Misdirection in magic: Implications for the relationship between eye gaze and attention

Gustav Kuhn a, Benjamin W. Tatler b, John M. Findlay a, Geoff G. Cole a

a University of Durham, Durham, UK
b University of Dundee, Dundee, UK

First Published on: 17 October 2007
To cite this Article: Kuhn, Gustav, Tatler, Benjamin W., Findlay, John M. and Cole, Geoff G. (2007) 'Misdirection in magic: Implications for the relationship between eye gaze and attention', Visual Cognition, 16:2, 391 - 405
To link to this article: DOI: 10.1080/13506280701479750
URL: http://dx.doi.org/10.1080/13506280701479750

Visual Cognition
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713683696

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Misdirection in magic: Implications for the relationship between eye gaze and attention

Gustav Kuhn
University of Durham, Durham, UK

Benjamin W. Tatler
University of Dundee, Dundee, UK

John M. Findlay
University of Durham, Durham, UK

Geoff G. Cole
University of Durham, Durham, UK

Magicians use misdirection to manipulate people's attention in order to prevent their audiences from uncovering their methods. Here we used a prerecorded version of a magic trick to investigate some of the factors that accompany successful misdirection. Prior information about the nature of the trick significantly improved participants' detection of the method. The informed participants fixated closer to the event in question, suggesting that they were monitoring it more closely once they knew about the trick. The probability of detection was independent of how far the participant was looking from the “secret” event as it happened, but participants who detected the event moved their eyes towards where it took place much earlier than participants who missed it. This result is consistent with the notion that attention is allocated ahead of the current locus of fixation, and we present evidence that attention may be allocated two or more saccade targets ahead of where the participant is fixating.

As we view our surroundings, our eyes sample discrete locations; a common view is that information from these discrete samples is somehow combined to form a visual representation of the world. The phenomenon of change blindness has been used recently to demonstrate that our conscious visual representation is far less veridical than our subjective experience would...
suggest. For example, observers often fail to notice seemingly obvious changes to a scene if the change occurs during a brief interruption of viewing (Rensink, O’Regan, & Clark, 1997), which can be a natural event such as a saccade (Grimes, 1996; Henderson & Hollingworth, 1999b; McConkie & Currie, 1996). This demonstrates that we do not retain fully detailed perceptual images across saccades. Furthermore, our subjective world does not correspond to the information supplied by a single fixation. The photoreceptors responsible for transducing the visual information are unevenly spread across the retina; there is a very dense allocation in the fovea, which becomes systematically sparser towards the periphery. This heterogeneous distribution results in high-acuity vision in the small foveal region covering approximately two degrees surrounding the current fixation point, but drops off rapidly towards the periphery. Under normal viewing conditions, we are rarely aware of our impoverished peripheral vision. This is largely because the visual system makes the most of the high acuity visual information at the fovea by strategically re-orienting the foveal fixation point (Buswell, 1935; Henderson & Hollingworth, 1999a; Yarbus, 1967). These saccadic eye movements are far from random. Instead, the system in general maintains the gaze very close to where the information is being extracted, thereby using the fovea’s high acuity to its full potential (see Land, 2006; Land & Furneaux, 1997; Land & Lee, 1994; Land, Mennie, & Rusted, 1999; Rayner, 1998).

While fixating an object provides high acuity visual information from the fovea, this does not inevitably lead to awareness of the fixated object. When people are preoccupied with an attentionally demanding task, they often fail to notice stimuli that appear at fixation, a phenomenon known as inattentional blindness (Mack & Rock, 1998). A striking example of inattentional blindness can be found in Simons and Chabris’s (1999) modification of Neisser’s (1967) selective viewing task, in which observers are asked to watch a video clip of two teams of basketball players passing balls to each other, and are required to count the number of passes made by one team. Unbeknown to the observers, a person wearing a gorilla suit walks through the midst of the two teams. Although the gorilla passes across the observers’ line of view, they often fail to notice it (see Most, Scholl, Clifford, & Simons, 2005, for a review). Observers failed to detect the gorilla because they did not attend to it. Although there is undoubtedly a close link between where people fixate and where they are attending to (Deubel & Schneider, 1996; Henderson, 1992; Rizzolatti, Riggio, Dascola, & Umiltà, 1987), inattentional blindness demonstrates that fixation and attention can be dissociated.

The phenomena of change blindness and inattentional blindness are of great theoretical importance and have led to significant revisions of current models of visual perception (O’Regan & Noe, 2001; Rensink, 2000). Although it is only recently that these phenomena have been investigated by vision scientists, magicians have exploited people’s limited perceptual
awareness for centuries. One of the fundamental achievements of magic is the ability to carry out actions that are not noticed by the audience. This form of deception often relies on sleight of hand and secret props, but a basic aspect of the magician’s art involves misdirection, a process by which observers’ attention is manipulated away from the secret action (Kuhn & Land, 2006; Kuhn & Tatler, 2005; Lamont & Wiseman, 1999; Tatler & Kuhn, 2007). Many previous inattentional blindness experiments have used relatively artificial paradigms and are therefore open to criticism for their low ecological validity. Misdirection in magic, on the other hand, offers a unique opportunity to investigate attentional manipulation in a more realistic setting.

Previous research in change detection has shown that the probability of detecting a change was negatively correlated with the visual eccentricity of the change (Henderson & Hollingworth, 1999b; see also O’Regan, Deubel, Clark, & Rensink, 2000). This suggests a straightforward relation between attention and fixation: That we attend primarily to where our eyes are directed. It might therefore be expected that the probability of detection during a magician’s performance would be related to the closeness of the foveal axis to the position of the to-be-concealed event. Kuhn and Tatler (2005) developed a magic trick to test this postulate, in which a cigarette and lighter seemed to disappear. The method used to create this illusion solely relied on misdirection (see Tatler & Kuhn, 2007, for a detailed description of how misdirection works). In full view of the observer, the cigarette was dropped into the magician’s lap. Although the dropping cigarette was potentially visible, most of the observers (18/20) failed to spot it. However, when the magic trick was repeated, all of the observers detected the dropping cigarette.

By measuring observers’ eye movements while they watched the magic trick being performed live, Kuhn and Tatler (2005) found, surprisingly, that participants’ detection of the dropping cigarette was largely independent of how far the eye was from the cigarette as it dropped. Neither did it relate to other factors, such as saccades or eye blinks, during the drop. They therefore argued that the misdirection employed by the magician involved manipulating covert, rather than overt attention (see Most et al., 2005, for a discussion of using inattentional blindness as a measure of attentional capture; cf. Li, VanRullen, Koch, & Perona, 2002).

The live performance of the magic trick provided high ecological validity. However, as live performances use subtle interaction between the magician and the audience, it is virtually impossible to ensure complete consistency across performances, thus making it difficult to analyse the data in terms of its temporal aspect. Such a (necessary) lack of experimental control meant

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1 It should be noted that Tatler and Kuhn (2007) showed that there was relatively high consistency over trials.
that a precise account of the likely factors in the magician’s success was hard to formulate. In the present study, we measured participants’ eye movements while they watched a prerecorded version of the magic trick; thus, each participant saw exactly the same performance of the trick. In addition to looking at the eye movements at the time of the drop, in an attempt to replicate the Kuhn and Tatler (2005) finding, we were particularly interested in the postdrop oculomotor behaviour. In the previous, real-world study, only two participants detected the cigarette on the first trial, meaning that comparing participants who detected the cigarette and those who missed it could only be conducted by comparing across trials (i.e., comparison between the first and the second trial). Although the magic trick on the second trial was (as much as possible in the real world) identical to the first trial, the mere fact that the participants knew exactly what to expect on the second viewing changed the cognitive demand of the task considerably. Ideally, one would therefore have wanted to compare the eye movements between participants who detected the cigarette on the first trial and those who missed it. In our previous work, we showed that there was a close link between where the magician fixated and where the observer looked (Tatler & Kuhn, 2007). This was attributed to people’s susceptibility to cues for joint (or social) attention (see, e.g., Tomasello, 1995, 1999): People tend to follow one another’s gaze (Kuhn & Benson, 2007; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). Previous work (e.g., Gullberg & Holmqvist, 2002) has suggested that such cues for joint attention are less effective when viewing a video of a speaker on a television screen than when face-to-face with a real speaker. We therefore predicted that in the present experiment, the magician’s misdirection would be less effective and therefore more participants would detect the dropping cigarette on the first trial. Higher detection rates on the first trial would allow for the comparisons in eye movements between participants who detected or missed the cigarette drop on the first trial, thus controlling participants’ expectations and familiarity of the trick.

Surprisingly, Kuhn and Tatler (2005) showed that prior information in the form of knowing that participants were about to see a magician making a cigarette and a lighter disappear had little effect on detection rates and eye movement strategies (Tatler & Kuhn, 2007). However, as only two participants detected the cigarette on the first trial, it is possible that the similarity between the naïve and the informed participants’ performance was dominated by any factors associated with not detecting the cigarette. Prior knowledge about the nature of the magic trick should enhance participants’ interest in the cigarette. Several studies have shown that people detect changes more easily if they occur to parts of a scene that are of high interest (O’Regan et al., 2000). We would therefore expect that the prior knowledge should improve participants’ detection of the dropping cigarette.
The present study provides the opportunity to follow up some intriguing recent findings from studying magic in the real world. Crucially, the added element of control and the anticipated higher rate of detection of the trick on the first performance will allow us to critically evaluate our previous claims of dissociated attention and fixation when detecting the cigarette drop and to investigate the time course of participants’ eye movements.

METHOD

Participants
Forty-six University of Sussex undergraduates took part in the experiment for course credit.

Material
The magic trick was identical to the one used by Kuhn and Tatler (2005) (see Figure 1 for a full description). The magic trick was filmed using a digital video camera (PAL) at 25 fps, and edited using Windows Movie Maker (see http://www.dur.ac.uk/gustav.kuhn/Kuhn_et_al_2007/material.htm for the video clip). The dropping cigarette was visible for six frames (240 ms). The edited movie was then recorded back on to mini DV and presented on a 27-inch Sanyo colour TV screen (50 Hz), at a viewing distance of 90 cm, and their head was fixed using a chinrest. Participants’ eye movements were measured using an ASL5000 head mounted video-based eye tracker at 50 Hz. The eye movement data was captured on DV and analysed on a frame by frame basis (25 Hz). The method used to make the lighter and the cigarette disappear both relies on dropping the objects into the lap. For the cigarette, this drop happened in full view, whilst the lighter drop was concealed by the hand, and therefore could not be perceived.

Procedure
Half of the participants were informed that they were about to see a magician making a cigarette and a lighter disappear, and that their task was to find out how this was done (informed participants). The other half of the participants were merely told that they were about to see a video clip of a magician performing a magic trick (naïve participants). All other aspects of the experiment were identical for both groups. Participants were seated in front of a colour TV. The eye tracker was calibrated using nine calibration points, presented on the TV monitor. Following the video clip, participants
were asked a series of questions, which assessed first, whether they saw the method used to make the cigarette or the lighter disappear, and second, how they thought the trick was done. Participants were reminded about the difference between perceiving an event and knowing how it was done. The experiment was terminated when the participant successfully reported detecting the dropping cigarette, otherwise the clip was repeated.

RESULTS

Behavioural data

On the first trial, 7 (out of 23) of the naïve participants and 13 (out of 23) of the informed participants detected the dropping cigarette. A sceptic
might argue that participants’ who reported having detected the drop based their report on inference, rather than perception. If participants’ verbal reports were based on inference, we would expect them to report seeing the lighter drop as well as the cigarette. However, none of the participants who detected the cigarette drop claimed to have seen the lighter disappear, which suggests that participants’ reports were based on what they saw, rather than on inference.

As outlined in the introduction, despite previous work (Kuhn & Tatler, 2005; Tatler & Kuhn, 2007), we predicted that when viewing the videos of the magic trick, prior knowledge ought to lead to higher detection rates. This was indeed the case: Participants who knew in advance that a cigarette would be made to disappear were more likely to detect the drop, $\chi^2 = 3.19, p = .037$ (one tailed). On the second trial, only 5 (out of 26)$^2$ participants missed the cigarette drop, and all of the participants detected the cigarette on the third trial. Similar to Kuhn and Tatler’s (2005) real-world experiment, repeated viewing increased the chance of participants detecting the cigarette. However, in the prerecorded version, participants spotted the cigarette more easily than in the live performance, which allowed us to compare eye movements between participants who detected the cigarette compared to those who missed it on the first trial alone.

**Eye movement data**

The aim of this analysis was to investigate any systematic differences in eye movements that could account for participants’ failure in detecting the cigarette, and the extent to which participants’ eye movements were affected by the prior knowledge. Eye tracking data from one participant was discarded due to signal loss (informed condition).

Kuhn and Tatler (2005) showed that detection rates were not influenced by the occurrence of blinks or saccades at the time of the drop. In the present study, we confirm these suggestions. No blinks occurred at the time of the drop and although occasionally participants made a saccade during the 240 ms period that the cigarette was visible, these were equally likely to occur for participants who detected the drop (4 out of 19)$^3$ as those who did not (5 out of 26), $\chi^2 = 0.82, p = .46$.

Kuhn and Tatler (2005) suggested that the distance between fixation and the dropping cigarette did not influence detection. However, due to the small number of participants in the real-world experiment and the lack of precise consistency between performances of the trick, this result required more

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$^2$ Only participants who missed the cigarette on the first trial were included.

$^3$ Data from one participant was excluded due to tracker loss.
extensive investigation. The present study provides the opportunity to do this. We, therefore, might predict that those who detected the cigarette drop would have been fixating closer to the cigarette as it dropped than those who did not detect it. Figure 2 shows that no obvious systematic differences were found. In order to fully explore the relationship between fixation at the time of the drop and detection, we measured the distance between participants’ fixation point at the time of the drop and the dropping cigarette (see data shown in Table 1). A two-way independent measures ANOVA with prior knowledge (naïve vs. informed) and detection (detected, missed) as between-subject factors on visual eccentricity found no significant main effect of

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4 The drop lasted for six frames and measurements were taken on the third frame of the drop, when the falling cigarette was in full view.
detection, $F(1, 41) = 0.047$, $p = .83$. Neither was there any significant detection by prior knowledge interaction, $F(1, 41) = 2.15$, $p = .15$. Furthermore, independent $t$-tests revealed no significant difference in visual eccentricity between participants who detected the cigarette compared to those who missed it for the naïve group, $t(21) = -0.81$, $p = .43$, or in the informed group, $t(20) = 1.31$, $p = .20$, demonstrating that participants’ detection was independent of visual eccentricity. These results verify previous suggestions made from the less controlled setting of the real world (Kuhn & Tatler, 2005). However, we did find that although detection was not related to visual eccentricity, the informed participants fixated significantly closer to the dropping cigarette than the naïve participants, $F(1, 41) = 11.35$, $p = .002$. This result was not found under real-world conditions. In the present more-controlled study, which had greater experimental control of viewing conditions, we found that the prior knowledge of the participants did influence how close to the cigarette participants were fixating at the time that it was dropped. The observed difference might reflect enhanced interest in the cigarette for the informed participants.

In accordance with previous work, we found little influence of oculomotor behaviour at the time of the cigarette drop upon detection. However, in the present study, we found a strong relationship between oculomotor behaviour immediately following the drop and whether the dropping cigarette was detected. Specifically, there was a relationship between detection and how quickly after the drop the participants moved their eyes to the (now empty) cigarette hand. Table 2 shows the times between the cigarette drop and participants’ first fixation on the hand that previously held the cigarette (cigarette hand). An ANOVA with prior knowledge (naïve vs. informed) and detection (detect vs. undetected) as between-subjects factors found no significant prior knowledge by detection interaction, $F(1, 40) = 0.000$, $p = .99$, but a significant main effect of detection, $F(1, 40) = 11.83$, $p = .001$. Detection of the cigarette was followed by more rapid gaze shifts towards the cigarette hand on the first trial. This effect was also found in the second trial for those participants who failed to detect the

### Table 1
The average distance in degrees between participants’ fixation and the cigarette at the time of the drop

<table>
<thead>
<tr>
<th>Condition</th>
<th>Undetected</th>
<th>Detected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Naïve</td>
<td>9.27</td>
<td>2.14</td>
</tr>
<tr>
<td>Informed</td>
<td>8.10</td>
<td>1.62</td>
</tr>
</tbody>
</table>

*Data from one participant was excluded due to signal loss.
drop on the first trial but did so on the second. On the second trial, 12 participants detected the cigarette in the periphery (visual eccentricity > 3 degrees) and 5 participants missed it. Participants who detected the cigarette were significantly faster at shifting their gaze towards the cigarette hand ($M = 120$ ms, $SD = 439$) than participants who missed it ($M = 1172$ ms, $SD = 344$), Mann-Whitney $z = 2.54$, $p = .011$. The fact that this effect was found for both trials suggests that this finding is robust.

The “postdrop” scan paths revealed that most of the participants fixated on the face (27) prior to looking at the hand, with only 15 who moved their fixation directly to the cigarette hand. Although participants who detected the cigarette were somewhat more likely to fixate directly on the cigarette hand (9 out of 19)$^5$ than participants who missed it (6 out of 26), this difference was not significant, $\chi^2 = 2.92$, $p = .09$. It is rather surprising that nine of the participants who detected the cigarette fixated on the face prior to looking at the cigarette hand, rather than moving their eyes directly towards the cigarette hand. However, even when we only consider these nine participants, they still moved their eyes significantly more quickly to the cigarette hand ($M = 888$ ms, $SD = 361$) than the participants who missed it ($M = 1257$, $SD = 450$), $t(33) = 2.34$, $p = .026$. The scan paths after the drop also reveal some intriguing findings with regards to the two participants who fixated near the cigarette, but who missed the drop. Immediately after the drop, both participants moved their eyes towards the lighter hand, which might suggest that covert attention had already moved and thus prevented them from perceiving the drop.

**DISCUSSION**

Using a prerecorded version of the magic trick developed by Kuhn and Tatler (2005), we have been able to explore misdirection in more detail. Unlike Kuhn and Tatler, our results showed that the detection of the

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$^5$ Data from one participant is missing due to tracker loss.

**TABLE 2**

The average duration in ms between moving the fixation towards the cigarette hand and the drop event

<table>
<thead>
<tr>
<th>Condition</th>
<th>Undetected</th>
<th>Detected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Naïve</td>
<td>1330</td>
<td>403</td>
</tr>
<tr>
<td>Informed</td>
<td>1112</td>
<td>412</td>
</tr>
</tbody>
</table>

*Data from two participants were removed: Foveal detection; signal loss after the drop.
cigarette was influenced by participants’ prior knowledge and expectations of the trick. The additional information about the fact that the magic trick would involve the disappearance of a cigarette significantly improved participants’ detection of the cigarette drop. Using a change detection paradigm, O’Regan et al. (2000) showed that at the same visual eccentricity, participants spotted changes occurring to objects of high interest in the scene more easily than changes to objects that were of marginal interest. Similarly, it is likely that the informed group’s improved detection resulted from their enhanced interest in the cigarette, and thus allowed them to override the magician’s misdirection by paying more (covert) attention towards it. These results are in contrast to previous findings in the real world where prior knowledge had very little effect on participants’ susceptibility towards the magic trick.

In the real-world situation, participants were seated face to face with a real person, thus allowing for social interactions between the two (Tomasello, 1995, 1999). One important factor here is that in a dynamic real-world setting, the magician is able to pick up on the participant’s nonverbal signals and subtly tailor his or her misdirection to each individual participant. In the present experiment, the magician’s misdirection could not be adjusted to the spectator, and this lack of feedback may account for the higher detection rate. Moreover, the closer proximity between the magician and the participant in the real-world situation compared to the video situation would have resulted in the latter being less engaging (see Gullberg & Holmqvist, 2002). It is therefore likely that in the real-world situation, the misdirection was so effective that even if participants wanted to disengage from it, they failed to do so. However, in the less engaging video condition, participants may have found it easier to disengage from the misdirection, thus allowing prior knowledge to influence their detection and oculomotor behaviour. These results may also explain magicians’ reluctance to inform their audience about the outcome of the trick prior to it being performed. Interestingly, participants’ enhanced interest in the cigarette was also reflected in their eye movements. The informed participants fixated significantly closer to the cigarette than the naïve participants, independent of whether it was detected or not. This finding provides further support that the informed participants monitored the cigarette more closely and may have been keeping a closer eye on it.

As several observers detected the cigarette drop on the first trial, it allowed us to investigate the factors that lead to its perception by comparing the eye movement records of the participants who detected the cigarette with those who missed it on the first trial. Detection of the cigarette was unaffected by perceptual factors, such as saccades, eye blinks, and visual eccentricity at the time of the event. In the light of previous findings using a change detection paradigm (Henderson & Hollingworth, 1999b), it is rather
surprising that the detection of the dropping cigarette did not depend on where people were looking (but see Kuhn & Tatler, 2005; Tatler & Kuhn, 2007). In fact, two of the participants failed to detect the cigarette even though they were looking in its direction (3.7°, and 2.2° from the dropping cigarette). The fact that detecting the cigarette was independent of visual eccentricity strongly suggests that participants’ detection of the cigarette involved covert, rather than overt attention.

There is much controversy over the relationship between covert attention and eye movements. Although we can allocate attention to peripheral locations whilst maintaining fixation, thus suggesting that the two systems can work independently, there is growing evidence demonstrating a close link between the two (see Awh, Armstrong, & Moore, 2006, for a review). For example, functional magnetic resonance imaging has demonstrated a close match between the anatomical structures involved in attending to peripheral tasks in the absence of eye movements and saccadic shifts to the same location (Corbetta et al., 1998). Moreover, psychophysical studies have demonstrated that the preparation of saccades to a location employs allocation of covert attention to that location (Deubel & Schneider, 1996), and most research suggests that although overt and covert attention can be dissociated at times, the former is strongly influenced by the latter (Deubel & Schneider, 1996; Henderson, 1992; Rizzolatti et al., 1987; see Klein, 1980, for a different view). In our experiment, we used detection rates as an index of covert attention. In the future, it would be of interest to assess participants’ allocation of covert attention using more direct measures such as a Posner (Posner, 1980) type dot probe. If at the time of the drop, covert attention has been allocated to the lighter hand, rather than the cigarette hand, probes presented at the latter location should be detected more slowly than at the former.

Whilst participants’ detection of the cigarette was independent of fixation eccentricity at the time of the drop, there was a clear relationship between detecting the cigarette and the participants’ eye movements after the drop. Our results show that, on trials where the cigarette drop was detected, participants were quicker to move their eyes towards the cigarette hand after the drop. This later finding is consistent with the notion of a close link between covert and overt attention. At first sight, these results might bring comfort to theories of visual attention that presume covert attention’s primary role for saccade programming. However, inspection of the postdrop scan paths revealed some rather surprising findings. A substantial number of participants who detected the cigarette drop looked at the face prior to looking at the cigarette hand rather than immediately towards the cigarette hand. The fact that several of the participants who detected the cigarette did not move their eyes towards the cigarette hand immediately suggests that the detection was not directly associated with the preprogramming of a saccade,
as suggested by Henderson, Pollatsek, and Rayner (1989). As these data are correlational, we cannot be sure whether the detection of the cigarette resulted from intended shifts in gaze towards the cigarette hand, or whether it was the awareness of the dropping cigarette that attracted visual attention. However, they demonstrate that although fixation location at the time of the drop was unrelated to whether they detected the drop or not, the postdrop oculomotor behaviour was strongly predictive of their detection. It has been argued that in reading or visual search tasks, eye movements provide a valuable online indicator of the underlying cognitive processes (Liversedge & Findlay, 2000). Our findings showed that participants’ eye movements after the drop were more indicative of their detection than the fixation points at the time of the event. These results suggest that at least when faced with complex and dynamic scenes, such as those used in our experiment, eye movements need to be analysed over a larger time window. Rather than merely looking at participants, fixation points at the time of the event, it may be more fruitful to focus on participants’ scan paths, and in particular the timing of these scan paths. In these situations, eye movement may therefore provide us with a somewhat less online indicator of cognition than in other domains such as reading or standard visual search tasks.

One interesting implication of this final finding is that the reduction in time to shift gaze to the cigarette hand, but with an intervening fixation, might suggest that attention is effectively operating several saccades ahead of the current locus of fixation. That is, when planning our eye movements, attention may be allocated not only to the next target site for fixation (as is commonly assumed in theories linking attention and saccade programming—see, for example, Deubel & Schneider, 1996; Henderson, 1992; Rizzolatti et al., 1987), but also to the target of the following saccade. This interesting suggestion has been reported under a more controlled psychophysical setting (Deubel, 2005; Godijn & Theeuwes, 2003). For example, Deubel (2005) found evidence for enhanced attentional processing at locations that are to be targeted not only by the next saccade but also up to three saccades in the future. Our present results lend some real-world support for this finding.

REFERENCES


