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SHORT REPORT

The Vanishing Coin Illusion: When sound congruence affects visual representation of motion

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Abstract
In the "classic" vanishing ball illusion (VBI), a magician pretends to throw a ball and the audience sees it go up and then disappear. To gain a better understanding of the mechanisms involved, we conducted two experiments to analyze the permeability of this type of illusion to auditory information. A modified version of the VBI (i.e., the Vanishing Coin Illusion [VCI]), was presented, and this was either accompanied by a sound or was not. The results show that the presence of a sound adds to the success of the illusion (Experiment 1), especially when this sound is congruent with the illusion (Experiment 2). Based on these results, we discuss the mechanisms at work in this illusion.

Keywords Magic · Visual illusion · Multisensory processing

Introduction

> A feint is made of throwing an orange into the air, when in reality it is still retained in the hand. As soon as we perceive the first act, we assume the second because it is the logical consequence, or simply the habitual accompaniment. We do even more than suppose it; we represent it so vividly to ourselves that we believe we see it. (Binet, 1894, p. 560)

Prestidigitation is one of those tools that stand out among the many tools that psychologists use to study cognition. Magicians possess knowledge, which is often intuitive, about the functioning of the human mind. Analyzing some of their "tricks" is an original and valuable approach that can help to shed light on certain dimensions of cognition (e.g., Kuhn et al., 2008; Rensink & Kuhn, 2015; Thomas et al., 2015). Among the first tricks studied by contemporary psychology, the vanishing ball illusion (VBI) undoubtedly occupies a place of its own. This phenomenon, cited at the beginning of this article by one of the founders of scientific psychology, Alfred Binet (see Thomas et al., 2016, for a presentation of this early work), was scientifically analyzed by Triplett from 1900. In recent decades there has been a considerable revival of interest in the VBI (see Kuhn & Rensink, 2016, for a review).

In this trick, a magician repeatedly tosses a ball in the air. During the last movement, the ball seems to move upwards and then suddenly vanishes. This spectacular illusion is based on a very simple performance: On the final toss, the magician pretends to toss the ball but actually holds it in the palm of their hand. Numerous studies have attempted to understand the psychological mechanisms behind this illusion. For instance, several studies focusing on the role played by "social cues" have shown that the effect is more pronounced if the magician follows the supposed trajectory of the ball with their gaze (Kuhn & Land, 2006, but see Thomas & Didierjean, 2016a). According to some authors (see, for example, Kuhn & Land, 2006; Kuhn & Rensink, 2016; Thomas & Didierjean, 2016a, 2016b), magicians' ability to create expectations in the minds of participants is one of the determining factors that explain the occurrence of the illusion. With this in mind, Kuhn and Rensink (2016) analyzed the effect of perceptual priming on the success of the VBI. In this study, participants were

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asked to watch a video in which a magician performed the VBI trick. In the first condition, referred to as the “primed condition,” the magician performed a first throw followed by a second fake throw. In the second condition, referred to as the “nonprimed condition,” only the fake throw was performed. The results show that participants in the “primed condition” were more likely to report seeing the ball rise in the air (64%) than those in the “nonprimed” condition (32%). Kuhn and Rensink (2016) argue that the perceptual inputs from the immediate past create immediate perceptual predictions in participants during the fake throw, thus reinforcing the illusion. While these studies shed light on several conditions that promote the success of the illusion, the mechanisms involved remain little known. To deepen our understanding of these mechanisms, we propose to investigate the susceptibility of this specific type of visual motion illusion to auditory information, in alignment with prior studies on the subject.

The role of auditory information in visual motion illusions

In their study on the *representational momentum* (RM) effect, Hubbard and Courtney (2010; see also Teramoto et al., 2010) demonstrated that auditory information could influence perceptual anticipation. They asked participants to follow a target moving horizontally and then to estimate its vanishing point. In some of the trials, the target was accompanied by a sound. This sound could be either ascending or descending (both on a linear frequency). In the other trials, the visual stimulus was presented without sound. First, their results show that, consistent with the findings by Hubbard and Bharucha (1988; see also Hubbard, 2020) on the RM, the participants judged the vanishing point as not only further along its trajectory but also slightly displaced downwards. They also show that this gravity effect was amplified in participants exposed to descending auditory motion, and eliminated in participants exposed to ascending auditory motion. According to the authors, the semantics of sound (ascending or descending) may lead individuals to anticipate the trajectory of the moving target, suggesting the permeability of the RM to prior knowledge (for a comparison between the RM and the VBI, see Thomas & Didierjean, 2016b).

In this vein, several studies demonstrated that sound could influence the interpretation of ambiguous visual stimuli, particularly when they are congruent (e.g., Grassi & Casco, 2009, 2010, 2012; Sekuler et al., 1997). For example, in the *audiovisual bounce-inducing effect* (Grassi & Casco, 2009, 2010, 2012), two virtual circles that start moving from opposite directions and overlap can be perceived as either bouncing off or streaming through one another. Grassi and Casco (2009, 2010, 2012) demonstrated that adding a sound when the circles overlap increases the “bouncing interpretation,” and all the more if it is a bounce-congruent sound (i.e., a billiard ball).

One step further, Hidaka et al. (2009, 2011) demonstrated that auditory signals can induce motion perception of a static visual stimulus. In their study, a blinking bar was presented at a fixed location and, in one condition, its flash onset was synchronized to an alternating left–right sound source. Results show that, in this condition, the bar was perceived to be moving laterally. Results also show that this sound-induced visual motion was strengthened when the visual stimulus was in low resolution (i.e., presented in peripheral vision). This result suggests that the sound could be used as a cue to interpret a visual stimulus, specifically when the quality of the latter is too low to be trusted.

Our study

As far as we know, no study has investigated the effect of auditory information on the VBI. However, studying this question is beneficial for several reasons. First, it could make an important contribution to the knowledge of the link between audition and vision. Previous studies reported that auditory information can influence the interpretation of a moving stimulus (e.g., Grassi & Casco, 2009, 2010, 2012; Hubbard & Courtney, 2010), or can induce motion perception of a static visual stimulus (e.g., Hidaka et al., 2009, 2011). However, to our knowledge, no study has investigated how a sound could influence the motion perception of an absent stimulus.

Second, it more specifically allows for investigation of the permeability of this illusion to high-level factors such as knowledge mobilized by an auditory stimulus (e.g., Kuhn & Rensink, 2016; Thomas & Didierjean, 2016a). Undertaking such a study, however, poses a methodological challenge. In the VBI, during the last (fake) toss, the ball disappears immediately after it is allegedly tossed. As a result, its trajectory cannot be accompanied by a continuous sound. Also, in the VBI, a ball is not expected to produce a sound when tossed. We therefore propose using a new version of the VBI—that is, the Vanishing Coin Illusion (VCI). In this trick, the magician performs a single (fake) toss of a coin instead of a ball, making it possible to associate a brief but congruent auditory stimulus with the representation of a real toss: the metallic clink of a coin. We posit that, if the VCI is permeable to the addition of semantic information, the presentation of a semantically congruent sound will lead more participants to perceive the coin as rising into the air.

Experiment 1

This experiment sought to examine whether adding the sound of a coin during the VCI was likely to increase the success of the illusion or whether the latter was impervious to prior knowledge.

Method

Participants

This experiment was conducted online via the Qualtrics platform. A total of 296 participants were involved. After data cleaning, 183 participants were selected[1] (66 men, 115 women, two nonbinary gender, mean age = 23.50 years, *SD* = 7.51). A sensitivity test on G*Power 3.1 (Faul et al., 2009) indicates that the sample gave us an effect size ω = .21, at an α = 0.05 and β = 0.80.

Material and procedure

In the first phase, after logging into the Qualtrics platform, participants were shown a video (1,080 p; 30 FPS)[2] presenting the VCI. The magician presented an American 1-dollar coin, 38 mm in diameter, held between his thumb and fingers. He then simulated a toss with his thumb, following the imaginary trajectory of the coin with his gaze. From the beginning to its disappearance, the coin was present for 2 seconds. The magician uses sleight of hand to invisibly keep the coin between his closed fingers. Two versions of the VCI were developed. Each participant was individually exposed to one of these two versions. While the video was not accompanied by any sound in the "no sound" condition, the metallic clink of a coin (for 570 milliseconds) accompanied the fake throw in the "with sound" condition. In the latter condition, participants were asked to turn on the sound of their computer and to set the volume to 80%. In a second phase, participants were asked to indicate the height at which they had perceived the coin for the last time, on a scale ranging from 1 to 28 (see Fig. 1). Lastly, they were asked to respond to the following question: "Did you see the coin rise into the air in this video?"

Fig. 1 Scale used in the height estimation task

Results and discussion

Illusion sensitivity

The participants were categorized into three groups. They were considered to be "sensitive to the illusion" when the estimated height was greater than the position of the magician's thumb (Position 19 in Fig. 1) *and* when they reported seeing the coin rise into the air (see Kuhn & Rensink, 2016; Thomas & Didierjean, 2016b, for similar criteria). They were considered to be "insensitive to illusion" when the estimated height was equal to or less than the position of the magician's thumb (19) *and* when they did not report seeing the coin rise into the air. Figure 2 presents the distribution of

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[1] The data of participants who reported having uncorrected vision and hearing impairments (26), who used a cell phone during the experiment (11), and who did not complete the experiment (55), were excluded from the study. The experiment lasted approximately 376 seconds, and the data of participants whose duration was greater than two standard deviations from the mean were also excluded (21).

[2] https://youtu.be/dtU-H9equsU

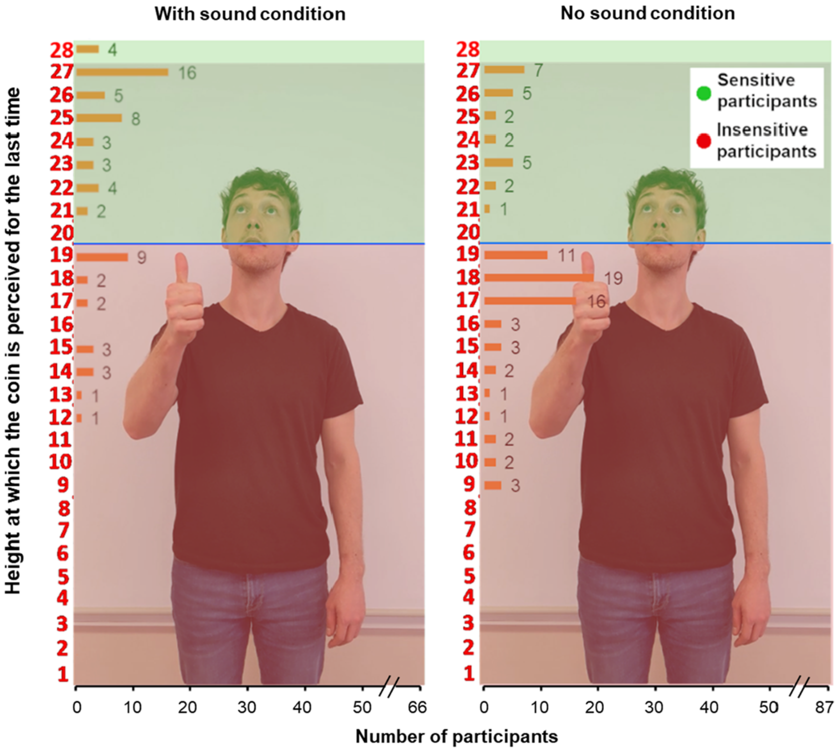

Fig. 2 Number of participants according to the estimated height of the coin as a function of the condition ("with sound" [$N = 66$] and "no sound" [$N = 87$]). The blue line represents the limit between sensitive and insensitive participants. (Color figure online)

sensitive and insensitive participants according to the estimated height of the coin during the fake throw, depending on the conditions ("with sound" condition and "no sound" condition).

A total of 30 participants (not present in Fig. 2) were considered "equivocal" because the estimated height (e.g., greater than the position of the magician's thumb) was not congruent with the verbal report (e.g., "I have not seen the coin rise into the air"). These equivocal participants were excluded from the analyses.

The results of a chi-squared test show that the number of participants sensitive to the illusion in the "with sound" condition (68%) is significantly higher than that observed in the "no sound" condition (28%), $\chi^2(1, N = 153) = 24.98$, $p < .001$; for an effect size of $v = 0.40$, see Fig. 3).

Location estimates for illusion-sensitive participants

Our objective was not only to study the impact of a sound on the activation (or not) of the illusion, but also to investigate its impact on the size of the illusion when it is activated. Perceptual displacement was calculated, for sensitive participants only (see the green portions of Fig. 2), as the difference between the coin's final physically visible position (Position 19 in Fig. 1) and its final reported position (see Kuhn & Rensink, 2016).

The results show no significant difference between the participants sensitive to the illusion in the "with sound" condition ($M = 6.44$, $SD = 2.02$) and those sensitive in the "no sound" condition ($M = 5.88$, $SD = 1.96$) $t(67) = 1.13$, $p = .26$; for an effect size of $d = .28$. This result suggests that the sound influences the activation of the illusion but not its strength.

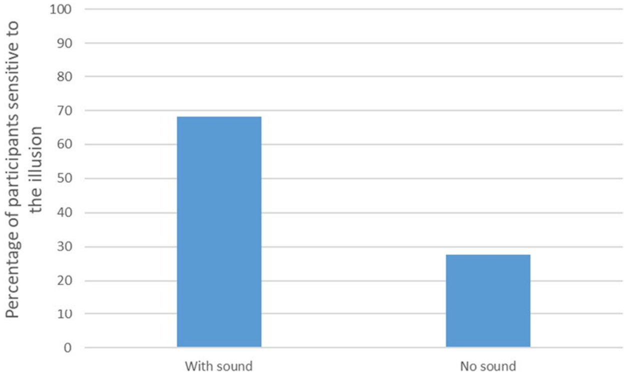

Fig. 3 Percentage of participants sensitive to the illusion according to the conditions ("with sound" and "no sound")

Discussion

First, sensitivity to the VCI in the "no sound" condition (28%) is close to the results observed with a single false toss in the VBI (32%, see Kuhn & Rensink, 2016). This suggests that the VCI is comparable with the VBI.

In addition, the results show that the metallic clink of a coin increases sensitivity to the VCI. The clink of a coin during the false throw may reinforce expectations regarding the trajectory of the coin and thus increase the illusion. This would mean that the VCI is permeable to the knowledge provided by auditory information. However, it may be considered that the addition of a sound could increase the illusion independently of its semantic congruence. According to this assumption, the presence of a sound could decrease visual attention and thus visual processing, reinforcing the anticipation effect (e.g., Hayes & Freyd, 2002).

Experiment 2

This second experiment sought to replicate the results of Experiment 1 which found that the addition of a sound increased the effect of the VCI. Its second objective was to analyze whether this result depended on the presentation of sound alone, or could also be influenced by the provision of semantic information. To this end, the semantic nature of the sounds accompanying the visual information was varied, making them semantically congruent (the metallic clink of a coin) or incongruent (the sound of an explosion or of a drop of water). This approach draws on the studies undertaken by Grassi and Casco (2010) on the audiovisual bounce-inducing effect.

Method

Participants

This experiment was conducted online via the Qualtrics platform. There were 479 participants. After data cleaning, 303 participants were selected[3] (48 men, 252 women, and three nonbinary gender, mean age = 21 years, *SD* = 6.50). A sensitivity test on G*Power 3.1 (Faul et al., 2009) indicates that the sample gave us an effect size ω = .18, at an α = 0.05 and β = 0.80.

Material and procedure

In this study, given that the material and procedure were similar to those used in the previous experiment, only the differences are noted. Participants were assigned to one of four conditions. Two conditions were identical to Experiment 1 (with or without the congruent sound of a metallic clink of a coin). In the other two conditions, the metallic clink was replaced by a semantically incongruent sound (representing a drop of water or an explosion[4, 5]).

Results and discussion

Participants were rated as sensitive, insensitive, or equivocal, using the same criteria as in Experiment 1.[6] Figure 4 presents the distribution of sensitive and insensitive participants according to the estimated height of the coin during the fake throw, depending on the conditions ("congruent sound," "incongruent sound," and "no sound" conditions).

Illusion sensitivity

We tested the effect of a specific difference between our two "incongruent sound" conditions (water [75%] versus explosion [68%]). Given that the results show no significant difference between these two conditions, $\chi^2(1, N = 123) = 0.88$, $p = .35$, for an effect size of $v = .09$, we grouped them together under the term "incongruent sounds" in the analyses below.

The results showed a significant effect of the condition (congruent sound vs. incongruent sound vs. no-sound) on the illusion sensitivity, $\chi^2(2, N = 257) = 41{,}94$, $p < .001$ (see Fig. 5).

Specific comparisons showed that more participants were sensitive to the illusion when the sound was congruent (85%) than when it was incongruent (72%), $\chi^2(1, N = 185) = 4.42$, $p = .036$, for an effect size of $v = .16$. Moreover, more participants were sensitive to VCI when there was an incongruent sound (72%) compared with the "no sound" condition (35%), $\chi^2(1, N = 195) = 25.27$, $p < .001$, for an effect size of $v = .36$.

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[3] The data of participants who reported having uncorrected vision and hearing impairments (31), who used a cell phone during the experiment (34), and who did not complete the experiment (83) were excluded from the study. The experiment lasted approximately 220 seconds, and the data of participants whose duration was greater than two standard deviations from the mean were also excluded (28).

[4] The duration of the stimuli used in Experiment 2 was 570 ms for the metallic clink of the coin and for the drop of water, and 520 ms for the explosion. We used two incongruent sounds to make sure that the results were not due to sound-specific characteristics, but to incongruence.

[5] https://youtu.be/jzIeDDE-nCo

[6] A total of 46 participants were categorized as equivocal, and their data were excluded from the results.

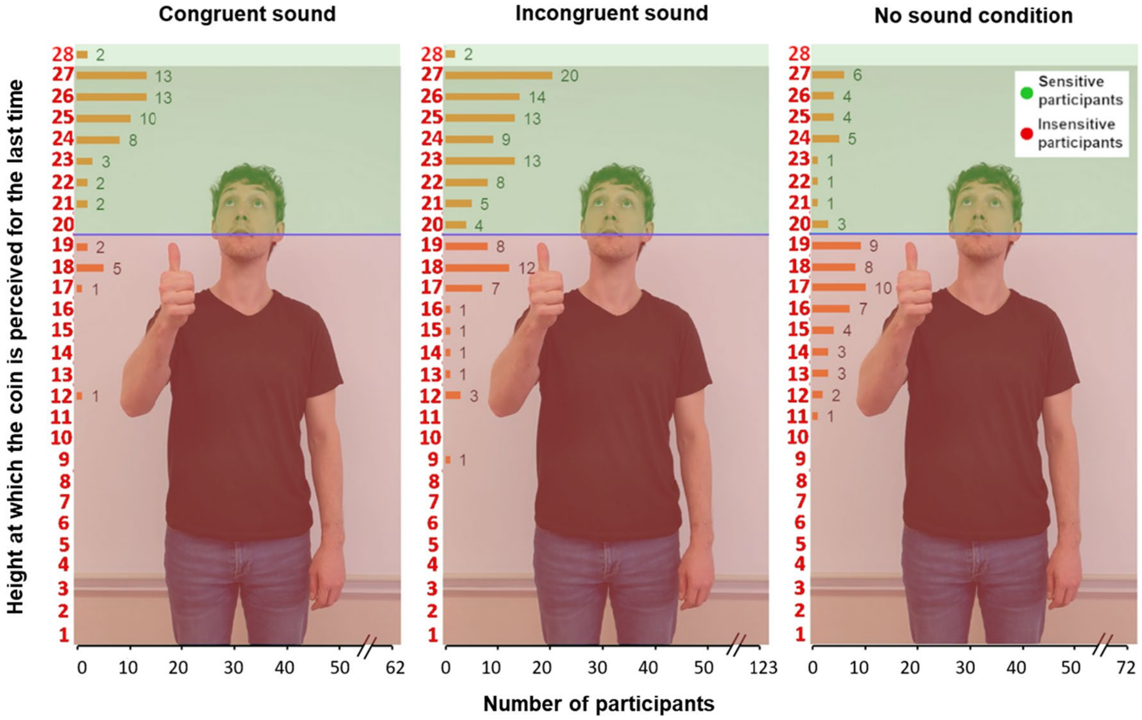

Fig. 4 Number of participants according to the estimated height of the coin as a function of the condition ("congruent sound" [$N = 62$], "incongruent sound" [N = 123], and "no sound" [$N = 72$]). The blue line represents the limit between sensitive and insensitive participants. (Color figure online)

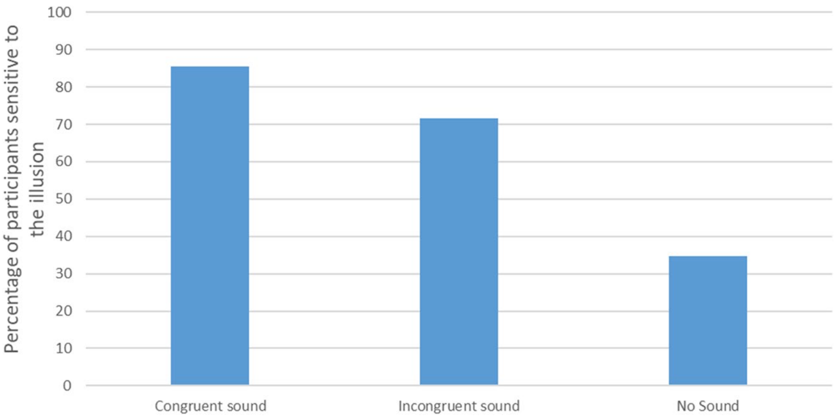

Fig. 5 Percentage of illusion-sensitive participants according to the conditions ("congruent sound," "incongruent sound," and "no sound")

Location estimates for illusion-sensitive participants

The Kruskal–Wallis test[7] showed no significant differences between participants sensitive to the illusion (see the green portions of Fig. 4) of the "congruent sound" condition (*Mdn* = 7, *IQR* = 3), the "incongruent sound" condition (*Mdn* = 6, *IQR* = 2, 25), and the "no sound" condition (*Mdn* = 6, *IQR* = 2) $H(2, 163) = 3{,}90$, $p = .14$; for an effect size of $\eta^2 = .03$. Like Experiment 1, this result suggests that the sound influences the activation of the illusion but not its strength.

General discussion

The objective of this study was to assess the extent to which the VCI, like several motion perception illusions (e.g., RM, audiovisual bounce-inducing effect,

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[7] Levene's test, $F(2.163) = 3.71$, $p = .027$, revealed unequal variances.

sound-induced visual motion), is permeable to prior knowledge, and more precisely to the association of a semantically congruent sound (metallic clink of a coin). First, the results of the two experiments show that the VCI sensitivity (28% in Experiment 1 and 35% in Experiment 2) is similar to the VBI sensitivity observed with a single false toss (32%, see Kuhn & Rensink, 2016). The VCI therefore seems a suitable tool for understanding the mechanisms involved in this type of perceptual illusion. Moreover, the results also show that associating a sound during the false toss increases illusion sensitivity, especially when this sound is semantically congruent with the representation of a coin tossed in the air (the clink of a coin) compared with situations where it is less semantically congruent (the sound of a drop of water or an explosion).

These results support our argument that the VCI (and certainly its counterpart, the VBI) is influenced by participants' prior expectations, especially those conveyed in a cross-modal manner by semantic cues present in the sound information. According to Thomas and Didierjean (2016a, 2016b), the VBI is possibly an ambiguous visual event that may create a dissonance between what the participants see (a ball that does not rise into the air) and what they expect to see (a ball rising into the air). To resolve this dissonance, some participants may privilege their expectations to the detriment of visual feedback, and therefore see what they believe they should see (a ball rising into the air). Conversely, participants insensitive to the VBI are more likely to believe what they see. In other words, they are more likely to favor their visual feedback to the detriment of their expectations. If sensitivity to the VBI depends on the weight of expectation (top-down information) versus the weight of visual feedback (bottom-up information), it is likely that increasing the expectations associated with throwing the ball increases the perceptual illusion. In the case of the VCI, it is likely that the sound of the metallic clink of the coin counteracted the visual feedback ("the coin is no longer there") and thus gave more weight to the expectations and representations associated with the illusion. In the VCI (as in the VBI), the visual sequence is rapid and it is difficult to know for sure whether the coin was ejected quickly or not. Thus, in order to overcome the ambiguity of this visual scene, our perceptual system may rely on other sensory cues (notably auditory) in a cross-modal manner in order to interpret this event (see Grassi & Casco, 2009, 2010, 2012). This assumption is in accordance with the studies undertaken by Hidaka et al. (2009) that demonstrated that illusory motion appeared more frequently in peripheral vision where spatial resolutions are lower. It is also in accordance with Kuhn et al. (2010) study on the VBI in individuals with autism spectrum disorder (ASD). The results of this research show that ASD participants are more sensitive to the VBI than a control group. According to the authors, ASD participants have difficulties in fixing the moving ball and thus have a bad spatial resolution of the small object. Because of this low resolution, they could use more trustful contextual cues (e.g., where the magician looks) to interpret the target's motion. In this vein, it would therefore be interesting to assess the extent to which the presence of cross-modal information (auditory or relating to other sensory modalities) could increase illusion-sensitivity in the VCI (and the VBI) when visual information is missing or has deteriorated. Triplett (1900) already pointed out in his time that the VBI seemed to have greater success in the evening, when light was reduced and visual information had deteriorated.

Our results also show that the simple presence of a sound (semantically incongruent) is sufficient to increase illusion sensitivity considerably. According to our hypothesis, the simultaneous processing of the sound (congruent or incongruent), and the ambiguous visual scene, are likely to pose a double challenge to participants. Allocating attention to auditory information may lead to a shallower processing of visual information, and therefore to greater uncertainty as to its interpretation (Hayes & Freyd, 2002). Expectations ("the coin will rise into the air") could thus be privileged over this uncertain visual information.

A complementary assumption to explain the influence of an incongruent sound on the VCI could be that the sound (congruent or incongruent) may initially be interpreted as evidence of an impact, before its semantics is more specifically processed. By the time the semantic information has been processed, some participants may have already used this general "impact" evidence as being sufficient to interpret the visual event in line with their expectations. Furthermore, when an incongruent sound is presented simultaneously with a visual scene, it may activate, by analogy, the real congruent sound in the minds of the participants. For example, when children play with their miniature toy cars while imitating the sound of a car in a caricatural manner, this undoubtedly activates in the spectator the real representation of the sound of a car. This representation, however, would be weaker if the scene were silent. Similarly, cartoon sound effects are generally unrealistic, yet they create analog representations which are consistent with the image, likely reinforcing the impression of motion in certain dynamic scenes. In this vein, Maeda et al. (2004) has showed that "metaphorically congruent sounds" (ascending or descending pitch) with no apparent motion information can influence the interpretation of an ambiguous visual stimulus (i.e., superimposed and oppositely moving gratings).

Surprisingly, our results also show that, for participants who are sensitive to the illusion, the presence of a sound (congruent or not) does not affect the size of the illusory displacement. This result suggests that a sound (particularly a congruent sound) could favor the prioritization of participants' expectations (a ball rising into the air), but does not affect the nature of these prioritized representations. According to this hypothesis, the VCI and other similar perceptual illusions could depend more on the probability of activation of a preexisting representation than on a representational change during the perceptual event.

Additionally, it would be interesting to investigate the extent to which participants who are sensitive to the VCI (or the VBI) perceive the illusory coin (or ball) as if it were real bottom-up information. Recently, Intraub (Dickinson, & Intraub, 2008; Intraub, 2010, 2012) suggested that the distinction between false memory and perception biases could be thin. According to the multisource model (see Intraub, 2010, 2012; Intraub & Dickinson, 2008), when a visual scene is visible, participants have no difficulty discriminating the currently present visual sensory input (bottom-up information) from the expected and amodally perceived continuation of objects (top-down information). However, when their memory of the scene is tested a few milliseconds after its presentation (Intraub & Dickinson, 2008), participants could misinterpret top-down representations as if they were bottom-up ones. This confusion of the source could lead them to remember what they did not see as if it was really presented (e.g., boundary extension phenomenon). The same phenomenon could probably explain some visual illusions in which a visual event is briefly presented and violates participants' expectations (e.g., the VCI or the VBI). In this vein, the VCI could be a form of very brief false memory phenomenon: The cognitive system could activate for a short moment a preexisting knowledge in memory (a coin in the air) and misinterpret it as a bottom-up information. To test this hypothesis, it could be relevant to compare confidence rate and response reaction time of participants who are sensitive to the VCI (or the VBI) to participants who are exposed to a real throw, as has previously been done in other perceptual illusions (see Thomas et al., 2022; see also De Neys, 2006). If participants interpret the illusory ball as bottom-up information, their confidence rate and reaction time should be similar to those observed in the real throw condition.

Conclusion

In what is arguably the most famous magic trick in psychological research, the VBI, a magician appears to toss a ball that vanishes into the air. Our results show that this type of effect may be influenced by the simultaneous association with a sound, especially if this sound is congruent. These findings confirm magicians' intuition with regard to reinforcing a visual effect with sound effects. One of the most famous magicians in history, Robert-Houdin (1868), once said: "To create an even greater illusion, each time you pretend to place a nutmeg in the hat, you tap the insides with your index finger to simulate the sound of the nutmeg dropping" (p. 378).

Open practices statement None of the present experiments was preregistered. For all experiments, we have reported all measures, conditions and data exclusions. Data and/or materials are available online (https://osf.io/tq2xa/?view_only=213e2e62483d4949bc93b37dd76b37dc).

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