Correspondences

There's more to magic than meets the eye

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Our perception of an event is often modulated by our past experience and expectations [1,2]. Here we used a magic trick [3] to demonstrate how magicians can distort our subjective perception and we investigate the mechanisms behind this deception. We found that when a magician performed an illusion in which a ball was seen to vanish in the air, 63% of observers perceived the ball leave his hand, move upwards, and disappear even though the ball did not leave the magician's hand. Moreover, observers' illusory perception of the ball was determined by cues that indicated the ball's location, namely the magician's head direction, rather than the percept itself. Furthermore, eye movement records revealed participants' strategic use of social cues prior to looking at the ball. Surprisingly, however, when the ball was not physically present, observers did not look at the area where they claimed to have seen the ball vanish, suggesting that the oculomotor system was not fooled by the illusion. These results show that although people's subjective percept is determined by expectations, the oculomotor system is largely driven by accurate bottom-up information, which is consistent with the suggestion that there are separate mechanisms for perception and visuomotor control [4].

A striking example of magicians' deception is the vanishing ball illusion, in which a ball apparently disappears in mid air. This illusion is created by pretending to throw a ball up in the air, when in fact it remains secretly palmed in the magician's hand [3]. If done convincingly, the observer should perceive the ball as moving up in the air even though it is no longer physically present. Similarly, when observers view a moving object that suddenly disappears, the final position of the object is usually perceived as being further along the path of motion than its actual final position [5], a phenomenon known as representational momentum [6]. Much of the magician's deception relies on social cuing, in terms of his head and gaze direction, and we therefore predicted that the effectiveness of the vanishing ball illusion would be influenced by the magician's social cuing.

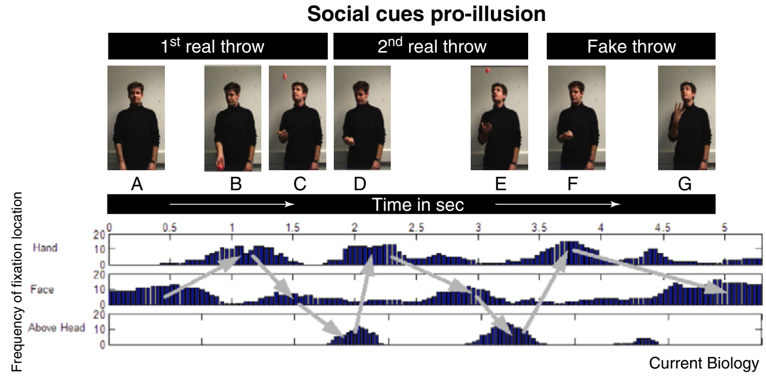

Figure 1. A time line of the social cues pro-illusion ball trick.

(A) The magician looks at the observer. (B) The magician's gaze is directed towards the ball held in his hand and the throw is initiated. (C) The ball is visible in the air. (D) The ball is caught for the first time. (E) The ball has reached its zenith for the second time. (F) The ball is caught for the second time. (G) The magician pretends to throw the ball in the air whilst secretly concealing it in his hand. Participants' eye movement data were analysed by coding where they were looking during the course of the magic trick. Three areas of interest were defined: Hand (holding the ball); Face; and Above Head (on the first two throws this typically coincided with the ball) (see Supplemental data for details). The cumulative histograms represent the number of participants who looked at these four areas during the course of watching the video clip, and the arrows show the typical eye movement strategies. The figure only shows the eye movement patterns of the participants viewing the pro-illusion social cues condition. The results for the anti-illusion condition were very similar and are therefore only reported in the Supplemental data. The histograms clearly illustrate a high consistency in the eye movement patterns across all participants. At the beginning of the clip (A) most participants (12) fixated on the face (the numbers in parentheses indicate the number of participants who looked at that particular location, out of 19). Once the magician prepared for the throw (B), participants typically looked at the hand holding the ball (12). When the hand moved upwards to throw the ball, participants typically glanced at the face (7) prior to looking at the ball (area above the head) (C) (12), and then looked at the hand catching it (D) (13). On the second throw, a very similar pattern of eye movement strategies was observed. When the ball was released from the hand participants typically looked at the face (14) before fixating on the ball (area above the head) (E) (12), and then looked at the hand once it was caught (F) (15). Finally when the magician pretended to throw the ball up in the air (G) the majority of participants (11) looked at the face, and only 5 participants looked at the area above the head.

Two different versions of the trick were created that addressed the extent to which the magician's social cues are responsible for the illusion. In the social cues pro-illusion condition, on the final 'fake' throw, the magician's eyes and head followed an imaginary ball moving upwards (Figure 1 and Supplemental data available on-line with this issue). In the social cues anti-illusion condition, the magic trick was identical except that on the final 'fake' throw, the magician looked at the hand concealing the ball, rather than following the imaginary ball (see Figure 2F). We also measured people's eye movements while they watched the video of the trick, to gain an online measure of the information obtained by the visual system. Immediately after having seen the magic trick, participants were questioned as to whether they perceived the 'illusory ball' moving towards the top of the screen on the final throw.

Participants who perceived the illusory ball had a vivid recollection of seeing the ball leave the screen at the top, and typically claimed that the illusion was created by someone catching it beyond the top of the screen. 68% of the participants in the social cues pro-illusion condition experienced the illusion, significantly more than in the social cues anti-illusion condition (32%, $\chi^2 = 5.16$, $p = 0.025$), thus demonstrating that the illusion was mediated by the social cuing.

Most of the participants claimed that they spent their entire time looking at the ball. However, these reports deviated strongly from where they were actually looking. Figure 1 shows a timeline indicating where participants were looking during the magic trick. We found a very high consistency in the eye movement patterns between the participants, suggesting that people employed similar eye movement strategies. On throws where the ball was visible, participants generally looked at the ball once it reached the apex. But rather than merely tracking the ball, most of the participants glanced at the magician's face before looking at the ball, indicating that the visual system uses information about where the magician is looking as a way of predicting the location of the ball.

Our results show that an observer's percept was driven by the magician's social cuing, and that participants utilized the magician's social cues. However, there was a surprising difference in the susceptibility of these two systems to the illusion. On the final illusory throw, most participants claimed to have seen the ball at the top of the screen. The oculomotor system on the other hand was not fooled by the illusion. Figure 2 shows that participants only looked at the top of the screen when the ball was physically present. These results illustrate a remarkable dissociation between what participants claimed to have seen and the way in which their eyes behaved. Whilst their percept was predominantly based on expectations, their eyes were largely driven by the actual visual input. Our results offer a striking example of how the dissociation between vision for perception and for action, well documented in neurological patients [4,7,8] and neurologically intact subjects [9], also translates to more real world situations.

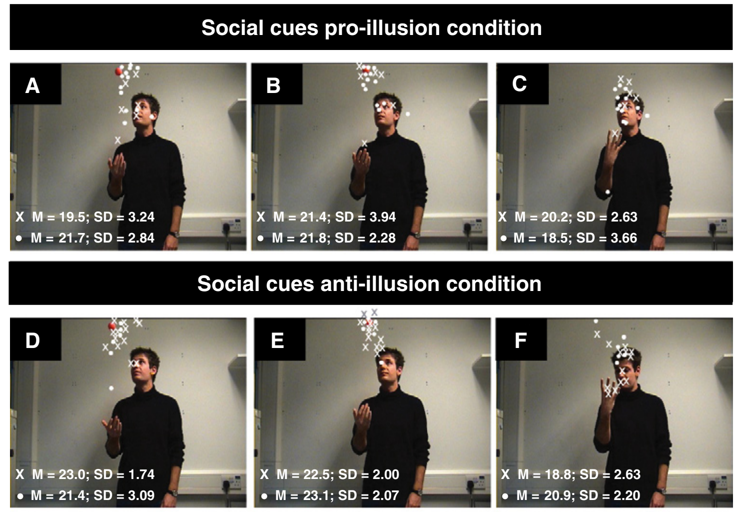

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Figure 2. Participants' fixation points for the social cues pro-illusion (top row) and the social cues anti-illusion (bottom row) conditions.

The dots represent the fixation points for the participants who experienced the illusion and the 'X' marks the fixation points for participants who did not experience the illusion. (A,D) At the point when the ball reached its zenith on the first throw. (B,E) at the point when the ball reached its zenith on the second throw. (C,F) At the point when the ball disappeared. For each participant the height of the terminal eye position on the monitor was calculated (distance between the fixation point and the bottom of the monitor, monitor height = 25°); each panel shows the means (M) and standard deviations (SD) for participants who experienced the illusion and those who did not. On the final throw (C,F) there was no significant difference between the final eye position of the participants who perceived the illusion compared to those who did not perceive it ($t(36) < 1$), which shows that participants' eye movements were not correlated with the perception of the illusion. On the final throw there was no significant difference in the terminal eye positions between the anti- and the pro-illusion condition ($t(36) < 1$), illustrating that participants' eye movements were not driven by the social cues. 19 participants experienced the illusion. For these participants the terminal eye position on the final throw was significantly lower than on the first ($t(18) = 3.23$, $p = 0.005$) and the second throw ($t(18) = 3.57$, $p = 0.002$).

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Supplemental data

Supplemental data including experimental procedures and video clips are available at http://www.current-biology.com/cgi/content/full/16/22/R950/DC1

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