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Does Magic Offer a Cryptozoology Ground for Psychology?

Cyril Thomas, André Didierjean, and François Maquestiaux
Université de Franche-Comté

Pascal Gygax
University of Fribourg

Magicians often trick spectators' senses by relying on cognitive limitations. To do so, they use intuitive but age-old knowledge of human cognition. Research into the relationship between magic and psychology has been growing for a number of years now. This work offers an original ground for studying cognitive processes, while also providing the opportunity to discover processes that are still poorly understood. In this respect, the study of magic in psychology resembles the domain of "cryptozoology," the name given to the search, real or humoristic, for unknown species. This article begins by briefly presenting some of the major research conducted over the past 10 years in the psychology of magic. We argue that, unfortunately, so far, no unknown cognitive species have been added to the "hunting bag" of these studies; in the second part of the article, we discuss the wide range of psychological facets of magic that are still to be explored.

Keywords: magic, cognitive processes, unexplored psychological processes

One of the fascinating aspects of magic is that it seems to violate the laws of nature. Magicians make cards, balls, and coins disappear; they make doves appear, bend keys from afar, and cut their assistants in three pieces before resuscitating them. Among the procedures that magicians use to trick the audience, many call upon precise knowledge of the human mind and its limitations. Magicians typically capitalize characteristics of certain cognitive processes, such as perception, attention, or memory. By the late 19th century, researchers in psychology had begun to conduct laboratory studies on the tricks of the most well-known illusionists of the time, in view of analyzing their psychological dimensions (see writings of Binet 1894a; Dessoir, 1893; Jastrow, 1896; Triplett, 1900). This early research mainly showed that magicians manipulate spectators' perception by relying on intuitive knowledge about the rules governing human cognition.

In the past 10 years, research in psychology and neuroscience has been applying today's knowledge to study the processes at play in magic (for reviews, see, e.g., Kuhn, Amlani, & Rensink, 2008; Kuhn & Martinez, 2011; Macknik et al., 2008; Rensink & Kuhn, 2014). In examining the processes underlying magic tricks, the goal of these studies was not only to gain new insight on known cognitive processes but also to uncover those yet unexplored (e.g., Kuhn, Amlani, & Rensink, 2008). In this respect, magic offers a cryptozoology ground for cognitive psychology.

Still, we argue that so far, no unknown cognitive processes have been uncovered, yet there is ample hope, as the topic is in its infancy. Although several articles have reviewed the topic of "psychology of prestidigitation" (e.g., Kuhn, Amlani, & Rensink, 2008; Kuhn & Martinez, 2011; Rensink & Kuhn, 2014), to our knowledge, none of them has focused on new psychological processes. Consequently, in the present article, not only do we present some of the explored issues in this topic but we also concentrate on new perspectives that may provide grounds for the discovery of as-yet-unidentified cognitive processes.

Although the range of psychological mechanisms associated to magic is vast, the present article only focuses on some of the most important ones. The first part of the article briefly examines some of the main studies on *misdirection* (for a more complete view see Kuhn, Caffaratti, Teszka, & Rensink, 2014) and introduces other psychological tools commonly exploited by magicians: *perceptual anticipation*, *patter* (i.e., specific use of words), *screens*, and the *pantomimic expertise* of magician. The second part of the article discusses a wide range of psychological facets of magic that are still to be explored.

Misdirection

During more than hundred years, magicians and researchers tried to establish a taxonomy of *misdirection* (Ascanio, 1964; Bruno, 1978; Fitzkee, 1945; Kuhn et al., 2014; Lamont & Wiseman, 2005; Randal, 1976; Robert-Houdin, 1877/2011; Sharpe, 1988). In a recent article, Kuhn et al. (2014) defined *misdirection* as magicians' ability to "manipulating the spectator away from the cause of a magic effect" (p. 1). According to these authors, misdirection covers a large panel of psychological principles and can be divided into three main categories: *perception*, *memory*, and *reasoning* (for more details about each categories, see Kuhn et al., 2014).

Ample research has been focused on the former (e.g., Barnhart & Goldinger, 2014; Kuhn & Findlay, 2010; Kuhn & Land, 2006; Kuhn & Tatler, 2005, 2011; Kuhn, Tatler, Findlay, & Cole, 2008), named *perceptual attentional misdirection* (Kuhn et al., 2014).

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Cyril Thomas, André Didierjean, François Maquestiaux, Laboratoire de Psychologie, Université de Franche-Comté; Pascal Gygax, Département de Psychologie, Université de Fribourg.

Correspondence concerning this article should be addressed to Cyril Thomas or André Didierjean, Université de Franche-Comté, 30 Rue Mégevand, 25030 Besançon, France. E-mail: cyril.thomas@univ-fcomte.fr or andre.didierjean@univ-fcomte.fr

Typically, magicians can manipulate "when" and "where" spectators will place their attention, the direction of their gazes, and their expectations to blind them to a so-called *secret* move. For example, in a series of studies by Kuhn and his collaborators, the authors showed participants a video of a magician using misdirection to make a cigarette lighter disappear (e.g., Kuhn & Findlay, 2010; Kuhn & Tatler, 2005; Kuhn, Tatler, et al., 2008; for a review, see Kuhn & Martinez, 2011). In the video, the magician holds the lighter in his left hand, lights it, and then pretends to grasp the flame with his right hand. While keeping his right hand closed, he gradually moves it away from his left hand. He then looks at his right hand and opens it, while at the same time discretely (but visibly) dropping the lighter (still in his left hand) onto his lap. The authors recorded participants' eye movements as they watched the video, and then analyzed what distinguished those participants who saw the "drop" from those who did not. The results showed that the detection of the secret move during the misdirection phase usually did not depend on the change in gaze direction (overt attention) but on the shift of attention (covert attention). In fact, the attentional shift preceded the gaze shift.

In another study on misdirection, Barnhart and Goldinger (2014) replicated and completed the previous results of Kuhn and colleagues (Kuhn & Findlay, 2010; Kuhn & Tatler, 2005; Kuhn, Tatler, et al., 2008). First, they showed that the detection of the secret move during the critical period depended on how appropriately participants deployed their covert attention. Second, unlike Kuhn and colleagues' (Kuhn & Findlay, 2010; Kuhn & Tatler, 2005; Kuhn, Tatler, et al., 2008) experiments, they showed that the detection of the secret move could be predicted by participant's eye movements, yet only if the secret move occurred during approximately 550 ms. Third and finally, their results showed that the secret move was more likely to be detected during the experimental trials when it was preceded by a repeated presentation of similar trials *without* the secret move. This was in line with the *perceptual load theory* (Lavie, 1995; Lavie, Hirst, de Fockert, & Viding, 2004), suggesting that the repeated experience of a primary trial (without the secret move) reduces the perceptual load of this trial, freeing attentional resources to detect the new distractor (the secret move) in the experimental trial. These results contradicted some magicians' hypothesis postulating that misdirection could well be preceded by visually similar nondeceptive actions to condition the audience to accept the sleight as a normal action (e.g., Fitzkee, 1945; Sharpe, 1988). In a series of experiments, Smith, Lamont, and Henderson (2012, 2013) even showed that misdirection in magic could also be used to enhance *change blindness* (e.g., O'Regan, Rensink, & Clark, 1999; for a review, see Simons & Rensink, 2005). According to Smith et al. (2013), magicians can create an attentional window within a dynamic scene, which can override stimuli competing for attention and even prevent detection of other salient visual changes near gaze fixations.

The difference between oculomotor behavior (overt attention) and attentional deployment (covert attention) is consistent with the literature on attention. In a study on *inattentional blindness* (for a review, see Mack & Rock, 1999), Pappas, Fishel, Moss, Hicks, and Leech (2005) tracked the eye movements of participants watching a short video of the famous experiment by Simons and Chabris (1999) in which a gorilla walks across the floor while human actors are passing a basketball. Their results showed that about half of the participants did not notice the gorilla even though it walked across the center of their visual field, while some other participants noticed the gorilla even when their gaze was not directed at it.

Is the phenomenon observed in misdirection tricks exactly the same as that described in psychology research on attention? Although some authors (see, e.g., Memmert, 2010) claim the specificity of the mechanisms at play in misdirection, the differences are probably too minor to see this as a new kind of psychological process (Barnhart & Goldinger, 2014; Kuhn & Tatler, 2011).

Still, an important issue for magicians is to understand what kind of tools can be used to create this perceptual attentional misdirection (Kuhn et al., 2014). A wealth of literature in psychology has shown that certain properties of a stimulus, such as motion, contrasting colors, and novelty, are likely to attract an observer's attention (e.g., Abrams & Christ, 2003; Cole & Liversedge, 2006; Franconeri & Simons, 2003; Yantis & Jonides, 1990). Once attention is captured, a shift of gaze toward the area of interest generally follows (e.g., Henderson, Pollatsek, & Rayner, 1989; Reichle, Pollatsek, Fisher, & Rayner, 1998). According to the magician Robbins (2007), illusionists know how to create an attentional frame for a short moment (primary zone of interest), in a way that everything that happens outside this frame (secondary zone of interest) is not detected by spectators. Attentional frames are very similar, if not identical, to Theeuwes's (1992, 2004, 2010) attentional windows, whose size varies with the task goal. For example, magicians often move their hand to capture spectators' attention, and their subsequent gaze, in what Kuhn et al. (2014) named *physical attentional misdirection*. During the brief instant when spectators' attention is captured by movement, they are blind to what the magician's other hand is doing (e.g., Otero-Millan, Macknik, Robbins, & Martinez Conde, 2011).

Magicians have also at their disposal another highly effective tool for creating misdirection: their own gaze (for other social misdirection cues, see Kuhn et al., 2014). Typically, the magician guides spectators' attention by looking themselves at a particular point in the surroundings, for example, at one of their hands (for the importance of social cues in misdirection, see Kuhn, Tatler, & Cole, 2009; Tachibana & Kawabata, 2014; Tatler & Kuhn, 2007). People's tendency to look at and focus their attention on the place looked at by a speaker has been widely studied in psychology (e.g., Driver et al., 1999; Mansfield, Farroni, & Johnson, 2003). This automatic shift of attention toward the place where others are looking was clearly demonstrated by Friesen and Kingstone (1998) using a standard cueing task based on Posner's (1980) paradigm. These authors presented their participants with a line drawing of a face whose eyes were either looking to the right, to the left, or straight ahead. Then a letter appeared on the left or right of face for a few hundred milliseconds. The participants' task was to quickly identify the letter. Although they were told that the face's direction of gaze did not predict the location of the target letter, the results showed that when the face's looking direction was congruent with the upcoming target letter's location, the participants identified the letter faster. In short, people's attention is automatically directed toward the place where others are looking. Magicians can use this principle to manipulate the audience's attention and direction of

gaze, even if those are inefficient (Cui, Otero-Millan, Macknik, King, & Martinez-Conde, 2011).

All of the studies on misdirection and magic have looked at tricks from a mental processing perspective, offering highly relevant illustrations of attentional mechanisms, as identified by cognitive psychologists. Although misdirection research has not yet unveiled any new psychological mechanisms, magic seems to offer an interesting ground for understanding attentional-processing limitations. As a matter of fact, although we only presented a subset of it (i.e., perceptual attentional misdirection), the new taxonomy of misdirection proposed by Kuhn et al. (2014) covers a large field of psychological principles.

In the following sections, we review additional psychological mechanisms at the very heart of magic, emphasizing both what has been already examined and what the development research may undertake for uncovering possibly new psychological mechanisms. Special focus is given on the different deception devices available to magicians, and their relation to known and/or unknown psychological mechanisms.

Other Psychological Devices in the Service of Magicians

Perceptual Anticipation

Magicians exploit various features of people's visual perception, including its anticipation capacity. To give itself more time to act, the perceptual system tends to anticipate what will probably be seen (for a review, see, e.g., Hubbard, 2005). A classic trick based on this phenomenon is the vanishing ball illusion. In this trick, the magician is seated behind a table. He or she throws a ball up in the air twice in a row and then pretends to throw it a third time while discretely dropping it onto his or her lap. Almost two thirds of the observers anticipate the third throw and actually believe they have seen the ball vanish into the air. This trick was first studied in the laboratory by Triplett (1900) and then by Kuhn and Land (2006) (see also Kuhn, Kourkoulou, & Leekam, 2010, for an extension of this studies with autistic participants).

Results habitually showed that participants in fact follow the third (nonexistent) throw with their eyes and *see* the ball disappear. Tracking participants' eye movements (Kuhn & Land, 2006) showed that participants did not fixate the place where they thought they saw the ball disappear: Their last fixations were much closer to the magician's hand than they had anticipated. Kuhn and Land's (2006) findings also revealed the large impact of the magician's gaze in this phenomenon: The anticipation worked even better when the magician himself watched the fictitious trajectory of the invisible throw compared with when he watched his throwing hand.

Kuhn and Land's (2006) results raised several interesting issues. First of all, they supported the idea that the magician's gaze is a powerful *social cue* that directs spectators' gaze toward an area of interest (Kuhn et al., 2009). Second, they confirmed the existence of a dissociation between the processes involved in the oculomotor system and those involved in perception itself, in line with Goodale and Milner (1992). Third and finally, they showed that the perception of a moving object is modulated by people's expectations, which aligns with psychology research on the *representational momentum*. The latter concept is defined as the tendency of observers to see the final stopping point of a moving object as displaced forward in the object's direction of motion (Freyd & Finke, 1984; for reviews, see Didierjean, Ferrari, & Blätller, 2014; Hubbard, 2005). Even if the size of the illusory forward displacement (i.e., the distance from the perceived end point to the actual end point) during the vanishing ball illusion task is indisputably higher—from the magician's hand to the top of the screen—than the one identified in the literature for most of the representational momentum tasks (several centimeters), an interesting question is probably the link and differences between the processes involved in the two tasks. It is interesting that a large amount of studies showed that representational momentum effect could be influenced by several factors, such as knowledge concerning *the target characteristics and the context*, knowledge of particular *physics laws*, participants' *attention* during the task, or participants' *expertise* (for reviews, see Didierjean et al., 2014; Hubbard, 2005). We believe that testing the impact of these different factors on the vanishing ball illusion could give researchers insight into the true link between the illusion and the representational momentum effect.

The Role of Patter

Quite naturally, magicians need to master certain language devices to guide the audience into believing in certain tricks. The most well-known language device for magicians is called *patter* (Kuhn et al., 2014). As Binet (1894a, p. 912), who was well aware of the importance of patter, mentioned: "There exists another artifice that makes the effect of a trick 10 times stronger, it is patter, a pleasant little speech through which the spectator's mind is oriented in the direction most favorable to the illusion" (p. 912). Wiseman and Greening (2005) conducted an experiment to study the impact of a magician's verbal suggestions on how spectators perceive magic tricks (for other studies about the role of suggestion during anomalous events, see also Bering, McLeod, & Shackelford, 2005, and Wiseman, Greening, & Smith, 2003). Participants watched a video of a magician who said that he was bending a key by the sheer power of his mind (in reality, he uses sleight of hand). After this first phase, the magician puts the bent key on the table, where the key remains, still, until the end of the video. Half of the participants watched the video with no sound; the other half watched it and heard the magician suggesting that the key was still bending on the table (which of course was not). The results showed that a significantly greater number of subjects saw the key continuing to bend among those who heard the verbal suggestion (40%) than among those who did not hear the suggestion (4%).

In terms of mental mechanisms, patter has probably several functions. For example, it could generate false memories in the spectators' minds (e.g., Loftus, 1997; Loftus, 1992; see also Lamont & Wiseman, 2001, for the Indian rope illusion). Wilson and French (2014) replicated Wiseman and Greening's (2005) experiment with an accomplice witness. Results showed that after watching video, when the accomplice witness suggested that the key was still bending, more participants reported that the key continued to bend on the table compared with a condition without witness or a condition with a negative suggestion (i.e., "the key did not continue to bend").

Patter may also play a role in misdirection (e.g., Kuhn et al., 2014), as it can, explicitly or implicitly, guide spectators' attention, expectations and hypothesis, to create a zone of low or high interest. For example, because of social codes such as politeness, spectators may look at the magician in the eyes, preventing them to focus their attention on the magician's suspicious hands. Magicians can also use jokes or suggestions to decrease or increase spectators' level of attention toward an object (for more details, see Kuhn et al., 2014). Only few of these language devices have been investigated in the area of psychology and magic. We believe that quantifying these devices may enable researchers to evaluate their efficiency, as well as their importance, individually or in combination, in misdirection or more generally in the magic act.

Although patter is generally used to implicitly or explicitly guide spectators' attention toward an action or an object, there might be two underlying, yet hypothetical, psychological bases that account for the role of patter in the control of spectators' load of attention. First, patter may globally overload participants' perceptual attention. In other words, when spectators focus most of their attention on patter, their remaining attentional resources are not sufficient to uncover any secret move. For example, asking spectators to memorize a number is an efficient way to reduce spectators' attentional resources. Second, the cognitive load generated by patter may induce focal attention to the magician's capture. Studies have indeed shown that the higher the cognitive load, the greater the attentional capture (e.g., de Fockert, Rees, Frith, & Lavie, 2001; Lavie et al., 2004). Consequently, misdirection will most likely be improved by patter.

In line with the consistent examination of the mechanisms underlying patter, one may examine the impact of suggestion with different types of participants, focusing on characteristics such as religion or paranormal beliefs. These characteristics may be most prominent in magic tricks such as the so-called *forcing* tricks (for various examples, see the section Forcing the Spectator's Choice) or perceptive tricks such as the illusory vanishing ball described earlier. This idea is based on research reporting a positive relationship between these beliefs and several different measures of suggestibility (e.g., Benassi, Singer, & Reynolds, 1980; Haraldsson, 1985; Wiseman et al., 2003).

The Use of a Screen

Beside those devices directly associated to the magician's behaviors, there are also visual devices that are commonly used to deceive spectators. Among them, visual occlusions can be used by magicians to momentarily prevent the audience from seeing an object or a manipulation needed to perform a trick. People's perceptual systems have a tendency to complete what they do not see, thus enriching their perceptual trace with elements that are not visible. This phenomenon has been studied in many in psychology, including those interested in *boundary extension* (e.g., Intraub & Richardson, 1989; for a review, see Hubbard, Hutchison, & Courtney, 2010). Research on boundary extension has shown that when individuals are exposed to a photograph, even if very briefly, perceptual traces are completed with elements that are not present in the photograph but are likely to be found in the area around it (see, e.g., Intraub & Dickinson, 2008). In magic, the process by which people complete what is presented to them (using their own knowledge) was examined by Barnhart (2010), who investigated various illusions based on the Gestalt principle of *good continuation*. This principle states that when two points or shapes are close to each other, they are first perceived as being continuous, in other words as extensions of each other. Barnhart's (2010) experiment made use of the "cut-and-restored" illusion in which a rope is cut and then put back together. Side by side in his right hand, the magician holds two pieces of rope that seem to be of equal length. He cuts each one at about a third of its length and then magically restores them as a single long rope. Crucially, in this illusion (see Figure 1), at the beginning of the trick, the magician is indeed holding two ropes, but they are not equally long and they are not actually placed side by side (Figure 1a). A short rope folded in half simulates the two upper ends of the two ropes, and a second, much longer rope, also folded in half, simulates the two lower ends of the two ropes. The folding point of both ropes is concealed behind the magician's hand. Aligned, the two different-length ropes folded in half give the illusion of two same-length ropes placed side by side (Figure 1b).

The rest of the trick relies on manipulations by the magician. The spectators do not suspect any artifice because they see two aligned objects close to each other and automatically assume the continuity of each rope (i.e., the law of good continuation). When an object is presented in an unusual or ambiguous way, people's perceptual systems will analyze the image in the simplest and most common manner (e.g., Pomerantz & Kubovy, 1986). Two continuous ropes of equal length are easier to picture mentally than two unequal folded ropes, though both contexts are hidden by the magician. According to Ekroll, Sayim, and Wagemans (2013), a key to understanding the impressive powerfulness and robustness of magical routines using screens or occlusions is the concept of *amodal volume completion* (e.g., Tse, 1999; van Lier & Wagemans, 1999). When part(s) of an occluded object or volume is (are) visible, the perceptive system can complete a global impression of the total object on the basis of probabilistic physics laws, yet can be influenced by a lot of factors as proximity, good volume continuation, or global context.

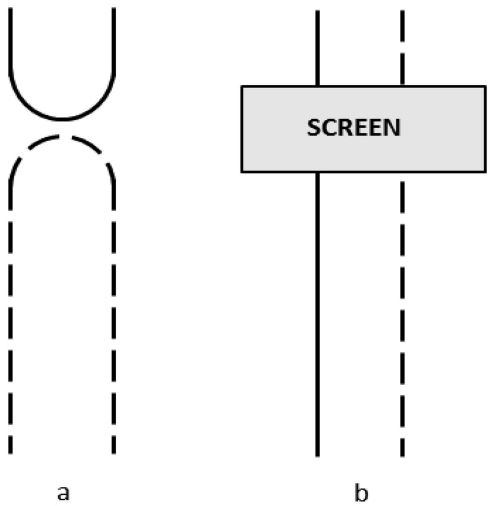

Figure 1. (a) The true positions of the two folded ropes, and (b) the audience's view of the cut rope when the screen (the magician's hand) is hiding the fold.

The screen (e.g., the magician's hand) can also be used to prevent participants to detect a change in identity of a coin during the magic trick. For example, Smith et al. (2012) showed participants a coin (e.g., a quarter) dropping on a table, for which they had to guess whether the coin would fall on its face or tail. One fourth of the coins were exchanged by the magician, very rapidly (approximately 325 ms), with another coin (e.g., a quarter is exchanged with a half dollar), in the magicians occluded hand. Most participants failed to monitor the change in identity of the coin, even if their eyes fixed the coin during most of the trick.

Screens in magic, which effect might be grounded on gestalt principles, may give researchers insight into the way people's systems complete scenes, even to the extent that they may do so in most irrational circumstances (e.g., having an uncut rope after having cut it).

The Pantomimic Expertise of Magician

Although we presented the preceding section as an illustration of visual occlusion in magic, they still truly depend on the magician's skills, as do all the tricks presented so far. It is important to note that these skills need a lot of practice, and may in turn depend on the magician's pantomimic competences.

In the past five years, a series of social network analysis and interviews of 120 Finnish magicians showed that magical expertise and the cultivation of its associated competences required a lot of practice, even if informal, and that pantomimic expertise was essential (Rissanen, Palonen, & Hakkariainen, 2010; Rissanen, Palonen, Pitkänen, Kuhn, & Hakkarainen, 2013; Rissanen, Pitkänen, Juvonen, Kuhn, & Hakkarainen, 2014). In other words, magicians need to act, fake, and simulate. Their expertise to do so is central to convincing an entire audience that they are holding, for example, a coin with the tip of their fingers, or a dove in their hands, when in reality this is not the case. The *French drop* trick perfectly illustrates this idea. In this trick, the magician pretends to grab a coin with his or her right hand while in fact keeping it concealed in his or her left hand. In this illusion, the magician must be careful to *grab* the coin in a way that looks like he or she is actually holding it.

The ability of magicians to simulate pantomimic gestures was examined in a study by Cavina-Pratesi, Kuhn, Ietswaart, and Milner (2011), who asked magicians and control participants to pretend they were picking up a rectangular object that varied in size. Two conditions were compared: a *visual-feedback* condition, in which the real object was visible to the participants, and a no-visual-feedback condition, in which the object was not visible. All participants were asked to make both a *normal* pantomimic gesture and an *unusual* one (i.e., picking up the object with one's little finger and thumb). The results showed that in the visual-feedback condition, when the object was visible, the magicians were significantly better than the control participants at making a gesture that resembled the real one. The gap between their fingers was very close to the one needed to actually pick up the object, whichever type of gesture was requested (i.e., normal or unusual). But in the no-visual-feedback condition, the magicians obtained very similar results to the controls. These findings suggest that magicians are not genuinely better than control participants at making pantomime movements but use the visual input coming from the real object nearby to make their visuomotor system carry out an action resembling the real one. In other words, magicians have the expert ability to use the same visuomotor programs as those used in the real world, but they can shift the action from the perceived object to another location in space. Practice at simulating real movements based on real visual input may allow magicians to develop greater flexibility in using visual information to control their actions. The study of pantomimic expertise among magicians is likely to offer some new research perspectives for gaining insight into the links between perception and action.

Additional Challenges for Magicians

To conclude this section on the psychological devices in the service of magicians, it is important to note that although magicians can easily fool novice spectators, one of their goals is also to fool other magicians. In fact, some magic tricks are only done between magicians. The underlying psychological constructs of these particular tricks are particularly interesting, both in terms of intellectual challenges as well as in terms of metacognition. For example, magicians may manipulate other magicians' suspicions to trick them. For example, as magicians know the *false coin transfer* principle, pretending to put a coin from one hand to the other while keeping it in the initial hand, a performing magician may purposefully *actually* really transfer the coin as magician spectators may focus their attention on the initial hand. The mental processes at hand are different here, and although they have never been studied, they may shed some interesting light into people's cognitive system limitations.

Conan Doyle's (1912) *Lost World,* Magic, and Psychology

Now that we have presented some of the issues that have been raised in the literature on magic and psychology, we depart from the studies that *have* been conducted to prospect those areas that researchers eager to study magic may also consider as possible research directions. We even argue that those areas may illuminate theories not only on magic and psychology but also on psychology in general. We believe that, very much like the expedition discovering new species in Conan Doyle's (1912) *Lost World*, magic should enable researchers to unravel new psychological processes that have been most often ignored so far. There is hardly any doubt that magic illustrates a much larger range of psychological properties than the ones presented so far, and in the following sections, we review some of the most promising areas that we believe deserve full attention.

Mind Setting

When confronted to an insight problem, there might be a providential instant when the solution comes to mind, with a feeling of surprise and obviousness, forming what has been called the "Aha!" experience (e.g., Gick & Lockhart, 1995, Ormerod, MacGregor, & Chronicle, 2002). Recently, some authors have started to investigate this "Aha!" experience associated to magic tricks (Danek, Fraps, von Müller, Grothe, & Öllinger, 2013; Danek, Fraps, von Müller, Grothe, & Öllinger,

2014a, 2014b). Results from these studies showed that the "Aha!" experience during the resolution of a magic trick involves a high emotional reaction, which might in turn facilitate the retention of insight solutions in long-term memory. In other words, if spectators understand the secret or the method behind a magic trick, they will maintain it in long-term memory. Magicians might be condemned to never show these spectators the same or a similar trick. Knowing this, the aim of the magician is to prevent this "Aha!" experience to occur. One possible way to do this would be to lead spectators into a similar experience, yet misplaced on a wrong solution.

According to one of the greatest 19th century magicians, Robert-Houdin (1868, p. 45), a key principle of magic is as follows: "One must never neglect anything that might contribute to distracting the spectator's mind. So when you are doing a trick, try to have its execution ascribed to any other principle than the one that produces it". Spectators often try to understand the method used to create an illusion. They usually attempt to mentally reconstruct the trick to discover the gimmick. For this, the illusionist can give false explanations of the trick, either has they perform it or afterward (Kuhn, Amlani, & Rensink, 2008; Tamariz, 1988). The basic idea here is that the presence of an incorrect solution in the spectators' minds will prevent them from finding the right solution. This is reminiscent of the *Einstellung* effect (Luchins, 1942) described in the *problem-solving* literature. Typically, when an idea comes to a person's mind—such as the false explanation of a trick—it becomes so salient that it is no longer possible for them to seek or find another solution. This kind of phenomenon has been well documented for the game of chess. In their studies on chess experts, Bilalić, McLeod, and Gobet (2008a, 2008b) presented experts with chess problems, one of which had two possible solutions for putting the opponent's king in checkmate. The first solution was a very familiar one; the second, not so familiar. The players' task was to find both solutions. The expert players found the familiar solution very quickly, but most failed to find the other solution. To show that it was indeed the salience of the first solution that prevented the experts from finding the second solution, the authors replicated the same experiment with a slight modification in the board layout that made the first solution impossible. This time, the players quickly found the unfamiliar solution they had not managed to see in the first version of the experiment. To better understand the mechanisms responsible for this phenomenon, Bilalić, McLeod, and Gobet (2010) recorded participants' eye movements. They noted that players who had found the familiar solution to the two-solution version of the problem were unable to dissociate from it. It was as if their eyes were irresistibly attracted to the elements involved in the first solution, and this prevented them from seeing the second. These results suggest that when a simple idea suffices to solve a problem, it is difficult to stop focusing on it and consider other less-familiar alternatives. Classical Einstellung effects require participants to have some level of expertise, or a lot of training, yet in magic tricks, magicians may quickly create sense of Einstellung effect (false solution tricks), without spectators needing any prior training or expertise. Likewise, during the Einstellung effect, a familiar solution prevents the activation a less familiar one. It is interesting to observe, and such a difference from the habitual Einstellung experience that deserve some attention, that during magic tricks, magicians can used anomalous or unfamiliar false solutions (e.g., "I can influence your choices with my mind") to prevent spectators to find an easiest and more normal or familiar solution ("the deck of card is rigged").

Creating False Causalities

Magicians often manipulate spectators by bringing them to establish causal links between events that follow each other (Macknick et al., 2008). When Event A precedes Event B, the mind often deduces that A is the cause of B, even "if it violated the expected causal relationships that form an implicit belief system about what is possible in the world around us" (Danek, Öllinger, Fraps, Grothe, & Flanagin, 2015, p. 1; for another fMRI studies about the causality violation during magic tricks, see Parris, Kuhn, Mizon, Benattayallah, & Hodgson, 2009). Evidence of this phenomenon has been found in *illusory correlation* studies in psychology (e.g., Chapman & Chapman, 1967). Magicians may intuitively know how to take advantage of these inferences (Teller, 2007). By suggesting a causal link between two separate events, they orient spectators' attention and make them blind to more discrete events. For example, a magician may explain that placing two coins under a card makes it possible for one of the two coins to disappear. When one of the coins has indeed disappeared, the audience assumes that the card is the cause of the disappearance. By implicitly suggesting that the card causes the coin to disappear, the magician shifts spectators' suspicions toward an irrelevant object (the card), which prevents them from focusing their attention on the relevant object, here, the rigged coin on the table. This trick may work well because, in analogy with the spatial gestalt principle of good continuation, when a suggested cause (the card) and an effect (the coin disappearing) are near in time, the mind naturally completes the bridge between these actions, creating an illusion of correlation. This is a tentative explanation, as understanding how magicians manage to create illusory correlations even with anomalous or unfamiliar cause-to-effect relations (e.g., Subbotsky, 2004) has largely been unexplored so far.

As a final note to false causality, a good illustration of the illusion of correlation is the magician concept of *multiple outs* (see Kuhn et al., 2014). According to this concept, regardless of spectators' choice, magicians have different ways to achieve a trick. For example, a magician may have an ace of heart turned face up in his deck of card, an ace of spade in his right pocket, an ace of diamond ink-tattooed on his right arm and an ace of clubs in the top of the deck. By asking any of the spectators to freely choose an ace, the magician has multiple choices, yet always leading spectators in believing in a unique causality effect. A better understanding of this *multiple-out* effect could lead researchers to better understand the processes by which people generate illusions of correlation.

False Memories

Memory plays an important role in magic tricks, especially in the misdirection act. For example, magicians can bias spectators' memories by manipulating several factors, such as increasing the delay between the trick procedure and the effect, or increasing the salience of a nonpertinent event (e.g., Kuhn et al., 2014). Some of

these processes mimic those associated to the psychological concept of *false memories* (for reviews about false memories, see Ayers & Reder, 1998; Loftus, 2005). For example, a magician may show an observer a deck of cards and ask him or her to cut the deck. Once the observer gives the deck back, the magician shuffles the cards, yet in a systematic way (i.e., a so-called false shuffle). Later, the magician may refer back to the initial sequence to create a false memory in spectators' mind by saying, for instance, "*You* shuffled the deck so I couldn't check to see where the cards were." The observer will remember that the deck had indeed been cut and shuffled, and in all likelihood, will not remember that it was the magician who had done the shuffling. Magicians often recount events that did not occur to influence spectators' memories (Kuhn et al., 2014), using devices generating memories in the same way that false memories are created (e.g., as extensively studied by Loftus, 2005).

Beyond their similarities, however, there are differences between the paradigms generally employed in false-memory research and those used in magic tricks. First, during a magic trick, spectators do not always settle for simply observing a scene; they may actively participate in the trick. The magician hampers with the memory of this real activity only a few seconds after it was carried out. To our knowledge, only few studies on false memories have had their participants take an active part in the phenomenon to be remembered. Second, in the majority of studies on false memories, it is a suggestion made a posteriori that causes the memory to deteriorate (e.g., Loftus, 2005). To our knowledge, no research in this domain has attempted to study the impact of an a priori suggestion on the future deterioration of a memory. Yet in a number of magic tricks, the false information (for instance, "you'll shuffle the deck") is given before the encoding stage of the trick.

Forcing the Spectator's Choice

As raised by Kuhn, Amlani, and Rensink (2008), one of the most commonly used tools by magicians is *forcing*, meaning, for example, forcing a card or an object onto a spectator. This magic principle has not been studied much in psychology. It is aimed at giving spectators the impression of being free to choose when in fact the magician influences the choice. For example, while riffling the deck, a magician may ask a spectator to remember one of 52 cards presented, the magician can clearly influence the spectator's choice by exposing the desired card for a (slight) longer amount of time than the others (Olson, Amlani, & Rensink, 2013). In fact, to illustrate this feeling of freedom to choose, a recent study by Shalom et al. (2013) showed that participants exposed to card-forcing feel as free to choose as when no forcing takes place.

This tool thus allows magicians to manipulate spectators' decisions while giving them the impression of being totally free to choose. According to Kuhn, Amlani, and Rensink (2008), magicians who want to amplify the forcing effect can create time pressure. By asking a spectator to pick a card quickly, the magician forces them to act in the most automated way. The psychological processes at play in certain kinds of forcing have still not been identified, but most likely involve mechanisms related to attention and decision making. Magicians can create an attentional focal point, such as a card that sticks out more than the others. This makes spectators highly likely to choose that card. Here, spectators are put in what Binet (1894b) in his study on magic called *least resistance*. The item chosen is often the one that involves the least amount of effort from the spectators.

Forcing a number or card may also be based on statistical knowledge of the most frequent choices. Binet (1894b) and Kubovy and Psotka (1976) showed that if a person is asked to think of a number between 1 and 10, 7 is chosen the most often. In line with these studies, Olson, Amlani, and Rensink (2012) studied the perceptual and cognitive characteristics of playing cards and showed that certain cards (e.g., the ace of spades) are visually more accessible, remembered better, and chosen more often than others. Making use of these statistics, magicians can increase their chances of knowing in advance what card spectators will choose among the 52 cards presented.

Certain magic tricks using forcing probably also rely on processes such as those involved in priming effects. In priming, exposure to a stimulus will affect the processing or production of another stimulus. According to the renowned magician Brown (2000), the choice of a card of a particular number or suit can be subject to a verbal or visual priming effect. In his book, the author explains that to force a card into spectators' mind (e.g., the three of diamonds), the magician can visually prime the number and the symbol of the three of diamonds using certain gestures. For example, to prime the *diamonds* symbol, the magician will delineate a diamond-shaped area with his fingers as he asks the spectator to think of a card. By implicitly activating the shape of a diamond in spectators' minds, the magician raises the probability that their choice will lean toward a card in the diamonds suit. A similar subtlety is used to force the number 3, for example.

According to Brown (2000), forcing can also be achieved by verbal priming. For instance, to force a card, the magician might talk to spectators about "making a mental picture of the card." This phrase could lead to the choice of a king, because the syllable [king] in the word *making* acts as a prime. It has never been done, and it would be interesting to experimentally test the effects described by Brown (2000), because they seem to involve a still poorly understood mental-influence technique based on a new type of priming, one that is more subtle and more implicit than those generally used in experimental psychology.

Creating a Rhythm to Affect Attention

Misdirection can occur in a defined space, but also in a defined timing (e.g., Fitzkee, 1945, as cited in Kuhn et al., 2014). Directing *when* spectators are looking is as important as directing *where* they are looking. It can be used to reduce spectators' attention during a secret procedure or to increase attention during the *magical* effect. Because spectators' attention fluctuates during a magic show, magicians can time a secret *procedure* to occur when spectators' attention is decreasing, often called *the moment* by magicians (e.g., Robert-Houdin, 1868). For example when a preceding trick has just ended, or when spectators think that it has not started yet. In these instances, a magician can easily make secret moves because the audience's attention is not focused on the magician. There are ways to facilitate *the moment*, by telling jokes for example or by specifically timing the effect when suspicion is

at its lowest (e.g., just after a trick has been performed). It is surprising that the role of timing during misdirection acts have not been much investigated, besides studies by Beth and Ekroll (in press) and Demacheva, Ladouceur, Steinberg, Pogossova, and Raz (2012).

Although never empirically tested, magicians have used other ways to generate *the moment*. For example, in a majority of great illusion shows, magicians align their magical effects to the beat of background music. This is reminiscent of research in psychology showing that inducing a tempo has an impact on attention. Indeed, according to dynamic attending theory (Jones & Boltz, 1989; Large & Jones, 1999), exposure to a musical rhythm causes attentional oscillation. Studies in this area have found evidence of synchronization between rhythmic beats and attention peaks. Rhythm is thought to induce attentional high points and low points, in such a way that perceptual events occurring during attention peaks are anticipated better (Ellis & Jones, 2010) and processed better (Abecasis, Brochard, Granot, & Drake, 2005; Brochard, Abecasis, Potter, Ragot, & Drake, 2003). In a study by Escoffier, Sheng, and Schirmer (2010), the authors found that participants discriminated faster if pictures of faces and buildings shown upright or inverted were presented on-beat. In line with this, magicians may make use of rhythmic beats to better control the attention peaks of spectators. During a misdirection trick, for example, the magician can amplify the attention-capturing effect by making a distracting movement that lands on-beat with the background music. Attention peaks would lead spectators to process the distracting movement more deeply and ignore other stimuli deemed less relevant. The misdirection technique no doubt offers fertile ground for studying the impact of rhythm on visual attention capturing in dynamic contexts.

Perceived Characteristics of Magicians

A lot of research in psychology shows that the way magicians are introduced can bias spectators' interpretation of anomalous events (e.g., Benassi et al., 1980; Mohr, Koutrakis, & Kuhn, 2015; Wiseman & Greening, 2005). Recently, Mohr et al. (2015) have shown that a magic tricks is interpreted as more paranormal if the magician is presented as a psychic instead of an illusionist. However, no study has tried, to our knowledge, to discover the impact of a magician's gender, charisma, age, or expected expertise in spectators' experience during a magic trick. According to Robert-Houdin (1868, pp. 252–259), an illusion presented by a young magician will be less powerful than an illusion presented by an old one, because spectators expect the old one to have more expertise in the domain of magic. If spectators expect the old magician to fool them, they may relax their attention because they know that the secret will be invisible.

As blatant as this may sound, other characteristics may be more difficult judge. For example, a magician's perceived skills may act as a double-edged sword. As stated by Robert-Houdin (1868, pp. 71–73), magicians should present all their tricks with simplicity and tranquility, because if they try to impress the audience, they will reveal their dexterity. Magicians showing lot of manipulations will impress the audience with their dexterity, but magical experience may be reduced because spectators will find a natural and physical cause (the manipulation) for every effect, and the impression of *impossible events* could be suppressed. Conversely, it is possible that magicians' dexterity is perceived in terms of expertise, and expected expertise may prevent the desire of researching the solution (as discussed above).

Empirical investigations of perceived magicians' characteristics may well unravel cognitive biases that have never been examined so far. The fact that perceived characteristics may fluctuate perceptual and attentional processes might give researchers new insight into the flexibility of these cognitive processes. Of course, perceived characteristics need not to be limited to expertise, or age, as other factors, such as gender (or perceived gender), may well be of great interest, especially that magic has been mainly investigated by male magicians. In terms of spectators, in a recent article, Olson, Demacheva, and Raz (2015) showed that the perception of a magic trick (making a pen vanish) depended of spectators' age and gender. Younger children (4–7 years old) found more supernatural explanations for the tricks, compared with the older ones (for other articles about the perception of magic by children, see Chandler & Lalonde, 1994; Johnson & Harris, 1994; Phelps & Woolley, 1994; Subbotsky, 2004) and men seemed to be more confident in their explanations (even if they were wrong) compared with women. This latter fact is interesting, as socially constructed norms may well creep into perceptual processes.

Perceptive Illusions

A large amount of magical tricks are based on perceptive illusions. These illusions result from *amplification*, *suppression,* or a *combination* of some visual information (e.g., Macknik, Martinez-Conde, & Blakeslee, 2010). For example, in the rubber pencil illusion (Pomerantz, 1983; Thaler, Todd, Spering, & Gegenfurtner, 2007), the magician holds a pencil, and with a combination of a translation and a rotation moves at a specific frequency, and the rigid pencil seems to be rubbery. The cause of this perceptive illusion is the incapacity for spectators to follow precisely the move of the pencil combined with simultaneous and quick changes in space and time. Consequently, the brain, having to process different images at the same time, encodes only the most salient form of this combination: a wavy form (for another illusion using the same kind of principle, see Hergovich, Gröbl, & Carbon, 2010). This illusion perfectly illustrates how magicians can bias low levels of perception by combining several moves at a certain speed and frequency.

As discussed earlier with *the vanishing ball illusion* (Kuhn & Land, 2006), high-level mechanisms, such as *expectation*, can also create impressive perceptive illusions. The magicians' technique called *flushtration count* is another good illustration of such high-level mechanisms. In this technique, the magician seems to show, one by one, four same cards (example, four 6s of heart), but in fact, the four cards are different, as only one 6 of heart composes the deck of four cards. For this trick, the magician keeps the four cards face down in his left hand, and when they peal the top card of the deck (face down), instead of showing the face of this card, he or she shows the face of the bottom card of the remaining three card deck, and he or she drops the pealing card face down on the table. Spectators never saw the face of the pealing card. For the rest of the trick, the magician does the same thing three times for the three remaining cards. The processes associated to this trick are so robust that it can be done slowly. However, if you give spectators

a deck of four cards face down and you ask them to show one by one the four cards of the deck, they will peal the first one, showing its face, drop it on the table, and do the same for the three remaining cards. Although the latter procedure is different than that performed by the magician, they still fail to notice the difference. This perfectly illustrates the processes by which unnatural or unfamiliar moves are still perceived as natural or familiar, which investigation would provide researchers with great insight into the extent to which people try to maintain a coherent representation of familiar events.

Conclusion

So far, cognitive processes associated with magic have been found to mimic those identified in other domains of psychology. In this article, we argue that magic, in its complexity, or richness, illustrates a much larger range of psychological properties than the ones that have been studied so far. These properties may enable researchers to unravel mental processes that have not yet been studied, inside or outside the magic realm.

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