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The Vanishing Ball Illusion: A new perspective on the perception of dynamic events

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ABSTRACT

Our perceptual experience is largely based on prediction, and as such can be influenced by knowledge of forthcoming events. This susceptibility is commonly exploited by magicians. In the Vanishing Ball Illusion, for example, a magician tosses a ball in the air a few times and then pretends to throw the ball again, whilst secretly concealing it in his hand. Most people claim to see the ball moving upwards and then vanishing, even though it did not leave the magician's hand (Kuhn & Land, 2006; Triplett, 1900). But what exactly can such illusions tell us? We investigated here whether seeing a real action before the pretend one was necessary for the Vanishing Ball Illusion. Participants either saw a real action immediately before the fake one, or only a fake action. Nearly one third of participants experienced the illusion with the fake action alone, while seeing the real action beforehand enhanced this effect even further. Our results therefore suggest that perceptual experience relies both on long-term knowledge of what an action should look like, as well as exemplars from the immediate past. In addition, whilst there was a forward displacement of perceived location in perceptual experience, this was not found for oculomotor responses, consistent with the proposal that two separate systems are involved in visual perception.

1. Introduction

Our ability to respond rapidly to changes in our surroundings relies on anticipating and predicting future events. This occurs at all levels of visual perception. In its simplest form, prediction is needed to compensate for delays caused by the propagation and processing of neural signals (Cavanagh, 1997). It is also needed for anticipating the movements of various objects in the environment, both animate and inanimate (Hawkins, 2004). And at a higher level yet, social interactions often require us to predict what other people will do (Frith & Frith, 2006). This increased recognition of the importance of prediction in perception coincides with the recent development of models in which high-level knowledge modulates perceptual processing via feedback connections (Clark, 2013; Friston & Kiebel, 2009; Kilner, Friston, & Frith, 2007). In general, then, evidence is converging that much—if not most—of our conscious experience reflects prediction rather than the actual state of the world (Changizi, 2009; Nijhawan, 2008).

The involvement of prediction can be seen in a variety of phenomena involving the perception of dynamic events. For example, *representational momentum* shows that people generally misremember the disappearance point of a moving object along its trajectory (Freyd & Finke, 1984); this bias appears to reflect predictions about how its movement will unfold over time. Although these effects are relatively small, they are nevertheless robust and fairly general in nature; for example, representational momentum has been found for several stimulus dimensions, including rotation, motion trajectory (Hubbard, 1995), and the panning of a camera though a scene (Munger et al., 2006). These biases can be greatly influenced by people's assumptions about how events should behave (for reviews, see Hubbard, 2005, 2010, 2014a)

Another such phenomenon is the *flash-lag effect* (Nijhawan, 1994): if a ball moves at a continuous speed and a point light suddenly flashes just as the ball passes it, observers perceive the point light as lagging behind the ball. One explanation of this phenomenon is that the future location of the ball is easily predicted, so that our visual perception of it can be based upon this; in contrast, such prediction is not possible for the flash, and so our percept of it must be based on its actual (rather than predicted) position. Like representational momentum, the flash-lag effect has been demonstrated in several stimulus dimensions, such as different colours. (For detailed reviews including other proposed explanations, see Hubbard, 2014b; Nijhawan, 2008; Sheth, Nijhawan, & Shimojo, 2000.)

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When predictions of this kind are correct they can be of great value. But when they are wrong they can lead to noticeable errors in our perceptual experience. Magicians have learnt to exploit many of these errors, developing strategies to maximize their impact (Kuhn, Amlani, & Rensink, 2008; Rensink & Kuhn, 2015). A striking example of this is the Vanishing Ball Illusion, in which a magician causes a ball to apparently vanish in mid-air (Kuhn, Kourkoulou, & Leekam, 2010; Kuhn & Land, 2006; Thomas & Didierjean, 2015; Triplett, 1900). Here, the magician tosses a ball up and down in the air a few times, and on the final toss, merely pretends to throw the ball. Interestingly, most audiences experience the ball as moving upwards and suddenly vanishing in thin air. In accord with the idea that perceptual experience can be based on predicted events, this illusion is influenced by top-down expectations, such as the social cues used by the magician to misdirect expectations (e.g. head and gaze direction, see Kuhn & Land, 2006; Thomas & Didierjean, 2015).

It is commonly believed that the success of this illusion relies on a visually similar, non-deceptive action preceding the deceptive one (Fitzkee, 1945; Kuhn, Caffaratti, Teszka, & Rensink, 2014; Lamont & Wiseman, 1999; Sharpe, 1988). Triplett suggested that a "ghost ball" is experienced on the deceptive throw, based on the "perceptual residue" of the previous real throws. But in the flash-lag effect (at least in the form where there is an onset of the point light), there is no such "residue", suggesting that this is not necessary for at least some kinds of perceptual displacement (Khurana & Nijhawan, 1995). More generally, it is unclear what predictions of this kind are based upon: Do they rely entirely on long-term knowledge of what an action should look like? Do they need an exemplar from the immediate past to establish a perceptual context of some kind? The aim of the current study is to answer these questions for the Vanishing Ball Illusion. In particular, it examines the effect of the perceptual priming caused by showing participants a real throw before the deceptive one.

2. Method

2.1. Participants

Fifty undergraduates (35 female, ages 18–25) at the University of Durham participated in exchange for payment (£2). The experiment received ethical clearance from the Durham University Psychology department's ethics committee.

2.2. Material

Participants viewed edited versions of the Vanishing Ball Illusion previously used by Kuhn and Land (2006). A magician (G.K.) is seen throwing a ball up in the air and catching it after each throw (Fig. 1 & Online supplementary material). On the final throw (pretend throw), he only pretends to throw the ball; in reality, it remains concealed in his hand. For the current experiment, this clip was edited to create two test conditions: primed and non-primed. In the primed condition, the magician threw the ball once before executing the pretend throw.[1] In the non-primed condition, the clip contained only the pretend throw (with the magician initially holding the ball in his hand). Only one of these was shown to each participant. Both clips started with a frozen frame displayed for 2 s, and ended with a frame presented for 5 s. The video clip in the primed condition lasted 10.72 s; in the non-primed condition, 9.04 s.

The video clips (25 fps) were presented using Experiment Builder (SR-Research) and displayed on a 21-in. CRT monitor (Samsung SyncMaster 1100 MB) with a refresh rate of 75 Hz. The screen resolution was set to 1024×768, whilst the videos measured 720 by 576 pixels. The clips were presented in the centre of the screen, and the remainder of the screen was black.

Eye movements were recorded with a head-mounted, video-based eye tracker (EyeLinkII; SR Research Ltd., Osgoode, Ontario, Canada), and were sampled at 500 Hz. Eye movements were recorded monocularly, and analyzed using Eyelink Data Viewer (SR-Research). The eye tracker was calibrated using a 9-point calibration and validation procedure.

2.3. Procedure

Participants were randomly allocated to the primed or the non-primed condition (between-subject design); they were told they would see a magic trick and that their task was to find out how this was done. Each participant saw only one video clip (primed or non-primed). Immediately after the video clip, participants were presented with an image of the last frame of the video clip, measuring 14.7 cm (horizontal) by 11.7 cm (vertical), and were asked to mark the location where they saw (i.e., experienced) the ball for the last time. The true final location was the last point at which the ball was physically visible; this was a point 4.1 cm from the bottom of the image[2] (white solid line in Fig. 2).

After this, participants were asked to do three additional things: (a) report whether they had seen the ball move up on the pretend throw (yes/no forced choice), (b) describe what they saw, (c) explain the method they thought was used to create this illusion. (For the latter two, they were asked to respond in their own words.) Participants were then debriefed and informed about the true method used.

2.4. Measures

Several measures were used to assess participants' susceptibility towards the illusion: (i) forced-choice verbal reports of whether they had seen the ball move upwards (even though it was not physically present), (ii) verbal estimates of where they last saw it, and (iii) patterns of their eye movements as they watched the videos (see Kuhn & Land, 2006; Kuhn et al., 2010). A written questionnaire then assessed their awareness of what they saw, and how the trick might have been done.

3. Results

3.1. Forced-choice reports

Participants were classified as having experienced the illusion if the forced-choice report indicated they experienced the ball moving towards the top of the screen during the pretend throw. Participants in the primed condition were twice as likely to have experienced the illusion (64%) as participants in the non-primed condition (32%), ($\chi^2 = 5.13$, $p = .024$). Importantly, the rate of reporting the illusion in the non-primed condition was also significantly different from zero (Binomial test, $p < .0001$).

3.2. Location estimates

Perceptual displacement was calculated as the difference between the ball's final physically-visible position (solid white line in Fig. 2) and its final experienced position (as given by conscious verbal estimate); positive numbers indicate a forward (upwards)

[1] In the original clip, the magician throws the ball *twice* before executing the pretend throw.

[2] After this point the hand continued to move upwards, and thus the ball is occluded for 3 frames before it fails to appear on the expected motion path.