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Effects of different types of misdirection on attention and detection performance

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The purpose of this study was to examine how misdirecting motions and illusions differ. Studies of visual attention are increasingly using more complex and dynamic stimuli to investigate how attention works in natural situations. In particular, misdirection, a technique for controlling attention, thoughts, and memory in the real world, has been used to reveal the characteristics of perception and cognition in daily life. However, it is unclear how misdirecting motions and illusions affect change detection because these two types of misdirection have been combined in previous studies. To solve this problem, we studied misdirecting motions (straight and curved) and illusions (appearance, vanish, and change) separately. In Experiment 1, we tested the effects of misdirecting motions. In Experiment 2, we tested misdirecting illusions. Results showed that while misdirecting motions had little effect on change detection, misdirecting illusions had strong effects, with the appearance illusion in particular influencing attention. These results indicate that misdirection induced by magic illusions, especially the appearance illusion, can successfully manipulate visual attention in the real world, suggesting that future studies should explore the effects of other types of illusions.

Key words: misdirection, magic tricks, visual attention

Introduction

How do we control our attention? The ability to skillfully control attention would provide brilliant methods for experiments and new findings about cognitive functions. Research on visual attention has revealed many characteristics that have inspired basic theories and knowledge (Carrasco, 2011; Cavanagh, 2011). However, most previous studies on visual attention were conducted with basic laboratory experiments. To break through the limitations of laboratory methods, studies of attention have been increasingly using more complex and dynamic stimuli to investigate how attention works in natural situations (Peelen & Kastner, 2014; Wolfe, Võ, Evans, & Greene, 2011; Wu, Wick, & Pomplun, 2014).

Change blindness refers to failure to notice large changes in a scene (Simons & Levin, 1998). In experiments using the change blindness paradigm (i.e., flicker method), participants are shown two pictures that differ in particular parts, separated by a brief blank. This procedure is used to understand attention, perception, and consciousness, and can even be extended to the study of memory (Ball, Elzemann, & Busch, 2014; Simons & Rensink, 2005). Change blindness studies typically use pictures of natural scenes, not simple line drawings, as stimuli.

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Similar to change blindness, inattentional blindness studies use more dynamic stimuli (movie clips). Inattentional blindness refers to failure to report an unexpected stimulus when participants are engaged in cognitive tasks such as counting or memorizing (Simons & Chabris, 1999). Previous studies show that visual attention is not always captured by unfamiliar or unexpected objects, even though these objects are clearly visible and highly salient, suggesting that inattentional blindness sheds light on how attention is controlled in real time (Drew, Võ, & Wolfe, 2013; Simons, 2000).

Choice blindness is a unique phenomenon that involves decision making and preference rather than attention. Choice blindness refers to the fact that we fail to notice mismatches between our decisions and their outcomes (Johansson, Hall, Sikström, & Olsson, 2005; Johansson, Hall, Tärning, Sikström, & Chater, 2013). Even if a participant chooses something with confidence, he or she will not notice if the thing they chose changes. While research on change blindness and inattentional blindness has been conducted in laboratories, recent studies of choice blindness were done in real world settings (e.g., purchasing in a marketplace) (Hall, Johansson, & Strandberg 2012; Hall, Johansson, Tärning, Sikström, & Deutgen, 2010). These experiments indicate how preference, attention, and memory are easily changeable, and, compared to findings from laboratory experiments, they help understand cognition in real and natural conditions.

These studies (change blindness, inattentional blindness, and choice blindness) provide new experimental methods for examining cognition and perception in the real world. However, there remain methodological problems. It is hard to reproduce classic methods (e.g., visual search and target detection tasks) with dynamic and complex stimuli to elucidate critical differences between laboratory and real world research. This is crucial because failure to clarify the differences may cause stagnation in experimental investigations. In previous studies, researchers investigated how participants perceived or judged natural stimuli. To conduct experiments using natural stimuli in the same way as in classic methods, it is necessary to develop and use stimuli that can reproduce classical methods and ensure that participants can perform the tasks correctly.

Misdirection has recently been used to control cognition in the real world. This method has been applied to many studies of change blindness, inattentional blindness, and choice blindness (Smith, Lamont, & Henderson, 2012; Kuhn & Tatler, 2011; Memmert, 2010; Moran & Brady, 2010; Most, 2010; Shalom et al., 2013).

Misdirection is a technique for controlling attention. Misdirection is defined as a magician's ability to manipulate people's attention, thoughts, and memory (Kuhn & Martinez, 2012). The dove magic illusion is a good example of misdirection. When a magician makes a dove appear in his right hand, the audiences watches with surprise. While they are watching the dove, the magician is preparing the next magic trick in his left hand, without being found out by the audience. To successfully perform magic tricks that would otherwise be obvious, it is necessary to divert the audience's attention toward a distracting act, which prevents observers from becoming aware of how the trick works (Lamont & Wiseman, 1999). For this reason, misdirection is used in successful magic performances, and this technique is essential for all magic tricks.

Misdirection is caused by gesture, motion, and magic illusions. Types of misdirection and magic illusions have been classified, and combining them results in successful magic performance (Kuhn, Amlani, & Rensink, 2008; Macknik et al., 2008).

In misdirection by gesture, magicians capture attention using their direction of gaze, hands, body, and so on (Tamariz, 1988). For example, if a magician directs his gaze or hands somewhere, people look there automatically. This is the most basic type of misdirection, called social misdirection (Cui, Otero-Millan, Macknik, King, & Martinez-Conde, 2011; Rieiro, Martinez-Conde, & Macknik, 2013; Tachibana & Kawabata, 2014).

In misdirection by motion, magicians manipulate attention using objects (Hergovich, Gröbl, & Carbon, 2011; Cavina-Pratesi, Kuhn, Ietswaart, & Milner, 2011; Otero-Millan, Macknik, Robbins, & Martinez-Conde, 2011). For example, when a magician wants the audience to look in some direction, he shakes a magic wand, and the shaking motion captures attention. Previous studies show that the type (e.g., curved or straight) and speed of motion are critical for misdirection (Hergovich et al., 2011; Otero-Millan et al., 2011).

In misdirection by magic illusions, magicians capture attention by causing some magical phenomenon. For example, if a magician makes a dove appear or disappear in his silk hat, the audience attends to the hat because they are surprised. Misdirection using magic illusions is a powerful way to manipulate attention because it both captures attention and controls expectations and suspicion. Magic illusions violate our understanding of causal relationships (Parris, Kuhn, Mizon, Benattayallah, & Hodgson, 2009). Impossible events such as magic illusions affect and heighten causal relationship processing, which increases attention to the event. Therefore, magic illusions might be the strongest form of misdirection, and magicians perform magic by combining gesture, motion, and magic illusions.

Psychologists have focused on misdirection to examine the characteristics of perception and cognition in daily life (Lamont & Henderson, 2009; Macknik et al., 2008; Skarratt, Cole, & Kuhn, 2012). Studies of change blindness and inattentional blindness have used natural scenes such as pictures or movies as stimuli, however, researchers could not control where participants directed their attention. As stated above, this is problematic for psychologists trying to use dynamic and complex stimuli in typical experimental paradigms, so our understanding of cognition in the real world remains unclear. Misdirection has been studied to solve this problem. In fact, research on misdirection provides useful findings and reflects fundamental knowledge obtained from basic cognitive research (Macknik, Martinez-Conde, & Blakeslee, 2010). Moreover, some studies suggest that misdirection is valuable for educational support and therapy (Kuhn, Kourkoulou, & Leekam, 2010; Harte & Spencer, 2014). Misdirection has proven to be one of the most useful approaches in studies using dynamic stimuli rather than some simple geometric figures to investigate natural cognition.

Nevertheless, it is unclear how misdirecting motions and illusions affect change detection. Most misdirection studies used movie clips of a series of magic performances as stimuli.

Consequently, misdirecting gesture, motion, and magic illusions were combined: the magician shook a magic wand, pointed at his silk hat with the wand, and a dove suddenly appeared. In this case, it remains ambiguous which type of misdirection is more effective for controlling attention. How misdirecting gestures (i.e., social misdirection) such as gaze direction and pointing affect magic performance and manipulate attention has been disputed. Whether the effects of social misdirection influence the manipulation of attention is still unclear. In contrast, types of misdirecting motions and illusions have clear effects (cf. Lamont & Wiseman, 1999; Otero-Millan et al., 2011). Therefore, examining the effects of motions and illusions separately, excluding social misdirection, would lead to new insights on the characteristics of misdirection.

The purpose of this study was to examine how misdirecting motions and illusions differ and which types of misdirection are most efficient for manipulating visual attention.

Experiment 1

The objective of this experiment was to investigate how misdirecting motions affect visual attention and task performance (i.e., detection of magic tricks).

A previous study on misdirecting motion showed that attention was better captured by a curved versus straight misdirecting motion (Otero-Millan et al., 2011). However, the misdirecting motion in that experiment included a magic trick (magic illusion that included misdirection and motion), so it is unclear whether the effect of misdirection was specifically caused by misdirecting motion.

We tested whether misdirecting motions by themselves influence the detection of magic tricks.

Method

Ethics statement

All experiments were approved by the ethics committee of the Graduate School of Arts and Letters, Tohoku University, Japan, and written informed consent was obtained from all participants. Participants were debriefed at the end of experiment, and the purpose of the study and the magic tricks were explained.

Participants

Ten participants (7 female, mean age = 22.1 years, SD = 2.59) with normal or corrected to normal vision participated in this study. Participants did not have prior knowledge of the magic tricks performed in the experiment.

Apparatus

Eye position was recorded with a Tobii TX300 eye tracker (Tobii Technology, Sweden) at

300 samples per second. The visual stimuli were controlled by Tobii Studio and displayed on a Tobii TX300 23 inch screen unit with a refresh rate of 60 Hz (Tobii Technology, Sweden).

Stimuli

We used movie clips of a classic magic trick (cups and balls) as visual stimuli. Cups and balls performances were filmed using a digital camera (iVIS HF G20, Canon, Japan) at 29.97 frames per second (fps). Movies were edited in Adobe Premiere Pro (CS6, Adobe systems, USA) and all movies were 5 seconds in duration (720 × 480, 13° × 18°). All movies showed four steps (Figure 1): (1) Before performance: Two silver cups and two red balls were placed on table; (2) Balls set: A magician covered the balls with the cups, and the left cup was pushed ahead while the right cup was not moved; (3) Misdirection: As the left cup was lifted revealing one red ball, the other ball hidden in the right cup was dropped under the table by tilting the cup. This is misdirection because it is difficult for participants to see that the ball was dropped from the right cup due to the motion of the left cup; (4) After performance: Cups and balls performance is finished and only the ball in the left cup is visible.

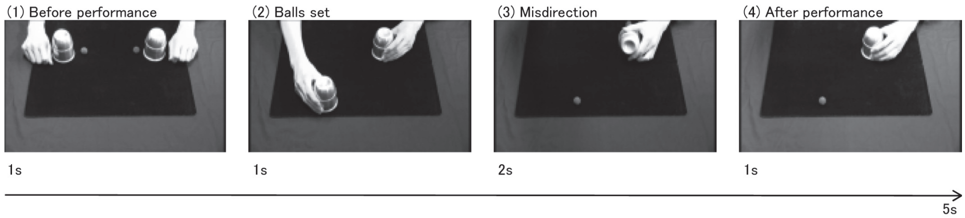

Figure 1. Sequence of movie clip events. In (3) Misdirection, misdirecting motions (control, straight, or curved) were performed, and participants judged whether or not the red ball hidden in the right cup was dropped.

There were three types of misdirection in the third step, based on Otero-Millan et al. (2011): (1) No misdirecting motion: There was no special misdirection, and the only motion was opening the left cup; (2) Straight misdirecting motion: Before opening the cup, the left cup was moved horizontally to the corner of the table; (3) Curved misdirecting motion: Before opening the cup, the left cup was moved in a semicircle to the corner of the table. In all three conditions, misdirection was performed with the left cup. In addition to these misdirection conditions, there were also ball conditions. When misdirection was done with the left cup, the ball hidden in the right cup was either dropped or undropped. In the ball dropped condition, the ball in right cup was actually dropped under the table. In the ball undropped condition, the magician just pretended to drop the ball by tilting the cup, but the ball was not actually dropped.

Thus, the experiment was a 3 (motion: control, straight, and curved) × 2 (ball: dropped or undropped) design (Figure 2).

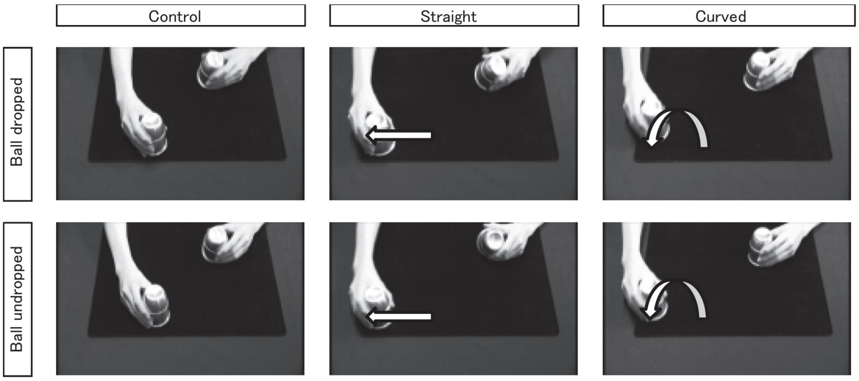

Figure 2. The experimental design. In the control condition, there was no misdirection. In the straight condition, the misdirecting motion was straight (the straight arrows indicate direction of motion). In the curved condition, the misdirecting motion was curved (the curved arrows indicate how the cup moved). The ball hidden in the right cup was dropped in the ball-dropped condition, and not-dropped in the undropped condition.

Procedure

Participants were informed that they would watch movie clips, and their task was to judge whether a red ball hidden in the right cup was dropped from the cup in each movie. All participants completed 60 trials (3 motion conditions × 2 ball conditions × 10 repetitions per condition). Movies were presented in a random order, and judgments were recorded by key press (yes or no). A fixation mark (3 seconds) was inserted before the start of each movie clip.

Prior to watching the video clips, eye position was calibrated using a nine-point calibration procedure. Eye position were recorded by an eye tracker during the experiment at a viewing distance of 60 cm (maintained with a chin rest).

Analysis

For eye position data, we calculated fixation time (ms) in areas of interest (AOI) around the two cups during misdirection over a two-second period. The visual angle of the AOIs for the two cups were 13° × 9°. These AOIs separated the movies into two sides (left and right). The left AOI covered the misdirection area, and the right AOI covered the trick area (i.e., where the ball was dropped or not). For behavioral data, we calculated judgment accuracy (%) in each condition.

Results

Eye position

Data from two participants were excluded from the analysis due to insufficient data acquisition.

We calculated mean fixation time during misdirection (two seconds) in each condition (Figure 3).

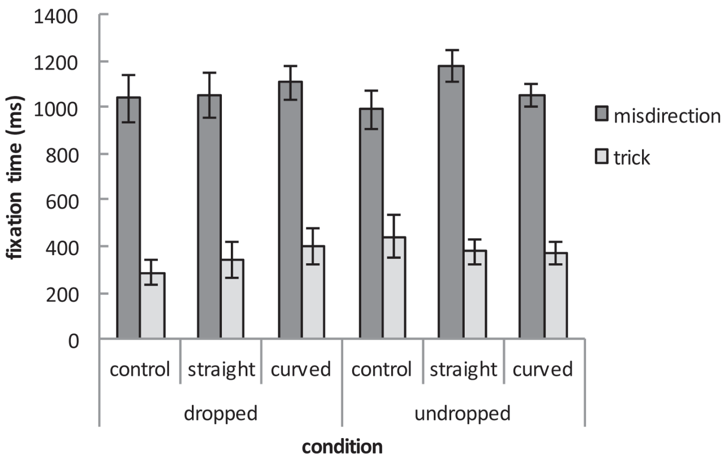

Figure 3. Mean fixation time (ms) in each condition. The dark gray bars show fixation time in the misdirection area. The light gray bars show fixation time in the trick area (ball dropped or undropped). Error bars show standard error of the mean.

A three way within-subject ANOVA [3 (motion) × 2 (ball) × 2 (AOI)] revealed a significant main effect of AOI ($F_{1,7} = 48.73$, $p < .01$), suggesting that fixation time was longer in the misdirection area than in the trick area in all conditions. Although there were no other significant main effects or interactions ($p > .05$), the motion × ball interaction was marginally significant ($F_{2,14} = 3.70$, $p < .1$). A simple main effect test showed that the motion effect was significant in the dropped condition ($F_{2,28} = 3.59$, $p < .05$). Multiple comparisons (Bonferroni method) showed that fixation time was significantly longer for the curved versus control motions in the dropped condition ($p < .01$). A simple main effect test showed that the effect of ball was significant in the straight condition ($F_{1,21} = 6.11$, $p < .05$). Multiple comparisons (Bonferroni method) showed that fixation time was significantly shorter for straight motion in the dropped versus undropped condition ($p < .01$).

Behavioral data

Data from one participant were excluded from the analysis due to insufficient data acquisition.

We calculated mean judgment accuracy (%) in each condition (Figure 4).

A two-way within-subjects ANOVA [3 (motion) × 2 (ball)] revealed a significant motion × ball interaction ($F_{2,16} = 4.00$, $p < .05$). A simple main effect test showed that the effect of motion was significant in the dropped condition ($F_{2,30} = 3.34$, $p < .05$). Multiple comparisons (Bonferroni method) showed that in the dropped condition, accuracy was higher in the straight and curved conditions than the control condition ($p < .05$). The simple main effect of ball was not significant ($p > .05$).

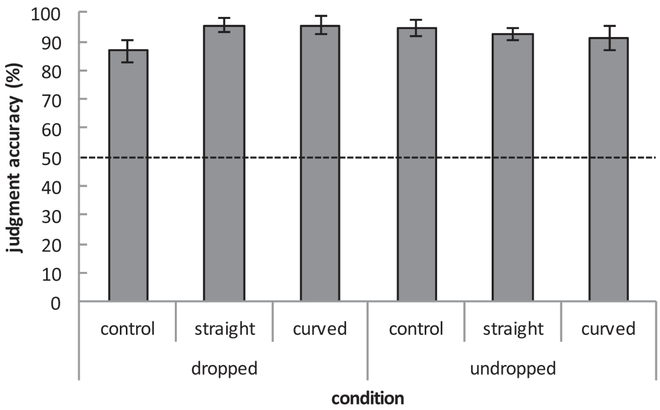

Figure 4. Mean judgment accuracy (%) in each condition. The dashed line indicates chance level (50%). Error bars show standard error of the mean.

Discussion

In contrast to Otero-Millan et al. (2011), our results suggest that misdirecting motions do not affect change detection because there were not differences in either eye position or behavioral data.

However, some results should be considered in more detail. In the eye position data, only the effect of AOI was significant. This indicates that the misdirection area was watched more than the magic trick area in all conditions, and there were no differences based on the type of misdirecting motion. The marginally significant increase in fixation time for curved versus control motion in the dropped condition and decrease in fixation time for straight motion in the dropped versus undropped conditions are due to eye movement characteristics. Curved motion causes smooth pursuit eye movements that result in comparatively long fixations. Straight motion causes saccades that result in short fixations. Hence, our eye position results can be attributed to types of eye movements rather than attention.

Task performance was high in all conditions (over 80%). This supports the eye position results and shows that there were no effects of misdirecting motions. Misdirecting motions did not affect change detection. In the dropped condition, task performance was higher in the straight and curved than control condition. This may be due to a strong expectation for magic tricks. Participants had strong expectations, rendering misdirection by motion ineffective, and, counterintuitively, leading to better performance in the straight and curved conditions relative to the control condition.

Experiment 2

The objective of this experiment was to investigate how magic illusions affect visual attention and task performance.

We focused on traditional magic illusions of appearance, vanish, and change (cf. Lamont & Wiseman, 1999) because these tricks have clear effects and are relevant to stimulus onset used to manipulate visual attention in basic psychological research (cf. Danek, Fraps, Müller, Grothe, & Öllinger, 2014).

Method

Participants

Eleven participants (8 female, mean age = 22.8 years, SD = 3.88) with normal or corrected to normal vision participated in this study. Participants had no prior knowledge of the magic tricks. These participants did not take part in Experiment 1.

Apparatus

The apparatus was the same as Experiment 1.

Stimuli

We used movie clips of cups and balls as visual stimuli. The movies were basically the same as in Experiment 1, except for the types of misdirection.

There were four types of magic illusions used as misdirection: (1) No misdirecting illusion: No magic illusion was performed, and opening the left cup was the only motion; (2) Appearance misdirecting illusion: A second red ball appeared from the left cup when it was lifted; (3) Vanish misdirecting illusion: The red ball disappeared from the left cup when it was lifted; (4) Change misdirecting illusion: The color of the ball changed from red to yellow when the left cup was lifted. The ball conditions were the same as Experiment 1.

The experiment was a 4 (illusion: control, appearance, vanish, and change) × 2 (ball: dropped or undropped) design (Figure 5).

Procedure

The procedure was the same as Experiment 1, except for the number of trials. All participants completed 80 trials (4 illusion conditions × 2 ball conditions × 10 repetitions per condition).

At the end of experiment, we asked participants whether they could reveal how the magic tricks were done (i.e., whether they could tell how the magician made the new ball appear, disappear, or change color).

Analysis

The analysis was the same as Experiment 1.

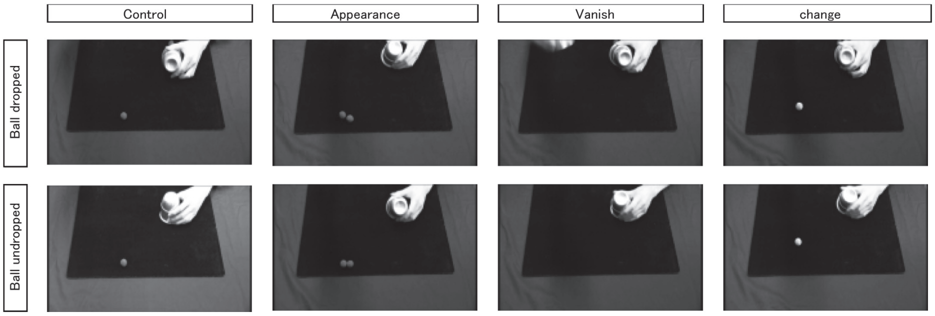

Figure 5. The experimental design. In the control condition, there was no magic illusion. In the appearance condition, the misdirecting illusion was the appearance of a new ball. In the vanish condition, the misdirecting illusion was the ball's disappearance. In the change condition, the misdirecting illusion was the ball's color change. The ball hidden in the right cup was dropped in the ball-dropped condition, and not-dropped in the undropped condition.

Results

According to verbal reports at the end of experiment, no participants knew how the magic illusions were done.

Eye position

Data from two participants were excluded from the analysis due to insufficient data acquisition.

We calculated mean fixation time during misdirection (two seconds) in each condition (Figure 6).

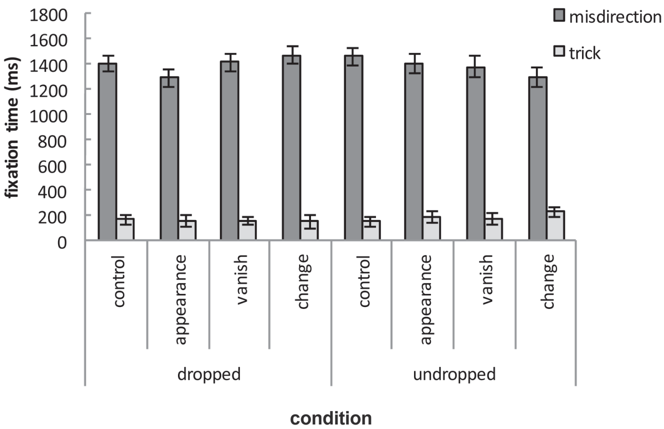

Figure 6. Mean fixation time (ms) in each condition. The dark gray bars show fixation time in the misdirection area. The light gray bars show fixation time in the trick area. Error bars show standard error of the mean.

A three way within-subject ANOVA [4 (illusion) × 2 (ball) × 2 (AOI)] revealed a significant main effect of AOI ($F_{1, 8}$ = 183.78, $p < .01$) and a significant illusion × ball interaction ($F_{3, 24}$ = 3.77, $p < .05$). The simple main effect test showed that the effect of illusion was significant in the ball dropped condition ($F_{3, 48}$ = 4.28, $p < .01$). Multiple comparisons (Bonferroni method) showed that fixation time was shorter for the appearance illusion compared to the other three conditions in the dropped condition ($p < .01$). A simple main effect test also showed that the effect of ball was significant in the appearance condition ($F_{1, 32}$ = 7.09, $p < .05$). Multiple comparisons (Bonferroni method) showed that fixation time for the appearance illusion was shorter in the dropped versus undropped condition ($p < .01$).

Behavioral data

Data from two participants were excluded from the analysis due to insufficient data acquisition.

We calculated mean judgment accuracy (%) in each condition (Figure 7).

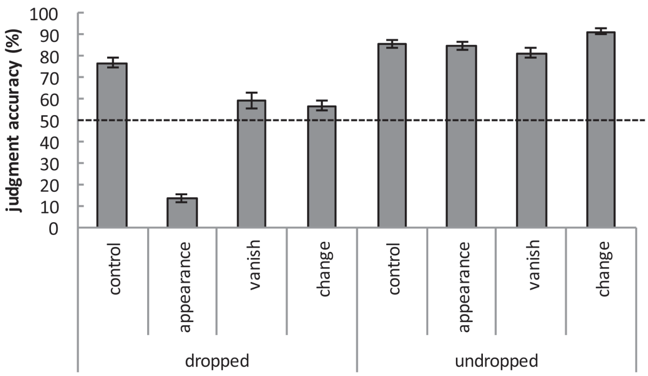

Figure 7. Mean judgment accuracy (%) in each condition. The dashed line indicates chance level (50%). Error bars show standard error of the mean.

A two-way within-subject ANOVA [4 (illusion) × 2 (ball)] revealed significant main effects of illusion ($F_{3, 24}$ = 15.43, $p < .01$) and ball ($F_{1, 8}$ = 32.80, $p < .01$), and a significant illusion × ball interaction ($F_{3, 24}$ = 8.35, $p < .01$). A simple main effect test showed that the illusion effect was significant in the ball dropped condition ($F_{3, 45}$ = 21.40, $p < .01$). Multiple comparisons (Bonferroni method) showed that accuracy was significantly higher for the control compared to the other three illusion conditions in the dropped condition ($p < .05$). Moreover, accuracy for vanish and change illusions were significantly higher than for appearance in the dropped condition ($p < .01$); accuracy in the dropped condition was lowest for the appearance illusion. Simple main effect tests also showed that the effect of ball was significant for appearance

($F_{1, 30} = 50.65$, $p < .01$), vanish ($F_{1, 30} = 4.95$, $p < .05$) and change ($F_{1, 30} = 11.89$, $p < .01$) illusions. Multiple comparisons (Bonferroni method) showed that accuracy for these illusions were significantly lower in the dropped versus undropped condition ($p < .01$).

Discussion

The results strongly suggest that misdirecting illusions influence change detection, and the appearance illusion is best for misdirection.

Eye position and behavioral data converge to indicate significant differences in the appearance condition. Fixation time was shorter for the appearance illusion in the dropped versus undropped condition. It is assumed that participants' attention in each appearance × drop condition was divided between misdirection and trick areas, and this divided attention affected eye movements: When participants were misdirected by the appearance illusion, they alternated between watching those two areas to detect the magic trick (ball dropped or undropped), causing short fixation times. In the behavioral data, while task performance was high in the undropped condition (over 80%), it was relatively low in the dropped condition. Moreover, the three illusions (appearance, vanish, and change) affected detection more than the control condition. Thus, misdirecting illusions clearly influenced change detection. Moreover, the effect of the appearance illusion was stronger than the effect of the vanish and change illusions, supporting the eye position results. Surprisingly, there was no difference between vanish and change illusions. This suggests that there are no differences between stimulus offset and color change as phenomena that capture attention.

General discussion

The purpose of this study was to examine how misdirecting motions and illusions differ, and which types of motions and illusions are most efficient for manipulating visual attention via misdirection.

The results reveal several differences in the effects of misdirecting motions and illusions. Misdirection illusions, but not motions, influenced change detection (detecting a magic trick). In particular, the appearance illusion had a strong influence on change detection, indicating a strong influence on attention.

In Experiment 1, we found that misdirection by motion only produced weak effects. Although eye position was directed by misdirection, task performance was not affected by any type of misdirecting motion. It is assumed that misdirection by motion is likely to affect the beginning of misdirection (Abrams & Christ, 2003). Although participants directed their attention to the misdirecting motion at first, they could easily shift attention to the magic trick because the misdirection was not strong enough to keep attention captured. Thus, task performance was high in all conditions. The motion velocity of objects in magic illusions is known to be critical for detecting magic tricks (Hergovich et al., 2011). Furthermore, the velocity and range of motion differ between our experiment and Otero-Millan et al. (2011).

Therefore, we should carefully examine whether misdirecting motions would have stronger effects at different velocities.

The results of Experiment 2 clearly showed that the appearance illusion produced the largest effects of misdirection. When a new object suddenly appears (i.e., stimulus onset), attention is directed to it automatically and rapidly. This is consistent with previous basic research on visual attention (Brockmole & Henderson, 2005; Cole & Kuhn, 2010; Miller, 1989), suggesting that attention is easily captured by abrupt new stimulus onsets, and this effect is robust in both laboratory and real world settings. However, our appearance illusion may have captured attention based on the number of distracters (Chastain & Cheal, 2001). Two balls were used in our appearance illusion. The appearance illusion included an abrupt new stimulus onset and increased the number of balls (from one to two). Future studies should examine effects of onset and number of distracters separately. Then, why did misdirection by vanish and change illusions have only weak effects compared to the appearance illusion? These illusions have been performed in magic shows. According to previous studies, vanish and change phenomena (offset and color change in attention research) have little benefit for acquiring new information when attention shifts to those locations (Cole & Kuhn, 2010; Gibson & Jiang, 1998). In fact, while the appearance illusion in magic can capture attention by itself, in most cases, disappearance and color change illusions are combined with motion to capture attention. In this study, we used color change from red to yellow. Future work should examine how combinations of different vanish and change illusions affect attention.

Conclusion

The present study revealed differences between misdirecting motions and illusions. While motion did not reinforce misdirection, misdirecting illusions affected visual attention. In particular, misdirection induced by an appearance illusion had the strongest effect. This is consistent with many previous studies showing that the abrupt onset of a new stimulus strongly captures attention (Brockmole & Henderson, 2005; Cole & Kuhn, 2010; Miller, 1989) because attention is automatically directed to objects that appear suddenly. This phenomenon is robust in both laboratory and real world settings. Future studies should establish quantification models that include the effects of various types of misdirection and their combinations to develop misdirection as a more efficient method for controlling attention.

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