Perception, 2005, volume 34, pages 1153 – 1161

DOI:10.1068/p3409bn

# Last but not least

## Interaction of vision and movement via a mirror

**Abstract.** I have noticed a striking effect that vision can have on movement: when a person makes circular motions with both hands, clockwise with the left hand, counterclockwise with the right hand, while watching the reflection of one hand in a parasagitally placed mirror, if one arm makes a vertical excursion, the other arm tends to make the same vertical excursion, but not typically if the excursing arm is viewed in plain vision. This observation may help in understanding how visual feedback via a mirror may be beneficial for rehabilitation of some patients with movement deficits secondary to certain neurologic conditions, and illustrates that the traditional division of neural processes into sensory input and motor output is somewhat arbitrary.

Recently, there have been a number of studies of the interaction of vision and proprioception in animals (Graziano 1999) and humans (Fink et al 1999; Farne et al 2000). Such an interaction may play an important role in understanding motor control in health, and also potentially in rehabilitation of patients with neurologic lesions affecting the motor system. While musing on such considerations, I recently noticed a striking effect that visual feedback via a mirror of the reflection of one arm can have on the movement of the other arm.

Stand abutted to a parasagitally placed mirror with one hand on either side of the mirror (figure 1). If one makes circular motions with both hands, clockwise with the left hand, counterclockwise with the right hand, while watching the reflection of one hand

**Figure 1.** The subject in the figure is moving both arms circularly in a horizontal plane—the right arm in the counterclockwise direction, the left arm in the clockwise direction—while watching the reflection of his right hand in a mirror. The left arm is occluded from viewing by the mirror, and the right arm is positioned, and the circular movements made, so that only the reflection of the right arm can be seen (which looks like the left arm). When the subject makes a vertical excursion of the right arm, this is often accompanied by an involuntary similar vertical excursion by the left arm. As described in the text, the task can also be performed with an experimenter standing directly behind the subject, the experimenter moving his/her right arm circularly counterclockwise in a horizontal plane with the subject's right arm at his or her side, and the subject moving the left arm (occluded) clockwise circularly in a horizontal plane. A vertical excursion of the experimenter's right arm often causes a similar vertical excursion by the subject's left arm. In the control task, the mirror is replaced by an opaque partition, and the subject, with the right hand at his/her side and the left hand occluded by the partition, watches the experimenter's right arm (in direct vision).

in the mirror, when one arm makes a vertical excursion, the other arm tends to make the same vertical excursion, but not typically if the excursing arm is viewed in plain vision. Similarly, if the arm viewed in the mirror stops moving or abruptly starts circling in the other direction, the arm occluded from view tends to do likewise: the arms are somehow yoked together by the mirror. The presence of a strong effect such as this even in normal subjects may help in appreciating, studying, and understanding how visual feedback via a mirror may be beneficial for rehabilitation of some patients with movement deficits secondary to certain neurologic conditions (Ramachandran et al 1995; Altschuler et al 1999; Sathian et al 2000; Giraux and Sirigu 2003; Hunter et al 2003; McCabe et al 2003; Moseley 2004). And indeed, in subjects with neurologic lesions, effects of illusions from mirrors may be stronger than in healthy subjects, as such subjects may not have all sensory modalities intact to alert the brain to an illusion. Looking for neurophysiologic correlates of such effects, for example by functional magnetic resonance imaging, is also easier in healthy subjects than in patients with neurologic lesions, and can then subsequently be studied in patients, with experimental design having been optimized.

After noticing the effect of vision on movement via a mirror, I mentioned it to six colleagues who also all obtained the effect. In some cases, the effect also could be obtained if an individual moved one arm while watching the reflection of the opposite arm of another person in a mirror. To examine the effect, a further forty healthy, naive subjects (thirty-seven right handed, ages 24 – 56 years) were positioned with one arm placed on either side of a full-length parasagitally positioned mirror. The subjects were randomized to one of four conditions—subject to move their own right (left) arm in a circular motion in the horizontal plane while watching either the reflection of the experimenter's left (right) arm in the mirror or watching the experimenter's arm in plain view with the subject's arm then blocked from view with the reverse side of the mirror acting as an occluder (control group). So as to give directions in a neutral manner, subjects were told to "make circles with their arm and watch the experimenter's arm". Initially, the experimenter's arm also performed circular motions in the horizontal plane, but then made an approximately 50 cm vertical excursion. Ten of the twenty subjects who viewed the experimenter's arm in a mirror also made a significant concordant vertical excursion (an excursion greater than the 1 cm reliability of measurement of excursion distance made immediately after the experimenter's vertical excursion and a possible excursion by the subject), while only one of the twenty subjects in the plain-view group did so (thus, taking the rate of making a significant vertical excursion as 50% in the mirror condition, and taking each subject trial as a Bernoulli trial, $p < 0.0001$, only one in twenty subjects in the control condition made a significant vertical excursion). The excursion averaged 40 cm (SD = 20 cm) for the ten subjects in the mirror group and was 15 cm for the one subject in the control group. To further exclude the possibility that subjects made a vertical excursion voluntarily because they thought they were supposed to, rather than because of a drive from sensory input, subjects were debriefed immediately after the trial and asked why their hand moved or did not move in the vertical direction. Those who responded that they did so because they thought the instructions were simply to mimic the experimenter were excluded from further analysis. There were six such subjects in the mirror group and four subjects in the control group. Inclusion of these subjects in the analysis would not have changed the conclusion of a highly significant ($p < 0.001$) difference in significant vertical excursion in the mirror group compared with the control group. Subjects in the mirror group, but not the control group, made comments suggesting an involuntary effect of visual input on their movement: eg "my hand got dragged up", "there is a magnetic force between the hands in the mirror", and "why did my hand go up?".

Many years ago, Rock and Victor (1964) had demonstrated that vision can dominate over somatosensory modalities. And the interaction of vision and proprioception has been studied recently in animals and humans (Graziano 1999; Fink et al 1999; Farne et al 2000). Ramachandran and colleagues had the clever insight to appreciate and show that visual input of the reflection of the intact arm seen in a mirror could be used to mobilize previously immobile phantom limbs. Subsequent studies have confirmed the findings of Ramachandran and colleagues (1995) in some phantom-limb patients (Giraux and Sirigu 2003; Hunter et al 2003), and case reports and small studies have shown that therapy similarly using a mirror may be beneficial for some patients with movement deficits of other causes (Altschuler et al 1999; Sathian et al 2000; McCabe et al 2003; Moseley 2004). The effect described here suggests a rather direct effect of vision on motion in healthy subjects, the study of which may be helpful in developing improved rehabilitation methods for patients with motor deficits secondary to neurologic disease. In preparing this paper, I also noticed another paper that demonstrates a different experimental system in which there is an effect of vision via a mirror on proprioception and movement (Franz and Packman 2004).

Eric Lewin Altschuler

Department of Physical Medicine and Rehabilitation, University of Medicine & Dentistry of New Jersey, 30 Bergen Street, ADMC 1, Suite 101, Newark, NJ 07101, USA; Mount Sinai School of Medicine, 1425 Madison Avenue, Box 1240, New York, NY 10029, USA; e-mail: eric.altschuler@umdnj.edu

**References**

Altschuler E L, Wisdom S B, Stone L, Foster C, Galasko D, Llewellyn D M, Ramachandran V S, 1999 "Rehabilitation of hemiparesis after stroke with a mirror" *Lancet* **353** 2035 – 2036

Farne A, Pavani F, Meneghello F, Làdavas E, 2000 "Left tactile extinction following visual stimulation of a rubber hand" *Brain* **123** 2350 – 2360

Fink G A, Marshall J C, Halligan P W, Frith C D, Driver J, Frackowiak R S J, Dolan R J, 1999 "The neural consequences of conflict between intention and the senses" *Brain* **122** 497 – 512

Franz E A, Packman T, 2004 "Fooling the brain into thinking it sees both hands moving enhances bimanual spatial coupling" *Experimental Brain Research* **157** 174 – 180

Giraux P, Sirigu A, 2003 "Illusory movements of the paralyzed limb restore motor cortex activity" *NeuroImage* **20** S107 – S111

Graziano M S, 1999 "Where is my arm? The relative role of vision and proprioception in the neuronal representation of limb position" *Proceedings of the National Academy of Sciences of the USA* **96** 10418 – 10421

Hunter J P, Katz J, Davis K D, 2003 "The effect of tactile and visual sensory inputs on phantom limb awareness" *Brain* **126** 579 – 589

McCabe C S, Haigh R C, Ring E F, Halligan P W, Wall P D, Blake D R, 2003 "A controlled pilot study of the utility of mirror visual feedback in the treatment of complex regional pain syndrome (type 1)" *Rheumatology* **42** 97 – 101

Moseley G L, 2004 "Graded motor imagery is effective for long-standing complex regional pain syndrome: a randomised controlled trial" *Pain* **108** 192 – 198

Ramachandran V S, Rogers-Ramachandran D, Cobb S, 1995 "Touching the phantom limb" *Nature* **377** 489 – 490

Rock I, Victor J, 1964 "Vision and touch: an experimentally created conflict between the two senses" *Science* **143** 594 – 596

Sathian K, Greenspan A I, Wolf S L, 2000 "Doing it with mirrors: a case study of a novel approach to neurorehabilitation" *Neurorehabilitation and Neural Repair* **14** 73 – 76

## Magic and fixation: Now you don't see it, now you do

How can a magician carry out actions in full view without the audience noticing? One of the key principles of deception in magic is misdirection; the magician distracts the audience in order to carry out unnoticed what would otherwise be an obvious action (see Lamont and Wiseman 1999). For many years, magicians have been exploiting visual phenomena that psychologists have learned only recently: those of *change blindness* and *inattentional blindness*.

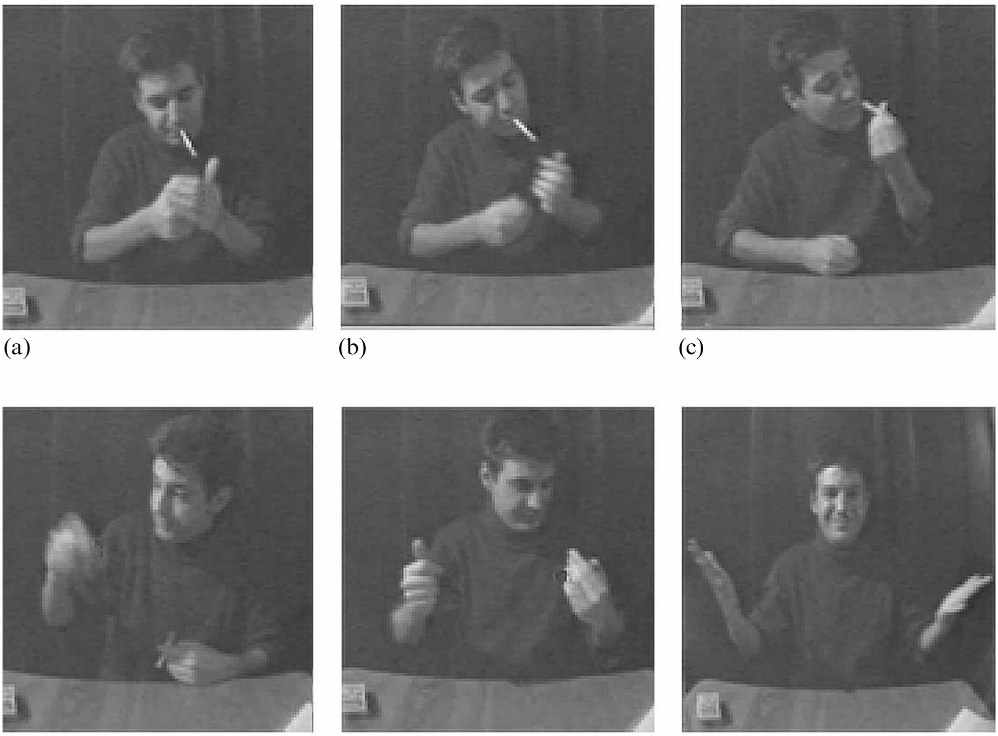
An observer will often fail to detect what would seem to be a very large change to an object in a complex scene (such as moving it to another position, changing its colour, or removing it completely) provided this change is made during a brief interruption to viewing (for a review see Rensink 2002). The interruption can be an eye movement (eg Grimes 1996; McConkie and Currie 1996), a blink (eg O'Regan et al 2000), or an artificial flicker of the image (Rensink et al 1995, 1997, 2000). Failure to detect such seemingly obvious changes has become known as change blindness and has been the focus of much interest since the mid-1990s. However, it is not only abrupt changes occurring during periods where the scene is occluded (which arguably makes these somewhat artificial and unlike everyday vision) that can go unnoticed by observers. Unexpected events can occur in full view of an observer and can continue for some time and yet not be detected. Simons and Chabris' (1999) compelling modification of Neisser's (1967) classic experiment illustrates this phenomenon elegantly; observers are asked to watch a video of two teams of basketball players passing balls to each other, and to count the number of passes made by one team. During the video, a person wearing a gorilla suit walks through the midst of the two teams of basketball players, yet observers often fail to notice this! This failure to notice the unexpected event arises because the observer's attention is focused upon the team of players and the task of counting passes, a phenomenon known as inattentional blindness (see Mack and Rock 1998).

Of course, a key concern with studying both of these phenomena has been to relate them to everyday vision and consider their implications for how vision normally operates [see Most et al (2005) for a similar position and a thorough consideration of the link between inattentional blindness and implicit attentional capture]. A flickering screen in a laboratory is somewhat removed from the realities of daily life and so researchers have attempted to test these ideas under increasingly realistic settings (eg Levin and Simons 1997; Simons and Levin 1998). What has been surprisingly neglected is the one clear instance that the authors can think of in which these phenomena are likely to occur in a real-world setting: magic (but see Lamont and Wiseman 1999 for a consideration of the psychology of magic). The misdirection employed by magicians parallels inattentional-blindness paradigms; it occurs seemingly in full view of the observer, yet is not noticed.

In this short note we report a study in which participants watched a magician (the first author) perform a magic trick in which a cigarette and lighter were made to 'disappear'. The trick was performed 'live' by the magician in front of the participant. We recorded eye movements while people watched the trick, using Land's custom-built head mounted device (for details see Land 1993; Land and Lee 1994). By recording eye movements while the participants watched the magician we could gain insights into the manner of the misdirection that the magician exploits: did participants miss the cigarette's disappearance because they were not looking at it at the right time, because they were blinking or moving their eyes at the time, or because they were not attending to it (irrespective of where they were looking)?

Half of the participants were told before the experiment that they were about to watch a magic trick in which a cigarette and lighter would be made to disappear and that they should try to work out how this was done. The remaining participants did not know that they were about to watch a magic trick; they believed they were about to take part in an experiment where they would rate pictures aesthetically. In this way, we were able to consider whether prior knowledge of the trick might influence either the likelihood of uncovering the manner of the deception, or the strategic positioning of gaze.

The magic trick that we used in this study was one that we developed in which a cigarette and a lighter supposedly disappeared in front of the participants' eyes (see figure 1 for a full description of the trick). The method used to make the cigarette disappear was simply to drop it; this drop was from a position 10 – 15 cm above the tabletop and was in full view of the participant. Inspection of the video record from the eye tracker shows that at the time of the drop (ie the 'disappearance') the cigarette was a high-contrast (the magician wore a black jumper) oriented bar, occupying approximately 4 deg by less than 1 deg of the participant's field of view and visible for 140 ms of the duration of its fall. Such a target should be readily detectable by the human perceptual system. Considering this, the effectiveness of the magician's misdirection is demonstrated by the low rate of detection that we found. Of the ten participants who did not know in advance that they were about to watch a trick, none detected the cigarette drop when asked after they had watched the trick. Of the ten who had been told they would be watching a magic trick, two detected the cigarette drop. While the detection rate in the informed group is higher, it is still quite low; eight of the ten informed participants did not detect the cigarette drop. The trick was then repeated for the eighteen participants who failed to spot the cigarette drop on the first trial; all of them correctly described how the trick was done after seeing it for a second time.



(a) (b) (c)

(d) (e) (f)

**Figure 1.** The sequence of events during the magic trick, as recorded from the eye tracker. (a) The magician 'mistakenly' puts the cigarette in his mouth the wrong way around and goes to light it. (b) The 'mistake' is noticed and the left hand (cigarette hand) reaches for the cigarette in order to turn it the correct way around. (c) The hand holding the lighter (lighter hand) moves to just above the table top, from where the lighter is dropped into the magician's lap. (d) The magician directs his gaze toward his right hand—which supposedly is still holding the lighter—as he raises it. While raising his right hand, the magician lowers his left hand, which is holding the cigarette, to a point 10 – 15 cm above the table top. He then snaps the fingers of his right hand to reveal that the hand is empty and the lighter has 'disappeared'. As the magician snaps his fingers, the cigarette is dropped into his lap from his left hand. (e) The magician directs his gaze to his left hand as he raises it. (f) The magician snaps his fingers to reveal that his left hand is now also empty and the cigarette has 'disappeared'.

In order to gain a clearer understanding of why participants fail to detect the dropping cigarette when they first see the trick, yet detect it if the trick is repeated, we examined the positions fixated at the time of the cigarette drop by the participants during the two performances of the trick.

One possibility is that the magician exploits techniques similar to those manipulated in change-detection experiments: perhaps the cigarette drop coincides with an eye movement or blink. This suggestion is possible because, in order to direct the observer away from the hand that was dropping the cigarette, the magician moved his other hand, looked toward it and snapped its fingers (see figure 1). These cues may have caused the participant to make an eye movement toward the distracting hand (or to make an eye blink). Perhaps, then, the magician's skill has been to learn to time his drop to occur at the same time as the eye movement that his distraction triggers? The data from two participants were left out owing to the poor quality of the video. The record from the eye tracker showed that on no occasion did the participant blink at the time of the cigarette drop. There were some occasions on which the participants moved their eyes around the time of the drop; seven such instances occurred during the first performance of the trick when the drop was not detected, and four such instances occurred during the second performance. However, detection rates were not significantly influenced by the occurrence of saccades during the drop ($\chi^2 = 1.8$, $p > 0.05$).[(1)] Furthermore, these saccades always started after the cigarette began to drop and ended before the end of the drop, and typically lasted for less than 40 ms, a time too short to be likely to prevent the participant from perceiving the 140 ms cigarette drop.

A further possibility is that participants missed the cigarette drop because they were looking in the wrong place. Using a change-blindness paradigm, Henderson and Hollingworth (1999) showed that participants' accuracy was higher for changes that occurred close to fixation, than for those which occurred further away. Figure 2a shows the location of gaze at the beginning of the drop for participants who missed the cigarette drop on the first trial and did not know in advance that they would be watching a magic trick. Figure 2b shows the location of gaze at this time for the participants who did know that they would be watching the trick. For both groups of participants, fixations were clustered around three distinct areas: near the hand that was supposedly holding the lighter, the right shoulder, and the face. It is clear from figures 2a and 2b that in the trials in which the dropping cigarette was not detected, it occurred some distance into the periphery. The average distance of the centre of fixation from the dropping cigarette was 19 deg (SD = 5.2 deg) for trials on which the drop was not detected.

By comparing where participants were looking when they failed to detect the drop, with where they were looking when they did correctly detect it, we could consider whether anything about the locations fixated or distance between fixation and the dropping cigarette might differ on these trials. On the first performance of the trick, the two participants who spotted how the cigarette was made to disappear were looking at similar locations to the other sixteen participants (see figure 2b), and therefore were fixating at a similar distance from the dropping cigarette (18 and 21 deg). Figure 2c shows where the participants were looking at the start of the cigarette drop on the second performance of the trick, for those participants who did not know that they were about to watch the magic trick. Figure 2d shows the location of gaze at this time for the participants who knew that they would be watching the trick. All sixteen participants spotted how the cigarette 'disappeared' on this performance of the trick. It is somewhat surprising that only four of the sixteen participants looked directly at the cigarette as it dropped, thus detecting the cigarette drop using their foveal vision. The remaining participants fixated very similar locations to those fixated

[(1)] Data were analysed with a McNemar change test.

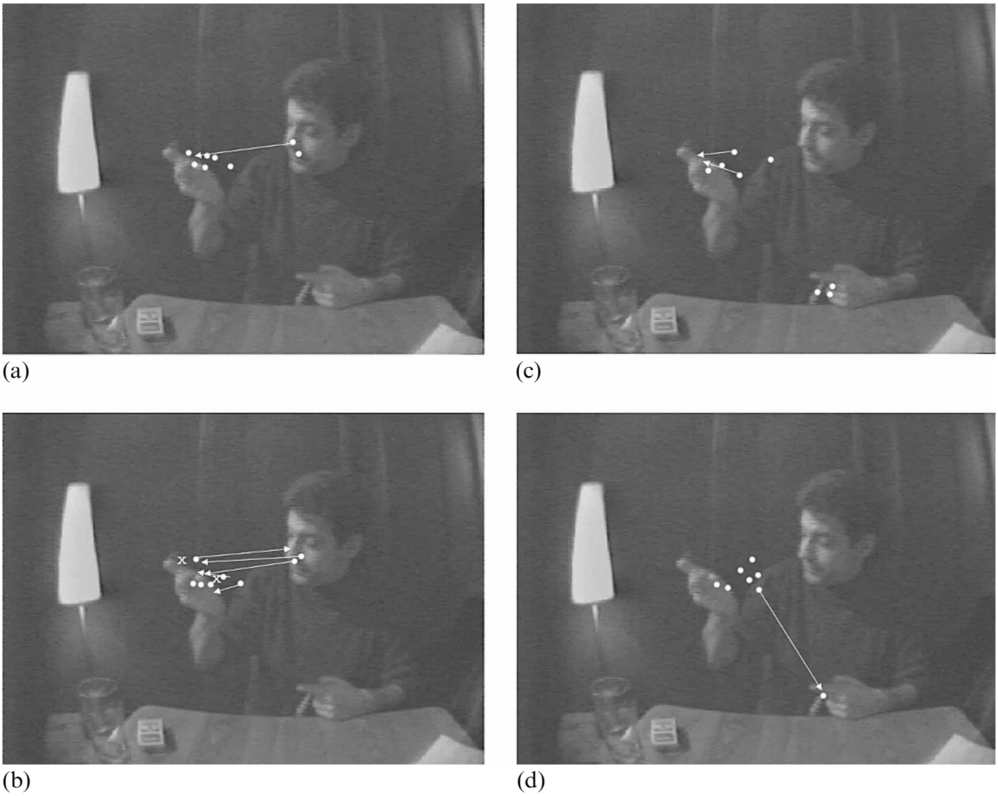



**Figure 2.** (a) A single frame taken from the eye tracker's video record at the time of the start of the cigarette drop in the first performance. The white dots indicate where each of the eight participants who did not know in advance that they were going to watch a magic trick was fixating at the start of the cigarette drop. The data from two participants were left out owing to the poor quality of the video. (b) The positions fixated at the time of the drop for the ten participants who did know that they were about to watch a magic trick. The $\times$s indicate the fixation points of the observers who detected the cigarette. (c) The white dots indicate where each of the nine uninformed participants was fixating as the cigarette dropped in the second trial. All of these participants correctly identified the drop. (d) The positions fixated at the time of the drop in the second performance of the trick for the eight informed participants who did not detect the drop on the first performance. In all panels of this figure, when participants made saccadic eye movements at the time of the drop, their directions and magnitudes are indicated by the arrows.

during the first performance of the trick: either the lighter hand or the right shoulder. As in the first performance of the trick, there was very little difference in the locations fixated by participants who knew that they were about to watch a trick and those who did not. The average distance from the centre of fixation to the position of the cigarette at the start of the drop (see figures 2c and 2d) was 16 deg (SD $=$ 4.1 deg) and detection occurred at a maximum of 24 deg from fixation.

The similarities between trials in which participants detected the dropping cigarette and those in which they did not are striking, both in terms of the locations targeted for fixation and the distances between fixation and the dropping cigarette. It does not appear that there was any particular requirement to fixate on or near the cigarette to detect its drop; neither would there appear to be any particular influence of what was targeted for fixation at that time (eg the shoulder, hand, or face). Clearly, purely retinal accounts of misdirection (the participants were blinking or moving their eyes, or the target was too far in peripheral vision for automatic detection) cannot account for the observed data. As might have been expected, the magician's manipulation is primarily of the observers' attention; thus, our chosen magic trick employs similar principles to those used in recent inattentional-blindness studies.

Of interest is the manner in which participants were able to overcome the magician's misdirection. It did not appear to require any particular differences in the deployment of the eyes at the time of the event that the magician wished to conceal. Rather, it required a redirection of covert attention at this time. Most participants were found to look in similar locations when they detected the drop to those when they did not. The strategies employed by the participants to overcome the magician's misdirection and detect the drop were therefore primarily attentional, and involved a covert, rather than overt, attentional strategy.

There were also striking similarities between the participants who had been told in advance that they would be watching a magician make a cigarette and lighter disappear, and those who did not expect to see a magic trick. It is somewhat surprising that the locations fixated at the time of the drop were so similar between these two groups in both performances of the trick. Knowing in advance that they would be watching the trick did not produce any clear differences in the strategic deployment of gaze at the time of the cigarette drop. Prior knowledge did raise the likelihood of detecting the manner of the deception in the first performance of the trick, but only slightly. It would appear that the knowledge that they were to watch a trick, and even the instruction that they were to uncover how the cigarette and lighter were made to disappear, were not sufficient to overcome the deception. In contrast, seeing the trick performed a second time was sufficient for all participants, irrespective of their prior knowledge.

Our little study was by no means an exhaustive exploration of misdirection in magic or the role of eye movements! It is merely intended as an initial look at these problems and to consider how recent studies of visual phenomena such as inattentional blindness and change blindness can be related to relatively common experiences. This being a real-world study, there are many uncontrolled factors: for example, as the trick was performed live, in front of the participant, there will have been small differences in the way that the trick was performed (although, the consistency with which it was performed was found to be remarkably high, when we looked at the videos from the eye tracker). Even given the limitations of this study, we can use it to gain insights into the mechanisms by which the magician achieves his misdirection, and the strategies by which his audience may overcome it.

We have seen that whether or not participants knew in advance that they were going to see the trick and that they should try to work out how the disappearance was achieved, most did not spot how the cigarette was made to disappear. It is hard to uncover the manner of a magician's deception even when setting out to do so. On the other hand, participants always spotted how the cigarette was made to disappear when they watched the trick for a second time. Interestingly magicians are very reluctant to repeat the same trick, fearing that this will increase the probability of the audience noticing the secret. The results from the present experiment have demonstrated that this fear may, in fact, be well founded.

Gustav Kuhn
Department of Psychology, University of Durham, South Road, Durham DH1 3LE, UK;
e-mail: Gustav.Kuhn@durham.ac.uk
Benjamin W Tatler
Department of Psychology, University of Dundee, Dundee DD1 4HN, Scotland, UK;
e-mail: B.W.Tatler@dundee.ac.uk

**Acknowledgments.** We are extremely grateful to Mike Land for his helpful comments and insights during the preparation of this manuscript and to Christoph Scheepers for his comments on an earlier version of this manuscript. We also thank Catherine Hughes for her invaluable help in recruiting participants for the experiment.

**References**

Grimes J, 1996 "On the failure to detect changes in scenes across saccades", in *Perception: Vancouver Studies in Cognitive Science* Ed. K Atkins (New York: Oxford University Press) pp 89 – 110
Henderson J M, Hollingworth A, 1999 "The role of fixation position in detecting scene changes across saccades" *Psychological Science* **10** 438 – 443
Lamont P, Wiseman R, 1999 *Magic in Theory* (Hartfield: Hermetic Press)
Land M F, 1993 "Eye – head coordination during driving", in *Proceedings of the IEEE Systems, Man and Cybernetics Conference, Le Touquet. 17 – 20 October* **3** 490 – 494
Land M F, Lee D N, 1994 "Where we look when we steer" *Nature* **369** 742 – 744
Levin D T, Simons D J, 1997 "Failure to detect changes to attended objects in motion pictures" *Psychonomic Bulletin & Review* **4** 501 – 506
McConkie G W, Currie C B, 1996 "Visual stability across saccades while viewing complex pictures" *Journal of Experimental Psychology: Human Perception and Performance* **22** 563 – 581
Mack A, Rock I, 1998 *Inattentional Blindness* (Cambridge, MA: MIT Press)
Most S B, Scholl B J, Clifford E R, Simons D J, 2005 "What you see is what you set: Sustained inattentional blindness and the capture of awareness" *Psychological Review* **112** 217 – 242
Neisser U, 1967 *Cognitive Psychology* (New York: Appleton Century Crofts)
O'Regan J K, Deubel H, Clark J J, Rensink R A, 2000 "Picture changes during blinks: Looking without seeing and seeing without looking" *Visual Cognition* **7** 191 – 211
Rensink R A, 2002 "Change detection" *Annual Review of Psychology* **53** 245 – 277
Rensink R A, O'Regan J K, Clark J J, 1995 "Image flicker is as good as saccades in making large scene changes invisible" *Perception* **24** Supplement, 26 – 27
Rensink R A, O'Regan J K, Clark J J, 1997 "To see or not to see: The need for attention to perceive changes in scenes" *Psychological Science* **8** 368 – 373
Rensink R A, O'Regan J K, Clark J J, 2000 "On the failure to detect changes in scenes across brief interruptions" *Visual Cognition* **7** 127 – 145
Simons D J, Chabris C F, 1999 "Gorillas in our midst: sustained inattentional blindness for dynamic events" *Perception* **28** 1059 – 1074
Simons D J, Levin D T, 1998 "Failure to detect changes to people during a real-world interaction" *Psychonomic Bulletin & Review* **5** 644 – 649

ISSN 0301-0066 (print) ISSN 1468-4233 (electronic)

PERCEPTION

VOLUME 34 2005

www.perceptionweb.com