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Misdirection, attention and awareness: Inattentional blindness reveals temporal relationship between eye movements and visual awareness

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Misdirection, attention and awareness: Inattentional blindness reveals temporal relationship between eye movements and visual awareness

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We designed a magic trick that could be used to investigate how misdirection can prevent people from perceiving a visually salient event, thus offering a novel paradigm to examine inattentional blindness. We demonstrate that participants' verbal reports reflect what they saw rather than inferences about how they thought the trick was done and thus provide a reliable index of conscious perception. Eye movements revealed that for a subset of participants their conscious perception was not related to where they were looking at the time of the event and thus demonstrate how overt and covert attention can be spatially dissociated. However, detection of the event resulted in rapid shifts of eye movements towards the detected event, thus indicating a strong temporal link between overt and covert attention, and that covert attention can be allocated at least 2 or 3 saccade targets ahead of where people are fixating.

Keywords: Covert attention; Overt attention; Inattentional blindness; Misdirection; Eye movements; Visual awareness.

Our subjective impression of the world is typically one of full coherence and rich sensory detail. However, phenomena such as change blindness demonstrate that our conscious representation of the world is far less complete than what our subjective experience would suggest (Rensink, 2000). In change blindness, observers typically fail to perceive relatively large changes to a scene, as long as the change takes place during a brief interruption (Rensink, 2002), or is very gradual (Simons, Franconeri, & Reimer, 2000), thus illustrating that much of our visual information is rapidly lost. There are two main factors that are responsible for this impoverished conscious visual representation. For one, the information received by the visual system largely depends on where we look, or fixate. This is because the photo receptors on the retina, responsible for transducing the visual information to the brain, are not uniformly distributed. Moreover, the projection pathways that pass the sensory information on to the visual areas do not treat all parts of the visual field

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equally (Findlay & Gilchrist, 2003). Instead, there is a very dense representation in the centre of the retina, which becomes much sparser towards the periphery, thus only resulting in high-acuity information from the small foveal region (two degrees surrounding the fixation point). However, we are typically unaware of this impoverished peripheral visual sensory information. This is because our visual system uses the high-acuity foveal information to its full potential through the use of strategic eye movements, by fixating areas that are of high interest (e.g., Henderson, 2003; Land, 2006).

In addition to where we look, our conscious perception is strongly influenced by where we attend to covertly. When engaged in attentionally demanding tasks where attention is directed away from the point of fixation, people often fail to perceive unexpected but fully salient events presented at this point, a phenomenon known as inattentional blindness (Mack & Rock, 1998). Inattentional blindness is a powerful demonstration of how information that is not attended does not enter our conscious awareness (Most, Scholl, Clifford, & Simons, 2005). However, certain aspects of a scene, such as its gist, are recognized with no need for focused attention (Mack & Rock, 1998). Moreover, certain categorizations, such as deciding whether a scene contains an animal or not, can be made very rapidly and without needing any top down attention (Li, VanRullen, Koch, & Perona, 2002). However, under more natural viewing conditions there is a fairly close correlation between attentional allocation and the details of a scene that are consciously reported. For example, participants are less susceptible to change blindness if the change occurs to areas of high interest (Rensink, O'Regan, & Clark, 1997) or to areas that are cued using a peripheral (Smith & Schenk, 2008) or central attentional cue (Langton, O'Donnell, Riby, & Ballantyne, 2006). For the purpose of the present study we therefore adopt the assumption that the perception of relatively small visual changes (such as the dropping of a lighter) requires covert attention (see Tse, 2004, for a more detailed discussion; but see Koch & Tsuchiya, 2007, for a different view).

What we see is related to both what we attend to overtly and what we attend to covertly. Most researchers accept the notion that under normal viewing conditions covert and overt attention are fairly closely linked (see Awh, Armstrong, & Moore, 2006). For one, there is a close overlap between the neural circuits mediating both overt and covert attention (Corbetta et al., 1998), and shifts in covert attention are often followed by shifts in overt attention. However, there is somewhat more disagreement over the exact relationship between the two types of attention. The premotor theory of attention suggests that covert attentional orienting is achieved by employing saccade preparation processes (Rizzolatti, Riggio, Dascola, & Umiltà, 1987) thus suggesting that covert and overt attention are driven by the same neural mechanism (Deubel & Schneider, 1996). Findlay (2005) has even suggested that during active scanning the sole purpose of covert attention is the planning of a subsequent saccade. However, Klein (1980) showed that this intricate link only applies when a saccade is being executed, but not when it is prepared but not executed.

There is much debate over the exact mechanism that relates covert and overt attention to situations where a saccade has been executed. Sequential models of attention assume that at some point prior to the execution of the saccade attention is shifted to the next saccade target. Once attention has moved to the new location, information processing at this location starts, and only some time subsequently does the next saccade occur (Henderson, 1992; Henderson, Pollatsek, & Rayner, 1989; Reichle, Pollatsek, Fisher, & Rayner, 1998). According to these models, covert attention is always directed to one location, but moves there prior to the eye doing so. However, alternative models assume that attention might be more of a parallel processing whereby saccades are directed to points of high saliency on a saliency map (salience is used in a generic way here rather than bottom-up "intrinsic" salience), rather than the next fixation location. Several of these models make different predictions about how far in advance attention can be allocated. Henderson (1992), for example, argued that covert attention can only be allocated one saccade target ahead of the current fixation. Alternative models assume that attention can be allocated to multiple saccade goals, prior to the execution of a saccade. For example, it has been argued that before the eye movement is executed, attention is shifted serially between the saccade goal and some of the no-saccade locations (Kowler, Anderson, Dosher, & Blaser, 1995). Similarly, Godijn and Theeuwes (2003) have shown that attention is allocated to multiple saccade targets in parallel.

Kuhn and his colleagues (Kuhn & Tatler, 2005; Kuhn, Tatler, Findlay, & Cole, 2008; Tatler & Kuhn, 2007) have developed a paradigm that allows for the investigation of attention that offers very high levels of ecological validity. Manipulating peoples' attention lies at the heart of most conjuring and magic tricks (Kuhn, Amlani, & Rensink, 2008; Macknik et al., 2008). Incorporating these principles and techniques into an experimental setting thus provides a powerful tool for attention research. This link between magic and experimental paradigms was achieved by developing a magic trick that solely relied on misdirection—that is, manipulating attention away from the method (i.e., how the trick is done) and towards the effect (i.e., magic effect experienced by the spectator). In this misdirection trick a lighter and a cigarette disappeared. Crucially the method used to make the cigarette disappear relied on misdirection, which prevented most people from seeing it being visibly dropped into the magician's lap. Although this event was visually salient (white cigarette in front of a black background) and took place in full view, a high proportion of the participants failed to report seeing it drop. This misdirection trick is analogous to inattentional blindness. However, whilst in typical inattentional blindness paradigms participants' attentional resources are restricted through the use of explicit attentionally demanding distractor tasks, in the misdirection trick participants' attentional resources are constrained though the systematic but implicit orchestration of attention.

The aims of the present paper were twofold. The first aim was to resolve some of the controversies of indexing participants' conscious perception of an event via verbal reports. The second aim was to use the misdirection paradigm to investigate the relationship between fixation and awareness and thus provide insights into the relationship between overt and covert attention.

In the previous studies participants' detection of the event was measured by asking them to describe what they saw. If participants claimed to have seen the cigarette drop, they were considered to have seen the drop. Simply asking people to describe what they saw makes it difficult to distinguish between perception and inference. Kuhn et al. (2008) tried to resolve this issue by explicitly instructing participants to distinguish between what they saw and inferences about how they thought the trick was done. However, this approach can never guarantee that participants' verbal reports about what they saw are not influenced by inference. One way of evaluating whether people's verbal reports reflect inferences rather than visual perceptions is to determine whether they would indeed falsely claim to have seen an event that is likely to be inferred but never took place. In the experiments reported here we used a similar misdirection trick but modified so that the misdirection was used to conceal the dropping of a lighter, rather than a cigarette. By digitally editing this video clip we then removed the dropping lighter, thus creating a "fake" misdirection trick. As the dropping lighter is now not visible, any claims of having seen the lighter drop is a clear indication of inference. A lack of such false alarms would indicate that the verbal reports are a true reflection of what they saw, rather than inference.[1] Evaluating the reliability of verbal reports is not only important in the context of the current paradigm, but also

[1] In the previous studies, the disappearance of the lighter was used as misdirection so as to prevent participants from detecting the visible cigarette drop. In the present study we designed a new misdirection trick in which only one object—namely, a lighter—disappeared. The simplicity of this trick was thought to further reduce any confusion between perception and inference.

consequential for research in change/inattentional blindness in general.

The second aim was to use the misdirection trick to investigate the relationship between overt attention and visual awareness. By assuming that detection of the event (i.e., awareness of the drop) requires covert attention, we can use participants' detection of the event as an index of covert attention (Tse, 2004). Participants' eye movements on the other hand provide a measure of overt attention. The combination of eye movement and awareness measures allows us to examine the relationship between overt and covert attention in a highly naturalistic task. Moreover, by exploiting the dynamic nature of our stimuli, we can study the temporal relationship between overt and covert attention. It has previously been shown that whilst there was no relationship between the detection of the drop and participants' fixations at the time of the event, the time it took subsequently for participants to fixate the hand that dropped the cigarette strongly correlated with the detection of the event. Participants who detected the drop moved their fixation much more rapidly towards the location where it took place than did those participants who missed it, thus demonstrating a close temporal link between overt and covert attention. The aim here was to follow up this intriguing finding and to establish the causal direction of this relationship and the nature of this link. The previous report demonstrated that participants typically fixated between two to four other fixation targets prior to looking at the hand, thus suggesting that covert attention may have been allocated several saccade targets ahead of fixation.

Method

Participants

A total of 40 undergraduate students participated for course credits. Mean age was 21.6 years ($SD = 5.11$; 18 male, 22 female).

Material

The effect in this magic trick was the disappearance of a lighter (see Figure 1 for a description of the trick). In this trick the magician picks up a lighter with his left hand (a) and lights it (b). He then

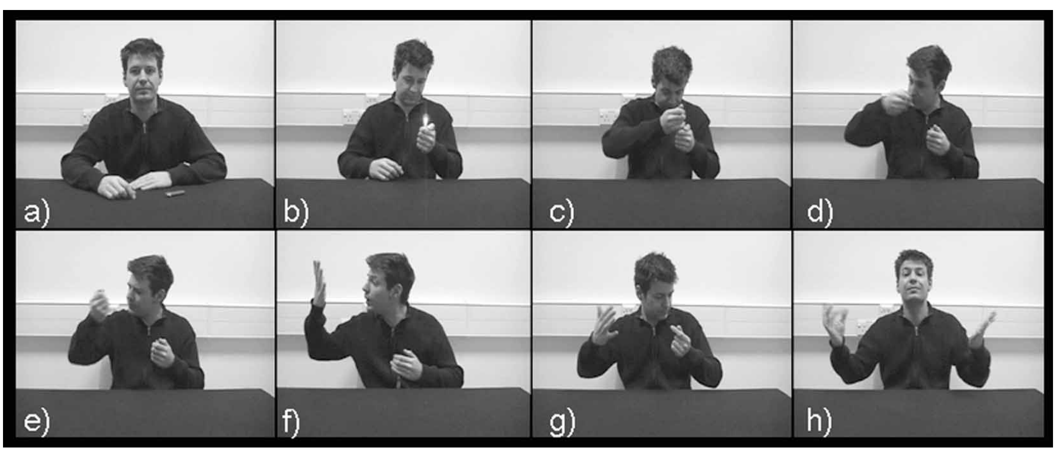

Figure 1. *The sequence of events in the misdirection trick. The effect in this magic trick was the disappearance of a lighter. In this trick the magician picks up a lighter with his left hand (a) and lights it (b). He then pretends to take the flame with his right hand (d) and gradually moves it away from the hand that is holding the lighter (d, e). During this manoeuvre the magician is looking at the right hand. Once it has reached the other side, he snaps his fingers, waves his hand, and reveals that it is empty (f). 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 (g), raises it, and snaps his fingers to reveal that his left hand is now also empty, and the lighter has disappeared (h).*

pretends to take the flame with his right hand (c) and gradually pretends to move it away from the hand that is holding the lighter (d, e). During this manoeuvre the magician is looking at the right hand. Once it has reached the other side, he snaps his fingers, waves his hand, and reveals that it is empty (f). 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 (g), raises it, and snaps his fingers to reveal that his left hand is now also empty, and the lighter has disappeared (h).

The magic trick was filmed using a digital video camera (PAL, JVC, GR-D240EK) at 25 frames per second (fps) and was then sampled using Adobe Premier (720 × 576). All of the video editing was carried out using Adobe Premier and Adobe Photoshop. The entire magic trick lasted 13.68 s (342 frames). A total of 125 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 dropping lighter was visible on 3 frames. The video was exported as a film strip and was edited using Adobe Photoshop. For the video clip in the "fake" condition the dropping lighter was removed using the Photoshop stamp tool on the 3 frames on which it was visible. The film strips were then converted back into an AVI file. The video clips were presented using SR Research Experiment Builder software, which guaranteed accurate frame display timing. The movies were displayed on a 21-in. CRT monitor (75 Hz). Screen resolution was set to 600 × 800 pixels so that the video clip filled most of the screen (24.9 × 31.9 degrees). Eye movements were recorded using an SR-Research Eyelink2 eye tracker (500 Hz). Viewing distance was 63 cm, and the head was fixed using a chin rest. Saccades were defined as eye movements with velocities and accelerations exceeding 30°/s and $8{,}000°/s^2$.

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. Participants were randomly allocated to seeing either the real or the fake magic trick. 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 degrees. 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.

Results

Verbal reports

Participants were classified as having seen the lighter drop if they answered yes to whether they saw the lighter drop. In the "real" condition, 13 (65%) participants saw the lighter drop. Of the 7 participants who missed it none thought that the method used to make the lighter disappear involved dropping it; 5 thought that the lighter went up the sleeve whilst the remaining 2 participants came up with rather elaborate explanations (e.g., video editing). In the "fake" condition none of the participants claimed to have seen how the lighter disappeared. However, when asked how they thought the magic trick was done 8 participants thought that the lighter might have been dropped, 8 thought it went up the sleeve, and the remaining 4 participants came up with rather elaborate answers, similar to the ones in the "real" condition.

As none of the participants in the "fake" condition claimed to have seen the lighter disappear, we can conclude that participants' verbal reports reflect what they saw rather than what they inferred. Moreover, several participants in the "fake" condition successfully guessed that the lighter was dropped, whilst claiming they did not see it drop, which again suggests that participants were able to differentiate between what they saw and how they thought it was done.

All of the 7 participants who did not see the drop in the "real" condition saw the lighter drop when the clip was played again, thus demonstrating that the dropping lighter was indeed fully visible for all.

Why did participants miss the drop?

Previous studies have shown that detection of the drop was not related to low-level visual disruptions such as eye blinks or saccades at the time of the drop (Kuhn & Tatler, 2005; Kuhn et al., 2008). Similarly for participants in the real condition, no eye blinks were detected, and participants who missed the drop were just as likely to make a saccade during the time of the drop (28%) as were those who detected it (23%), $\chi^2 = 0.073$, $p = .80$. (The drop was defined as the time during which the dropping lighter was visible, which accounted for 3 frames—Frames 314–316—and thus lasted for 120 ms.)

Relationship between detection and fixation

The aim of misdirection is to direct attention away from the method (i.e., the lighter drop). Successful misdirection should therefore result in directing people's fixations away from the hand holding the lighter. Our material allowed us to deal with the difficult problem of analysing eye movement data in relation to dynamic visual stimuli. The dropping lighter was visible over 3 frames. We therefore decided to analyse the fixation points exactly in the middle of the drop (10th sample, 2nd frame). Figure 2a shows participants' fixation points at the time of the drop for participants who saw the drop and those who missed it. All of the participants who missed the drop fixated either on the head or in the vicinity of the waving left hand. Of the 13 participants who detected the drop, 4 participants fixated in close proximity of the lighter hand (within 3.5 degrees of the hand). The remaining 9 participants fixated areas similar to the participants who missed it—namely, the head (5 participants) or the waving hand (4 participants). These 9 participants therefore detected the drop using peripheral vision and are classified as peripheral detectors. In order to quantify the differences between the peripheral detectors and the participants who missed the drop we calculated the distance between the fixation and the lighter. There was no significant difference in visual eccentricity (i.e., distance between fixation and change) between the participants who detected the drop in peripheral vision ($M = 11.1$ degrees; lower 95% CI = 9.40, upper 95%

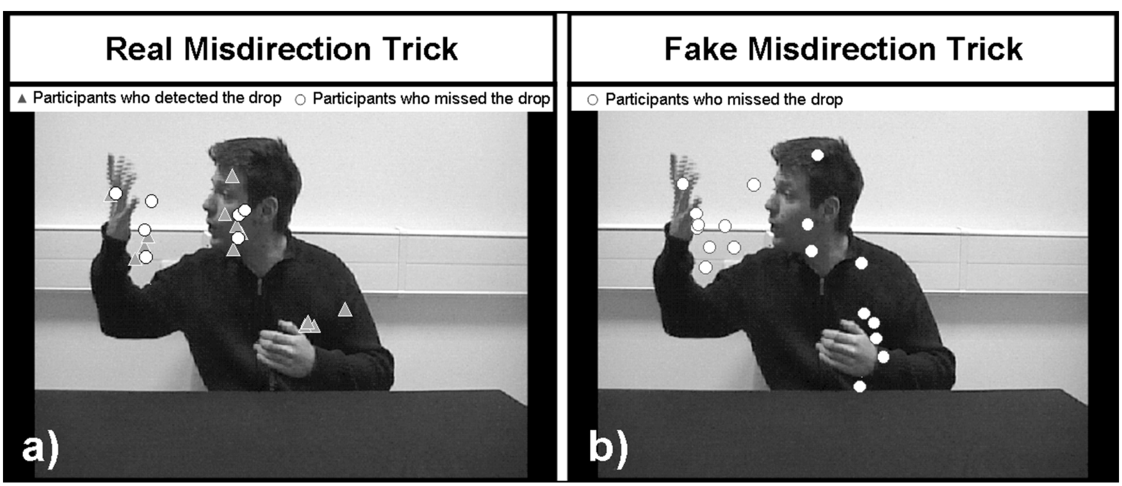

Figure 2. *Participants' fixation points at the time of the drop. Panel a shows fixation points for participants watching the "real" misdirection trick. Panel b shows fixation points for participants watching the "fake" misdirection trick. Data from 1 participant in the "fake" condition were excluded due to tracker loss.*

CI = 12.86) and those who missed it ($M = 11.6$ degrees; lower 95% CI = 9.41, upper 95% CI = 13.70), $t(14) < 1$. Although all of the participants who fixated the proximity of the lighter drop detected it, looking at it was not essential for its detection.

Eye movements after the drop

The difference between participants who detected the lighter and those who missed it may be due to differences in covert attentional deployment. Although participants who detected the lighter in the periphery may have been fixating the head or the hand, covertly they might have been attending to the lighter hand, thus enabling the detection of the drop. One possible way of investigating this hypothesis involves looking at participants' eye movements after the event. Kuhn et al. (2008) showed that participants who detected the drop moved their fixation to the area where the event took place more quickly than those who missed it. However, as these results were correlational, it remains uncertain whether it was the detection of the event that resulted in this rapid shift of overt attention to the location of interest, or whether it was the rapid shifts in fixation towards the event that results in its detection. The present design allows us to answer this question of causality by including the data from the participants in the "fake" condition. If it was the detection of the event that resulted in faster eye movements to the hand we would expect to find a difference in the timing data between the participants who detected the drop for real and those who did not claim to have seen it in the "real" and the "fake" conditions. Moreover, we would expect to find no difference between participants who missed the drop in the "fake" and the "real" conditions. If the causal relationship is reversed, we would expect participants who missed the drop for real to be slower than the participants in the "fake" condition. We defined an area of interest around the lighter hand that consisted of a circle (100 pixels in diameter, 4.3°), that was centred on the hand and was defined for each frame following the drop. For participants who fixated in one of the areas away from the lighter hand, we calculated the time between the beginning of the lighter drop (first sample on Frame 315) and fixating this area of interest. Figure 2b shows the fixation points of participants in the "fake" condition. All of the data were used apart from data for the 5 participants who were already fixating the lighter hand area (data from 2 participants are missing due to tracker loss). Of the remaining 28 participants all but two looked at the lighter hand at some point after the drop. This in itself is not surprising, since following misdirection the magician did direct peoples' attention back to the lighter hand. Table 1 shows the mean time it took for participants to move their eyes to the lighter hand.

A between-subject analysis of variance (ANOVA) with group ("real" detect vs. "real" miss vs. "fake" miss) as a between-subject variable found a significant main effect of group, $F(2, 23) = 4.59$, $p = .021$. Planned contrasts showed that participants who detected the drop were significantly faster than participants who missed it in the "real" and the "fake" condition, $t(23) = 3.05$, $p = .006$. However, there was no significant difference between the participants who missed the drop in the "fake" and the "real" condition, $t(23) < 1$. This pattern of results clearly supports the notion that detection caused a rapid shift in the fixation towards the location at which the event took place.

Although participants who detected the drop using peripheral vision moved their fixation to the hand that held the lighter earlier than those who missed it, only half of them fixated the lighter immediately. The other half of the participants made up to 3 saccades prior to fixating the lighter hand. Typically participants who fixated

Table 1. *Mean time between fixating the area of the lighter hand and the lighter drop*

Group	*M*	*SD*	*N*
Real detect	650	248	8
Real miss	1,712	806	7
Fake miss	1,720	1,070	11

Note: Mean time in ms.

the right hand at the time of the drop saccaded to the face before fixating the lighter hand. Another participant who fixated the face at the time of the drop saccaded to the right hand prior to fixating the lighter hand, thus demonstrating that several of these saccades went in the opposite direction to the lighter hand. These results demonstrate that covert attention can be allocated several saccade targets ahead of fixation.

Discussion

In this experiment we showed how misdirection could be used to prevent people from perceiving a salient event—namely, the dropping of a lighter. Misdirection was used to manipulate observers' attention away from the salient event and thus preventing participants from consciously perceiving it, thus offering an intuitive example of inattentional blindness. The field of perception and awareness is ridden with controversies regarding the measures of conscious perception. For example, how do we know that people's verbal reports are a true reflection of their conscious perception? In the context of our experiment, how do we know that participants who claimed to have seen the lighter drop did indeed see an object drop rather merely reporting a likely scenario? For one, our participants were explicitly asked to distinguish between what they saw and how they thought the trick was done, thus discouraging them from reporting inferences rather than perceptual experiences. However, more convincingly, as none of the participants viewing the "fake" lighter trick erroneously reported having seen the lighter drop, this provides evidence that participants' verbal reports were indeed a true reflection of what they saw. One could turn the argument round and ask whether participants failed to report having seen the lighter drop because even though they saw it drop, they rapidly forgot the event. This interpretation implies that failure to report having seen the drop resulted from rapid forgetting, rather than true failure in perception. Similar arguments have been made in the inattentional/change blindness literature (Wolfe, 1999). Given the time delay between the drop and the verbal report this interpretation may seem quite plausible. However, as participants were instructed to discover how the magic trick was done, it seems rather doubtful that having seen an object drop, participants would forget about this immediately, as the dropping lighter was an obvious cue as to how it was done. The inattentional amnesia hypothesis also gains little empirical support from the eye movement data. Participants' scan paths after the drop revealed clear distinctions between participants who detected the drop and those who missed it. Participants who detected the drop were significantly faster to move their fixation to the lighter hand than those who missed it. Moreover, there was no difference between the participants who missed the drop and those who did not see it for real, thus further supporting the view that participants who failed to report having seen the drop did indeed fail to see it. It is likely that the detection of the dropping lighter increased the salience of the lighter hand and thus made it an important target for future fixation. In sum we are confident that participants' verbal reports are a true reflection of their conscious perception and thus offers a valuable paradigm to investigate inattentional blindness. However, in some degrees, misdirection differs from traditional inattentional blindness (Mack & Rock, 1998; Most et al., 2005). In the misdirection paradigm, participants are instructed to watch a magic trick and to discover how it is done. One could therefore argue that contrary to the typical inattentional blindness paradigm, some of the participants might expect something unusual to take place. Though this may be the case, participants had no idea that the trick would involve a lighter disappearing, let alone that they should monitor something being dropped. Magic tricks range from predicting a person's future to making objects levitate, and thus even though participants knew that they were about to see a magic trick, the dropping lighter would have been rather unexpected. A further distinction is that in typical inattentional blindness paradigms, participants are given a primary attention task, such as counting the number of times objects cross a central line. In the misdirection paradigm, on the other hand, participants are merely asked to watch a magic trick. Misdirection therefore works by implicitly manipulating participants' attention. The absence of a primary distractor tasks prevents us from evaluating the amount of attention being paid to the trick. However, as all of the participants reported having seen a lighter disappear we can be fairly confident that they were attending to the trick itself. On a related note, misdirection only works if the observer is paying attention to the trick; then how do you misdirect attention that isn't there?

The second aim of this paper was to investigate the reasons as to why some people fail to perceive the drop and relate this to theories of attention. The main focus of this analysis was to look at the fixation points at the time of the event. In change blindness studies it has been shown that participants' detection of a change is negatively correlated with visual eccentricity (Henderson & Hollingworth, 1999), thus suggesting a close relationship between detection and fixation. However, using dynamic displays Kuhn and colleagues (Kuhn & Tatler, 2005; Kuhn et al., 2008) have found no relationship between participants' detection and visual eccentricity. Similarly, using Simons and Chabris's (1999) selective looking task, Memmert (2006) showed that participants who detected the unexpected event spent on average the same amount of time looking at the unexpected object as those participants who perceived it. In the present study we found mixed results. All of the participants who missed the drop fixated areas other than the lighter hand whilst all of the participants who looked at the lighter hand detected it. These results demonstrate a close relationship between visual detection and eccentricity. However, more than half the participants detected the drop in the periphery. These participants fixated areas other than the lighter hand, yet they still detected the drop. Moreover, there was no difference in visual eccentricity between these participants and those who missed it, thus demonstrating that fixating the object was not obligatory for its detection. Analogous to research on inattentional blindness we demonstrate that the detection of an event requires covert attention and is relatively independent of where people are fixating.

Although there was no difference between participants who detected the drop and those who missed it at the time of the event, the eye movement strategies after the event differed in a way that was highly predictive of their detection. Our results showed that detection of the drop resulted in fairly rapid eye movements towards the area where the event took place, thus demonstrating a close temporal link between covert and overt attention. By experimentally manipulating whether participants could see the drop or not, we can conclude that it was the detection of the drop that led to these rapid shifts in fixation.

We set out to answer the controversial question of the relationship between eye fixation and attention. Posner (1980) recognized that orienting of attention in the visual field facilitates the processing of the information present in the attended location and inhibits the processing of information present in the unattended location. As discussed earlier, when vision is being used actively, covert attention is closely linked to overt eye movements, although the latter form of orienting is distinguished by the self-evident fact that the eye can only be directed to one location at a time. At first sight our results appear to support a premotor theory of attention, which suggests that covert attention is required for the planning of an eye movement. This theory predicts that eye movements lag behind covert attention, which concurs with the results presented here. Different theories make different predictions about the size of the potential lag. Sequential models of attention assume that covert attention can only be allocated to the next saccade target. These models predict that the participants who detected the drop in the periphery should fixate the lighter hand within the next saccade. However some of the participants who detected the drop in the periphery made up to 3 saccades prior to fixating the lighter hand ($M = 1.9$; $SD = 0.83$). These results therefore concur with theories of attention that assume that attention can be allocated to several saccade targets prior to the execution of the saccade. Moreover, several of these saccades went in the opposite direction prior to fixating the hand, thus suggesting that contrary to previous results (Henderson et al., 1989) covert attention can be directed to multiple saccade targets. This interpretation concurs with recent findings using relatively impoverished displays claiming that covert attention is allocated to several saccade targets in parallel (Godijn & Theeuwes, 2003).

In most of the previous research that has investigated the relationship between overt and covert attention, participants are pressured into making speeded responses. Participants are usually instructed to carry out predetermined saccade sequences, followed by a speeded detection task. Although these types of experiment offer a great deal of experimental control, they raise questions as to the extent to which they are a true reflection of natural eye movements. It is very unusual for us to be explicitly instructed to fixate particular areas in fixed sequence. In fact, we rarely think about where we are looking and are typically unaware of our strategic eye movements (Kuhn & Land, 2006). In the current experiment participants were given no explicit instructions on where to look or attend, thus allowing us to tap into more natural oculomotor behaviour. Moreover, in the current paradigm we were able to use a highly ecologically valid setting (dynamic natural display) whilst retaining an extremely high degree of experimental control. In particular we have demonstrated that covert attention may be allocated to several (up to 3) saccade targets.

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