At the same time the lighter is dropped into the lap. The drop is fully visible. The magician now directs his gaze to his left hand, raises it, and snaps his fingers to reveal that his left hand is now also empty and the lighter has disappeared. The sequence in the nonmisdirection condition was identical to the original misdirection trick with the exception that at the time when the right hand goes to pick up the flame, the magician's gaze is directed towards the left hand holding the lighter, rather than following the right hand. The magician's social cues were therefore contrary to the misdirection (see Figure 1). As can be seen from the timeline, the timing of most of the movements in both conditions took place at virtually the same time.

The magic trick was filmed using a digital video camera (PAL, JVC, GR-D240EK) at 25 fps, and then sampled using Adobe Premier (720 × 576). All of the video editing was carried out using Adobe Premier and Adobe

[1] In the magic literature the term "effect" refers to what the spectator sees, whilst method describes how the trick is done (Lamont & Wiseman, 1999).

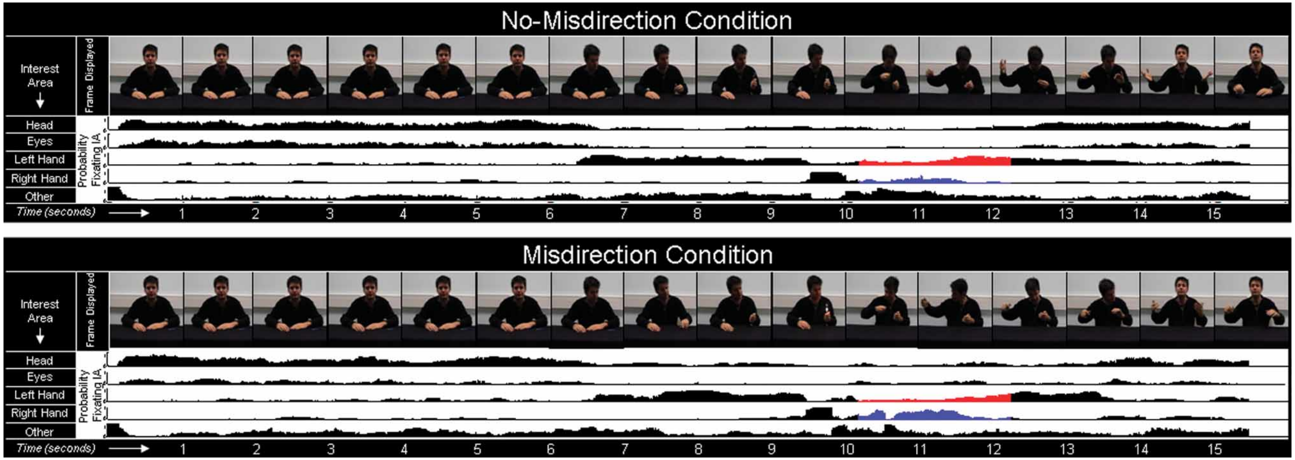

Figure 1. Time lines of the magic tricks performed for the nonmisdirection and the misdirection conditions. Time (in s) is represented along the x-axis. To illustrate what was happening at any particular time the frames corresponding to the particular time on the x-axis are included. The frame located at the 0–1 interval is the frame presented at time 0, the frame located at the 1–2 interval is frame presented at time 1 s etc. . . . the number in the parenthesis are the times at which the events take place (in s). In the misdirection condition (bottom plane) the video clip starts with a 5 s still image of the magician looking ahead (1–5). He then looks at the lighter located on the table which he picks up with his left hand (5–7) and lights it (7–9). He then pretends to take the flame and gradually moves it away from the hand holding the lighter (9-10). In the misdirection condition the magician looks at the right hand throughout the manoeuvre. Once the right hand has reached the other side, whilst still looking at the right hand, he snaps his fingers, waves his hand and reveals that it is empty (10–11). The misdirection employed involves a combination of cues in particular the waving hand and the magician's gaze direction, which is directed towards the right hand. At the same time the lighter is dropped into the lap. The drop takes place in full view. The magician now directs his gaze to his left hand (11–12), raises it, and snaps his fingers to reveal that his left hand is now also empty and the lighter has disappeared (12–14). The sequence in the nonmisdirection condition was identical to the original misdirection trick with the exception that at the time when the right hand goes to pick up the flame, the magician's gaze is directed towards the left hand holding he lighter, rather than following the right hand. The difference between the two conditions take place between 10.2 and 12.1 s. As can be seen from the timeline, the timing of most of the movements in both conditions took place at virtually the same time. Below each of the time lines are five bar charts which plot the probability of participants looking at any of the five interest areas against time. To view this figure in colour, please see the online issue of the Journal.

Photoshop. The duration of the trick from beginning to end was 10.48 s (262 frames).

The entire clip was exported as a film strip and edited using Adobe Photoshop. For both conditions the dropping lighters, which were visible for three frames, were removed using the stamp tool. Footage from a different trial using the same lighter was then digitally inserted to these frames. This meant that the dropping lighters in both conditions were identical and thus were equally perceptible. One hundred and twenty-five still frames were added to the beginning of the clip and 50 frames were added to the end of the clip resulting in the entire clip lasting 517 frames. The film strips were then converted back into avi files. The video clips were presented using SR Research Experiment Builder software which guaranteed accurate frame display timing. The movies were displayed on a 21 inch CRT monitor (75 Hz). Screen resolution was set to 600×800 pixels so that the video clip filled most of the screen. Eye movements were recorded monocularly (left eye) using an SR-Research Eyelink II eyetracker (500 Hz). Viewing distance was 63 cm and the head was fixed using a chinrest.

Procedure

Participants were informed that they were about to see a video clip of a magic trick and that their task was to discover how this trick was done. The eye tracker was then calibrated using a 9 point calibration procedure, which was immediately followed by a validation procedure. Calibrations were accepted if the mean error was less than 0.5°. Immediately after the magic trick participants were asked whether they saw how the lighter disappeared. If they answered yes, they were asked to describe what they saw. If they answered no, they were asked to speculate about the method they thought might have been used to make the lighter disappear. All participants were urged to differentiate between what they saw and how they thought it was done. Kuhn and Findlay (in press) showed that if the dropping lighter is digitally removed, thus making it invisible, participants did not falsely claim to see it drop, thus demonstrating that reports of detecting the lighter provide reliable indexes of what people have seen rather than inferences.

Dynamic scene analysis: Data preparation

In static scene viewing an interest area can be defined for each image and we can calculate eye movement statistics such as total number of fixations or dwell time per interest area. Analysing eye movements in dynamic scenes generates numerous additional challenges which need to be addressed. First, objects are likely to move over time and as such the interest area can change in location from frame to frame. Second, if the object changes in depth or orientation the perceived size and shape of the object may change over time. Third, if there are several objects in different depth planes, some objects are likely to become occluded by others, thus providing us with potentially overlapping interest areas. The first two issues can be solved by tracking objects as they move in time and adjusting the location and the size of the interest area as the object of interest changes. The second issue is more problematic, which is why in the present study, we tried to design a magic trick that avoided occlusion of objects as much as possible.

Five different interest areas were defined for each frame: Head, eyes, left hand right hand, and other (including everything else). Each area of interest was defined manually on every frame of the videos. Rather than defining each interest area by the exact outline of the object, they were defined by spheres, which were centred on the object of interest (see Figure 2). The size of these spheres was held constant throughout the trial and the size was selected to ensure that the entire object of interest was covered throughout the trial. As most of the actions took place in the same plane, and the camera angle was constant, the size of the objects did not vary much and thus the spheres were relatively accurate approximations of the true area covered by the object of interest. There was relatively little occlusion. When the right hand takes the flame from the left hand the two hands touch each other thus resulting in an overlap interest areas (nonmisdirection condition, 10 frames; misdirection condition, 11 frames), the interest area had to be

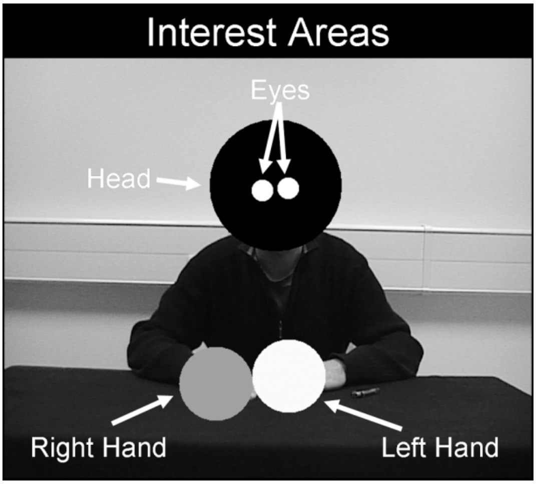

Figure 2. The interest areas (IA) as defined on the first frame. The relative sizes of the interest areas sizes in both the misdirection and the nonmisdirection conditions were as follows: Head =4.98%, eyes =0.28%, left hand =1.61%, right hand =1.61%.

adjusted manually. For the remainder of the frames there was no occlusion, thus resulting in mutually exclusive interest areas.

Data analysis was conducted using custom written software, which analysed the data on a frame by frame basis. Data acquisition was at 500 Hz, thus resulting in 20 samples per frame of the stimulus video. In static scene viewing eye movements are typically analysed in terms of fixation durations, or overall dwell times. In dynamic scenes, the interest area is likely to change on each frame, and participants often track slowly moving objects thus making this type of analysis rather problematic. We therefore propose a somewhat different approach. Rather than using a fixation-based analysis, we analysed eye movements for each gaze location sample, by classifying each sample according to which interest area was being looked at. By doing this we can calculate the proportion of participants looking at each interest area at any point in time (i.e., number of participants fixating interest area divided by total number of participants).[2]

RESULTS

Detection rates

In the nonmisdirection condition, nine participants (56%) detected the lighter drop compared to two participants (12.5%) in the misdirection condition. Although the dropping lighters in both conditions were identical, participants in the misdirection condition were significantly less likely to detect it than participants in the nonmisdirection condition, $\chi^2 = 7.46$, $p = .021$. The magician's gaze direction therefore played a significant role in the effectiveness of misdirecting participants' attention.

Overt versus covert misdirection

Our results clearly demonstrate that the magician's gaze direction was influential in misdirecting participants' attention. However, which type of attention was being manipulated? Did the magician's gaze direction help misdirect where participants were looking, and thus act upon participants' overt attention, or was the misdirection more covert in nature? In order to investigate this question we analysed participants' gaze positions at the time of the drop. The dropping lighter was visible on three frames. Fixations at the time of the drop were defined as fixation positions on the second frame of the drop (10th eye movement sample). Figure 3 shows participants' fixation

[2] In the context of this analysis, the term fixation will be used rather loosely, whereby fixations refer to gaze coordinates at each sample.

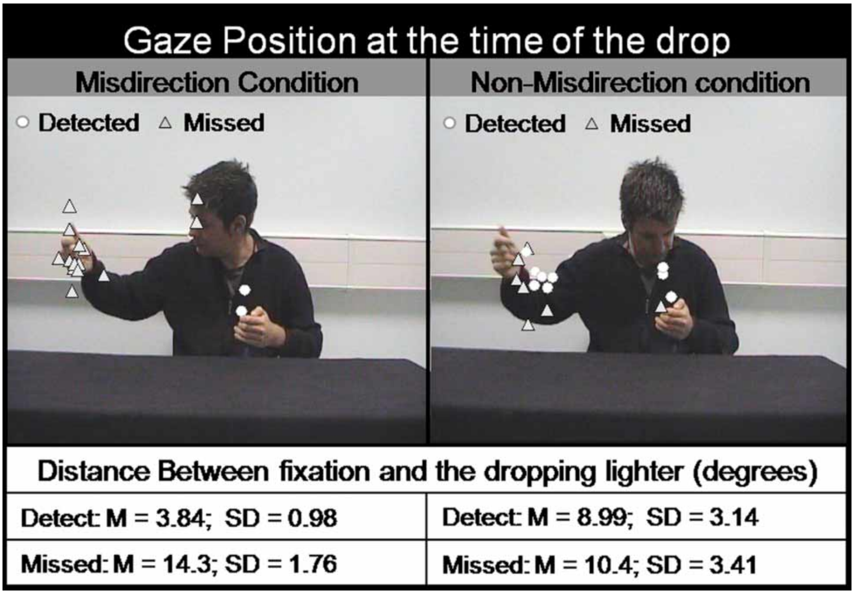

Figure 3. Participants' fixations at the time of the drop for participants in the misdirection and the nonmisdirection condition. Table 1 denotes the distances between the fixation and the dropping lighter for participants who missed the drop and those who detected it for both conditions (in degrees). To view this figure in colour, please see the online issue of the Journal.

points at the time of the drop. The aim of the misdirection was to direct attention away from the dropping lighter. We can therefore use the distance between the participants' fixation and the dropping lighter as an index of the strength of the overt misdirection. This figure also includes the distances between participants' fixations and the dropping lighter (in degrees). Overall, participants in the nonmisdirection condition fixated significantly closer to the dropping lighter than participants in the misdirection condition, $t(30) = 2.65$, $p = .013$, thus demonstrating that the magician's gaze direction affected overt attention. From the mean distances shown in Figure 3, there would appear to be an interaction between misdirection conditions and detection of the drop. However, with only two detected trials in the misdirection condition, it is hard to assess this possibility.

Thus far, we have only focused on participant's eye movements at a particular point in time, namely in the middle of the drop. However, as we are dealing with events that develop over time, it is more informative to analyse the data over time. The line graphs below each of the time lines in Figure 1 plot the proportion of participants looking at each of the areas of interest. These types of graphs allow us to depict and analyse participants' gaze behaviour over time (see also Kuhn & Land, 2006).

Overall analysis

The first striking feature is that most of the data are captured by the defined areas of interest (head, eyes, left hand, right hand). Although the areas of interest only covered 8.5% of the total area, 70% of all eye movements were captured by these interest areas. Given that the background in these displays is relatively uniform it might seem less surprising that participants spend relatively little time looking at it. However, these results clearly demonstrate that participants look at the key areas where the trick is being performed. Similar to previous studies (Birmingham, Bischof, & Kingstone, 2008a, 2008b; Birmingham et al., 2009, this issue; Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006) once the interest areas were weighted for size (see Figure 2 for relative size of the interest areas), the eyes accounted for an exceptionally high proportion of fixations (60.2%), followed by the left hand (21.3%), the head (9.8%), and the right hand (8.1%).

By looking at the time line it becomes apparent that the popularity of different interest areas varies systematically with time. Whilst viewing the still image in which the magician looks towards the viewer, most of the data are captured by the eyes and the head (up to 5 s). However, once the scene becomes animated (5 s and onwards), the left and the right hand rapidly gain in popularity. The dynamic aspect of the scene strongly influences participants' eye movement behaviour. On an informal level it is apparent that for most of the time, the hand that is being looked at by the magician becomes the most popular interest area, but when the magician is looking towards the observer, the eyes and the head gain popularity.

Gaze following over time

Throughout most of the trick, the magician's gaze is directed towards the object that is being manipulated, thus making it difficult to assess the unique contributions that the magician's gaze makes. However, as we experimentally manipulated the magician's gaze direction in orchestrating his misdirection we can evaluate the independent effect that the gaze direction has on overt attention. In the misdirection condition, the magician uses his right hand and the gaze direction to draw attention away from the left hand, which takes place between frames 256 and 303. In the nonmisdirection condition, attention is only drawn away from the lighter hand using (movements of) the left hand, whilst his gaze is directed towards the left hand. If the gaze direction affects overt attention we would expect participants in the misdirection condition to spend less time looking at the left-hand interest area than participants in the nonmisdirection condition. Table 1 shows the proportion of time spent looking at each of the interest areas for the two

TABLE 1
Percentage of time spent looking at each of the interest areas during the time in which the two conditions differed from each other (frames 256–303)

	Nonmisdirection		*Misdirection*	
Interest area	*Mean*	*SE*	*Mean*	*SE*
Head	5.46	2.81	9.24	2.81
Eyes	0.63	2.85	7.88	2.85
LH	32.0	5.87	14.1	5.87
RH	14.7	3.80	34.9	3.80
Other	47.0	5.49	33.5	5.49

conditions. Indeed, participants in the nonmisdirection condition spent significantly more time looking at the left hand than participants in the misdirection conditions, thus demonstrating that the magician's gaze cues were effective at orienting overt attention away from the left hand, $t(30) = 2.16$, $p = .039$. Moreover, participants in the misdirection condition spent significantly more time looking at the right hand than participants in the nonmisdirection condition, $t(30) = 3.75$, $p = .001$. These results demonstrate that the magician's social cues significantly reoriented participants' overt attention away from the left hand and towards the right hand and that this reorienting of attention was independent of any low level features.

Covert attention

Six of the participants who detected the drop in the nonmisdirection condition looked towards the waving hand, and one of the participants fixated the left hand yet missed the lighter drop, thus suggesting that detection of the drop was not solely related to where participants were looking. Indeed, similar to previous findings (Kuhn & Tatler, 2005; Kuhn, Tatler, et al., 2008), participants who detected the drop fixated no closer to the lighter than those who missed it, $t(14) < 1$. These results demonstrate that the misdirection did not merely involve manipulating participants' overt attention. Thus, participants did not miss the drop because of limited retinal resolution, which suggest that the misdirection was more covert in nature.

In the misdirection condition, there was a clear relationship between where participants were looking and whether they detected it. The two participants who detected the drop fixated the left hand, whereas all of the participants who missed it fixated elsewhere. Indeed there was a significant difference in visual eccentricity and detection, $t(14) = 8.1$, $p < .0005$. However, as there were only two participants who detected the drop, the generalizability of these results must be treated with caution.

DISCUSSION

Misdirection involves systematically manipulating people's attention so as to prevent the observer from detecting certain events. Typically magicians use a wide range of techniques, of which the strategic use of eye gaze has been particularly highlighted (Lamont & Wiseman, 1999; Sharpe, 1988). By experimentally manipulating a misdirection trick, we isolated the role that gaze cues have in orchestrating attention. Our results showed that participants were significantly less likely to detect the to-be-concealed event if the misdirection was supported by the magician's social cues, thus demonstrating that the magician's gaze direction plays an important role in directing peoples' attention. By analysing participants' eye movements at the time of the drop, we could gain an insight into the type of attention that was being manipulated, and the extent to which gaze cues influence participants' overt attentional allocation. Participants in the nonmisdirection condition fixated significantly closer to the dropping lighter than participants in the misdirection condition, thus demonstrating that the magician's gaze direction influenced participants' overt attention. However, for participants in the nonmisdirection condition there was no difference in visual eccentricity between participants who detected the drop and those who missed it, thus suggesting that the misdirection involved both the manipulation of overt and covert attention. Moreover, by disentangling the influence of gaze cues from other cues (such as the motion of the waving, empty hand), we have for the first time demonstrated that the social gaze cues were not the sole cues that are able to misdirect observers' attention.

One interpretation of the difference between the two conditions is that in the misdirection condition both the overt and covert attention of the participants was misdirected away from the dropping lighter. In the nonmisdirection condition the participants' overt attention is still misdirected away from the drop (75% were looking at the empty right hand at the time of the drop), presumably because of the motion cues in the waving hand. However, participants' attention was less strongly misdirected in the nonmisdirection condition in two distinct ways: First, gaze direction at the time of the drop was on average closer to the dropping lighter and so overt attention was less strongly misdirected. This implies a role for gaze cueing on overt attentional allocation. Second, participants were far more likely to detect the drop whether they were fixating near the drop or near the empty right hand. This suggests that irrespective of overt misdirection, participants' covert attention was less strongly misdirected in the nonmisdirection condition; we can speculate that the magician's gaze direction might cue covert attentional allocation to the gazed-at location.

Previous studies using static scenes have shown that faces, and in particular the eye region, are particularly salient features of a scene (Birmingham et al., 2008a, 2008b; Smilek et al., 2006). Our results dovetail this proposition by demonstrating that participants spent a large proportion of their time looking at the eyes. Once the interest areas were controlled for size, the eye region accounted for most of the data. However, the popularity of this interest area systematically varied with time. In particular the eyes were popular when the magician was looking towards the observer; once he started to move his hand and look towards the actions and objects being manipulated, the areas that were being looked at became more popular. This finding coincides with a simple rule in magic which states that: "If you want the audience to look at you, look at them; If you want the audience to look at something else, look at it" (Kuhn, Amlani, & Rensink, 2008), and with our previous studies (Kuhn & Land, 2006; Tatler & Kuhn, 2007).

Where another person is looking is likely to be of potential interest. Similar to other low level cues, such as luminance changes or the onset of motion, gaze cues are correlated with events that are of potential interest and as such warrant attentional allocation. Indeed numerous papers using gaze cueing tasks (see Frischen, Bayliss, & Tipper, 2007, for a review) have argued that people's attention is automatically oriented towards areas that are being looked at. For example, it has been shown that even when instructed to saccade in the opposite direction to where a distractor gaze is looking participants often followed the gaze in the cued but unintended direction even when the gaze was non- or counterpredictive of the intended saccade direction, thus highlighting the prepotency of gaze following (Kuhn & Benson, 2007; Kuhn & Kingstone, 2009; Ricciardelli et al., 2002). However, in most of the previous studies, the gaze cues are preselected, and the stimulus displays are rather artificial. Though consistent, and statistically reliable, the magnitude of these cueing effects is rather small. Our study found reliable gaze cueing effects using one trial, compared to the hundreds of trials typically required in conventional task. This suggests that increasing the ecological validity of the stimulus may also amplify the gaze cueing effect. By investigating social attention using rather impoverished displays we may thus be underestimating the true power of these types of attentional cues (Kingstone, Smilek, & Eastwood, 2008). However, the present study differs from the above cited ones in that participants were not explicitly instructed to ignore the gaze cue. Whilst our study demonstrates that under normal conditions people show a strong tendency to follow another person's gaze, it is agnostic as to the automaticity of this gaze following.

In misdirection, a combination of cues are used to orchestrate the spectator's attention. For example, the magician looks at the lighter whilst lighting it, thus creating both a general interest as well as salient low level features such as luminance contrast and movement. Merely focusing on the correlation between the magician's gaze direction and participants eye movements therefore cannot necessarily inform us about the actual contribution that gaze cues make in orienting attention. However, as the social cues were manipulated experimentally, we can identify the contributions that the gaze cue made independently of all other features. By measuring the distance between the lighter and the fixation at the time of the drop we obtain an index of how influential the misdirection was upon overt attention. Indeed, participants in the nonmisdirection condition fixated more closely to the lighter than those in the misdirection condition thus demonstrating that participants' eye movements were influenced by where the magician was looking. Over the course of the performance of the trick (i.e., during the time of the drop), we found that participants in the nonmisdirection condition spent more time looking at the left hand than participants in the misdirection condition. However, participants in the misdirection condition spent significantly more time looking at the right hand than participants in the nonmisdirection condition. This supports the notion that the magician's gaze cueing during the trick influenced the participants' gaze allocation above and beyond any influence of nongaze cues, such as low-level visual conspicuity, motion, or higher level task goals. To our knowledge this is the first experimental dissection of gaze cues from these other attentional cues.

In the nonmisdirection condition, 44% of the participants failed to see the lighter drop even though the magician's gaze was directed towards the dropping lighter. Although the magician's social cues played an important role in manipulating participants' attention, they clearly do not account for all of the misdirection. Misdirection involves a combination of attentional techniques. In this trick the misdirection works by initially drawing attention to the lighter which is being lit (high luminance contrast of the flame is used to capture attention), and then drawn away by the right hand which pretends to grab the flame, and then in a slow continuous motion moves to the right. At the time of the drop, the magician snaps his right fingers thus creating a motion transient which is though to attract additional attention and thus misdirect from the dropping lighter. In the nonmisdirection condition, the effectiveness of the misdirection is largely driven by these motion signals. The fact that most (75%) of the participants looked towards the moving hand highlights the importance that these motion transients play in capturing overt attention. Furthermore, this result highlights that it is not due to gaze cues alone that participants look at the empty right hand in the normal performance of this type of trick (the misdirection condition).

Our finding that people still look at the waving hand in the nonmisdirection condition suggests that motion cues might be important in gaze allocation. Traditionally the scene viewing literature has focused on static scenes. Although it is possible to find anecdotal situations in which the world we are viewing approximates to a static scene—such as viewing a table to find a set of keys—it is rarely the case that we operate in a truly static visual domain. Even when searching the table for our keys we are likely to move objects during the search and change our viewpoint by moving around ourselves. Thus, it is crucial to study attentional allocation under more dynamic viewing conditions. In the attentional capture literature it has become apparent that although perceptual features such as the onset of new objects may capture our attention in the absence of a transient overtly (Brockmole & Henderson, 2005) and covertly (Cole & Kuhn, 2009), most attentional capture results from luminance transients. Moreover, studies that have investigated eye movement behaviour in dynamic scenes have demonstrated that motion contrasts are more predictive of people's saccade targets than static features such as intensity variance or orientation contrast (Carmi & Itti, 2006). Our results further highlight the importance that motion transients can play in guiding peoples' eye movements. Although the onset of motion has been shown to capture attention, continuous motion is not thought to do so (Abrams & Christ, 2003). Here however, the continuous motion of moving the hand from one side to the other appears to be particularly attractive. In the nonmisdirection condition, half of the participants' gaze followed the right hand as it moved across the screen. The use of continuous motion in terms of gestures is often used in misdirection to orchestrate attention (Macknik et al., 2008). Our data demonstrate just how powerful these types of cues are, and future research could benefit from exploring the role of these types of gestures in attention research.

With regard to this Special Issue of *Visual Cognition*, we feel that our data speak to a much-neglected component of the decision about where to fixate in complex natural environments: Where others in the environment themselves are looking. To date the vast majority of research has considered static scenes, often without people, or at least the influence of the people in the scenes has not been thoroughly explored. Instead debate has centred on the relative contributions of low-level stimulus cues and high-level task goals in influencing where people fixate. Of course, social gaze cues could be thought of as just another example of a high-level task goal effect—for example we could assume that the task of the observer is to monitor where others are attending because these locations may be important to us as well. However, given the prepotent capturing effect of social gaze cues on observers' attention (Kuhn & Kingstone, 2009), it may be that these cues are effectively a type of cue in their own right—that is, something more than just bottom-up or top-down. Whatever type of cue we want to class gaze cues as, it is clearly time to acknowledge that these have a prominent influence on where humans fixate in dynamic social settings.

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