Exploring Psychology with Magic: Decision-making and Cognitive Development

Jay A. Olson

Psychiatry Department
McGill University
Montréal

March 2015

A thesis submitted to McGill University in partial fulfillment
of the requirements of the degree of
Master of Science in Psychiatry.

Contents

Abstract

For millennia, magicians have amazed audiences and developed intuitions about the mind. More recently, scientists have started testing these intuitions to learn more about psychology. This thesis comprises two such studies on the psychology of magic. The first explores *forcing*, which occurs when a magician influences the audience's decisions without their awareness. To investigate the mechanisms behind this effect, we examined several stimulus and personality predictors. In Study 1, a magician flipped through a deck of playing cards while participants were asked to choose one. Although the magician could influence the choice almost every time (98%), relatively few (9%) noticed this influence. In Study 2, participants observed rapid series of cards on a computer, with one target card shown longer than the rest. We expected people would tend to choose this card without noticing that it was shown longest. Both stimulus and personality factors predicted the choice of card, depending on whether the influence was noticed. These results show that combining real-world and laboratory research can be a powerful way to study magic and can provide new methods to study the feeling of free will.

In the second manuscript, we examine developmental differences in cognition by studying how children and adults explain magic tricks. We showed 167 children (aged 4 to 13 years) a video of a magician making a pen vanish and asked them to explain the trick. Although most tried to explain the secret, none of them correctly identified it. The younger children provided more supernatural interpretations and more often took the magician's actions at face value. Combined with a similar study of adults (N=1008), we found that both young children and older adults were particularly overconfident in their explanations of the trick. Our methodology demonstrates the feasibility of using magic to study cognitive development across the life span. In addition to these manuscripts, we outline views on the science of magic based on a survey of over a hundred

magicians. Combined, these studies demonstrate the usefulness of magic — both as a subject of study and as a method — to reveal more about the mind.

Résumé

Les magiciens émerveillent et fascinent les foules grâce à leurs intuitions de la psyché humaine. Les scientifiques ont récemment commencé à explorer ces intuitions afin de mieux comprendre la psychologie humaine. Cette thèse inclut deux études sur la psychologie de la magie. Dans un premier temps, nous examinons le phénomène de *forcing* qui se produit lorsqu'un magicien influence les décisions de l'auditoire à leur insu. Cette première étude vise à mieux comprendre les mécanismes psychologiques sous-jacents à ce phénomène. À cette fin, nous avons évalué différents facteurs liés à la personnalité et manipulé certaines variables relatifs à la présentation de stimuli. Cette étude a été complétée dans deux contextes écologiques différents: dans le monde réel, puis en laboratoire. Dans le monde réel, un magicien demandait aux passants dans la rue de choisir une carte parmi l'ensemble qu'il leur présentait très rapidement. Bien que certains participants aient été conscients de l'influence du magicien (9%), ce dernier a réussi à influencer le choix des participants dans une très grande proportion (98%). Dans le laboratoire, les cartes étaient présentées rapidement de façon sérielle sur un écran d'ordinateur. La carte-cible demeurait à l'écran plus longtemps que les autres cartes présentées. De la sorte, nous avions prédit que les participants choisiraient la carte-cible sans avoir conscience de la manipulation. Nos résultats montrent que les facteurs relatifs à la présentation de stimuli et à la personnalité prédissent le choix des participants dans la mesure où ceux-ci ont conscience de la façon dont leur choix a été influencé. Ensemble, ces deux expériences démontrent que l'exploration scientifique des phénomènes dans le laboratoire et le monde réel représente une stratégie efficace pour mieux comprendre la psychologie de la magie. Cette approche soumet également de nouvelles avenues méthodologiques pour étudier le sentiment du libre-arbitre.

Dans notre seconde étude, nous comparons la façon dont les enfants et les adultes interprètent et

expliquent les illusions visuelles lors des tours de magie. Cette étude vise à mettre l'emphase sur certaines différences cognitives d'un point de vue développemental. Les participants étaient invités à regarder une vidéo puis la commenter. Cette vidéo montre un magicien faisant disparaître un stylo. Les participants devaient alors expliquer cette illusion. Aucun enfant (N=167, âgé entre 4 et 13 ans) n'a pu expliquer le tour de magie correctement. Les plus jeunes ont notamment fait usage d'explications faisant référence au surnaturel, de même qu'ils ont souvent pris les actions du magicien pour acquis, c'est-à-dire sans user de sens critique. En comparant nos résultats avec ceux d'une étude similaire faite sur des sujets adultes, nous observons que le niveau de confiance des adultes dans leur explication est similaire à celui des enfants. Notre méthodologie démontre qu'utiliser la magie pour étudier le développement cognitif pendant une durée de vie est réalisable. Finalement, en plus de ces deux études, nous examinons la science de la magie à partir d'un sondage auprès de plus de cent magiciens. Ensemble, ces études démontrent l'utilité de la magie — à la fois comme un sujet d'étude et comme une méthode — pour avancer nos connaissances sur l'esprit humain.

Acknowledgements

First, I'd like to thank my advisor, Amir Raz, for letting me do any project I want even when he thinks (or knows!) it is a bad idea. I'd also like to thank Ronald Rensink, my previous advisor, for guidance that extended beyond the academic world.

Several people helped with experimentation: Kevin Ho, Martin Ladouceur, Galina Pogossova, Ramyar Sigarchy, and Chris Port. Chris and I used to spend summer days wandering the streets of Vancouver, stopping pedestrians, and convincing them to participate in magic studies. Thanks to Mathieu Landry, Chloé Lespérance, Diana Sitoianu, and Julia Yudova for translating the abstract.

Over the past four years, many people have given ideas or feedback which shaped the present research. These include Tony Barnhart, Mélanie Bolduc, Vince DiLollo, Craig Fox, Chris French, Thomas Fraps, Gustav Kuhn, Jeanie Kushnir, Mathieu Landry, Hakwan Lau, Zenon Pylyshyn, Brian Scholl, Shin Shimojo, Daniel Simons, Teller, and Julia Yudova. Also thanks to Shawn Farquhar, Steve Dickson, and numerous other magicians for teaching me how to perform and consequently planting many ideas for future research.

And of course, thanks to my parents, sister, and lady friends for putting up with years of my psychobabble, the smallest portion of which was coherent.

Author contributions

In Chapter 2, I designed the experiment, analysed the data, and wrote the manuscript; Alym Amlani was involved during the pilot testing; Amir Raz helped with manuscript revisions; and Ronald Rensink helped with the design, interpretation, and writing. In Chapter 3, Amir Raz and

I created the questionnaire then I analysed and described the data. In Chapter 4, I wrote the manuscript and analysed the data, Irina Demacheva designed the experiment and helped with the writing, and Amir Raz helped with the design and manuscript revisions.

1. Introduction

Magicians are like scientists. While performing, they develop and test intuitions about how the audience thinks (Rensink & Kuhn, 2014; Teller, 2012). Magicians experiment with different permutations of tricks — either deliberately or due to unexpected events while performing — to refine the effects. These intuitions and refinements spread to other magicians who further extend the tricks. In the end, just as the scientist builds a refined theory with specific predictions, the magician develops an elegant performance to predictably amaze audiences. Magicians have succeeded at this goal: many tricks, carefully performed, produce robust effects across varied ages and cultures. The body of wisdom enabling such effects has evolved for millennia before psychology became a discipline.

Little of this wisdom has been tested scientifically. Although magicians know how to fool audiences, they rarely know *why* their tricks work (Rissanen, Pitkänen, Juvonen, Kuhn, & Hakkarainen, 2014). A magician can make a coin vanish by manipulating the audience's attention and expectations without understanding the underlying psychological mechanisms. Still, much of the pragmatic folk psychology that magicians have constructed is likely accurate or at least informative to study.

Researching magic has several advantages (Kuhn, Amlani, & Rensink, 2008; Rensink & Kuhn, 2014). Magic produces larger and more consistent effects than are typical in psychology. Since magic tricks work in various environments, translating from stage to laboratory often retains much of the effect (e.g., Kuhn & Tatler, 2005; Olson, Amlani, Raz, & Rensink, 2015a). So far, magic and experimental psychology have progressed in parallel but largely independently; their interaction could reveal new insights for both magicians and scientists (Kuhn et al., 2008). This thesis demonstrates the usefulness of magic both as a subject and experimental method to advance

our knowledge in psychology.

The thesis has three parts. In Chapter 2, I present the manuscript *Influencing Choice Without Awareness* with co-authors Alym Amlani, Amir Raz, and Ronald Rensink.[1] We studied how magicians influence audience's decisions without their awareness. First, we examined this influence in a real-world environment using a card trick, then we attempted to isolate its mechanism in the laboratory. In Chapter 3, I summarise over a hundred magicians' views on the science of magic using an online survey we conducted. Finally, in Chapter 4, I present the manuscript *Explanations of a Magic Trick Across the Life Span* with co-authors Irina Demacheva and Amir Raz.[2] We used magic as a method to test predictions in developmental psychology. Children and adults watched a video of a magician making a pen vanish and then attempted to explain it; the explanations matched predictions about their cognitive development. Combined, these manuscripts demonstrate the usefulness of studying magic to explore the mind.

[1] Published as Olson et al. (2015a).
[2] Published as Olson, Demacheva, & Raz (2015b).

2. Decision-making

People make innumerable decisions every day. Although rational considerations often shape these decisions, subtle situational factors can also play a significant role. For example, the order of items can influence everything from food choices to donor compliance (Thaler & Sunstein, 2008). Despite such influences, however, people generally feel they have full conscious control over their choices (Wegner, 2003).

Previous studies have examined many of the subtle factors that influence decisions in everyday life. For example, moving food to a less convenient location reduces its consumption (Rozin, Scott, Dingley, Urbanek, & Kaltenbach, 2011), as does eating off of smaller (Wansink, 2007) or coloured plates (Bruno, Martani, Corsini, & Oleari, 2013). Even simply being asked to memorise a long number makes one more likely to choose cake over salad (Shiv & Fedorikhin, 2011). Although these situational factors reliably influence behaviour, most people disregard them and instead claim to have made the decision freely (e.g., Wansink & Sobal, 2007).

To study this feeling of free choice in the presence of an objective influence, one needs a method to influence decisions in a powerful yet subtle way. Magic offers one such possibility — *forcing* — which occurs when the magician influences the decisions made by the audience, without their awareness (Kelley, 1980; Kuhn et al., 2008). For example, 'pick a card' tricks often depend on the audience feeling that they have a free choice of card, although in reality the magician controls this decision.

Magicians commonly use two types of forcing. *Physical* forcing involves manipulating an object to make particular outcomes more probable. For instance, spreading a deck of cards in a certain way can make spectators more likely to choose a card in the middle rather than in other positions. In contrast, *mental* forcing exploits psychological tendencies. For example, asking someone to choose

any tool or any playing card tends to bring predictable candidates to mind, such as a hammer or the Ace of Spades (Banachek, 2000; Olson, Amlani, & Rensink, 2012).

Despite the magician's influence, spectators generally feel that they have a completely free choice. In other words, they can have subjective free choice without objective free choice. Although many scientists and philosophers have examined objective free choice (e.g., Libet, Gleason, Wright, & Pearl, 1983), relatively few have studied its subjective counterpart (Filevich et al., 2013; Wegner, 2003). Here we examine the subjective feeling of free choice in conditions where forcing has imposed constraints on selection.

Forcing in magic can be more precisely defined as increasing the probability of a particular outcome of a decision, without one's awareness of the influence. It differs from social persuasion, which is usually less discreet; a salesperson, say, can be quite overt when persuading someone to buy a product. It also differs from the use of *nudges* (Thaler & Sunstein, 2008) which attempt to shape decisions while maintaining objectively free choice.

The present study examines forcing in the context of the *visual riffle force*, in which the magician flips through a deck while the spectator visually selects one of the cards. Using a combination of physical and psychological forcing that we call *salience forcing*, the magician makes one card more salient than the rest which then causes the spectator to choose it.

One previous study has tested salience forcing (Shalom et al., 2013). A magician performed a visual riffle force and showed one card longer than each of the rest; about half (45%) of participants chose that card. In a second condition, participants watched videos of a magician riffling cards and were asked to choose a card from each video. People tended to choose the cards that were presented the longest (21%) or were in the last position of the series (15%). The present study extends these findings to determine which factors explain salience forcing.

Our investigation proceeds in two stages. Study 1 tests salience forcing in an environment intermediate between the stage and the laboratory. Study 2 examines a more abstract and controllable version of this method in a conventional laboratory. Together, these studies combine the realism of performance with the power of controlled experiment to explore the mechanisms underlying subjective free choice in the presence of objective influences.

2.1 Study 1: Salience forcing in an intermediate environment

In a magic performance, many situational factors influence spectators, such as the personality of the magician, expectations created by the setup, and pressures to conform (e.g., Demacheva, Ladouceur, Steinberg, Pogossova, & Raz, 2012; Kuhn & Martinez, 2012). Thus, if an effect fails to occur in the laboratory, it is difficult to tell whether the failure was due to some characteristic of the experiment or to these situational factors. By testing the effect in an intermediate environment, we could minimise contextual factors like expectations and pressures while still reproducing the salience forcing that magicians use on stage.

2.1.1 Methods

A professional magician (co-author J.O.) approached student-aged individuals or small groups on university campuses and on the streets of Vancouver, Canada. He asked them if they would like to participate in a brief psychology study. A total of 119 were approached; all but one participated.

The magician took out a deck of Bicycle Playing Cards (United States Playing Card Company, Erlanger, KY). He spread the cards and ensured that the participant knew the names of the different suits (i.e., Spades, Hearts, Clubs, and Diamonds). The magician then asked the participant to choose a card by glancing at one as he flipped through the deck. He raised the deck to just under the participant's eye level and riffled through it (see Figure 2.1). The entire riffle took around half a second. One of the cards — the *target card* — was intentionally shown longer than the rest; it was likely the only card that was clearly visible. In each trial, the target card was either the Two of Clubs, Ten of Clubs, or Ten of Hearts. None of these cards were extreme on any of their perceptual or cognitive properties such as visibility or memorability (Olson et al., 2012); thus, any effect would likely be due to the duration of their presentation. The magician then asked the following questions, waiting for each answer before moving on to the next:

1. Which card did you choose?
2. Did you feel that you had a free choice of any card, or did you feel that I influenced you to choose any particular card?

3. [For the last 64 participants:] Why did you choose that card?

The magician then revealed the selected card in an unexpected location (e.g., in his pocket) and subsequently debriefed the participant.

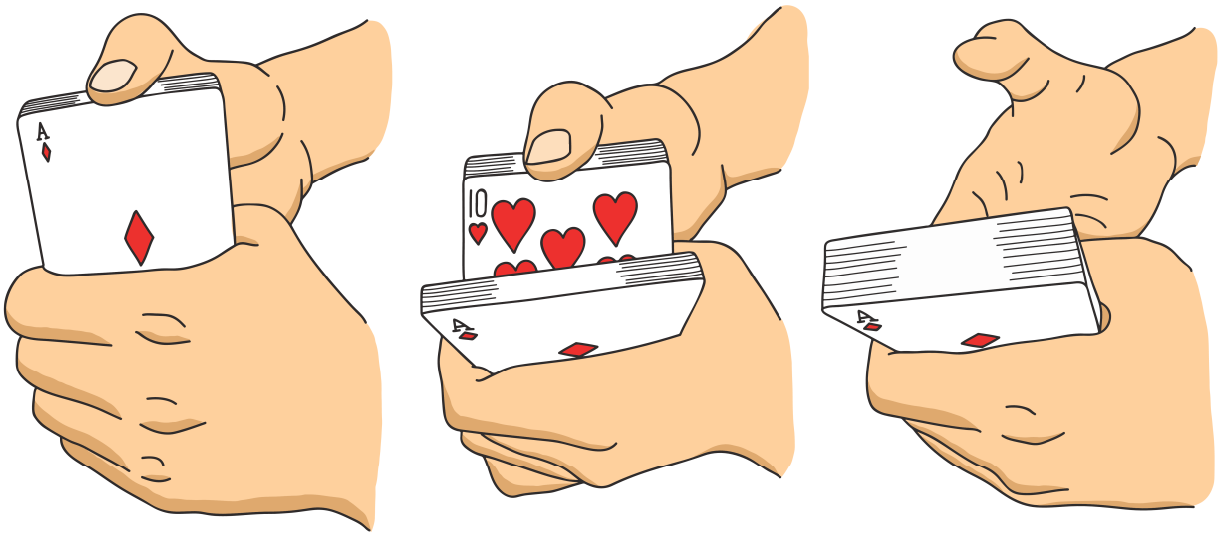

Fig. 2.1 The magician riffled through a deck while the participant visually chose a card. The cards were each visible for different lengths of time, but the target card (here, the Ten of Hearts) was shown longer than the rest.

To reduce confusion, the deck never contained the target's *pair card*, the card of the same value and colour. When the Ten of Hearts was the target, for example, the deck lacked the Ten of Diamonds. Thus, we could count those who chose the pair card (8%) as having chosen the target, since presumably that was their intention.

For each day (of ten) of data collection, the first participant was considered a practice trial and was excluded. The magician made a mechanical error on three of the trials so these were excluded as well. The analyses were thus run on a set of 105 trials.

2.1.2 Results and discussion

Participants told the magician (a) which card they chose, (b) whether it felt like a free choice, and (c) why they selected that card.

2.1.2.1 Chosen card

Almost all (98% [93%, 100%][1]) participants chose the target card. The two who chose other cards were run on the first day of data collection and could reflect an unnoticed mechanical error by the magician. This forcing rate exceeded one previously reported (45%; Shalom et al., 2013) likely because we showed the target card for a relatively long duration.

2.1.2.2 Subjective free choice

Of the 103 who chose the target card, the large majority (91% [82%, 95%]) reported feeling that they had a free choice. Of the 10 who did not, 2 reported feeling suspicious about the task without necessarily noticing the influence. One participant, for example, said the situation looked like a magic trick so she probably was being influenced.

2.1.2.3 Reasons for choice

Of the participants who chose the target, 61 were asked why they chose that card. Most (52%, $n = 32$) reported that they had no reason. Of the remainder, 38% ($n = 11$) reported that they clearly saw only one card and 28% ($n = 8$) said that their card "stood out". The remaining 34% ($n = 10$) provided *confabulations*, inaccurate post-hoc attempts to explain their decisions (cf. Johansson, Hall, Sikstrom, Olsson, & Sikström, 2005). Most ($n = 8$) said they chose the card because it had a bright colour; this explanation was given even when the card was black. One participant claimed that she chose the target (the Ten of Hearts) because "hearts are a common symbol and the red stood out". Another claimed to choose that card because she had been thinking of hearts before the trick began. Note that all of the target cards had only average levels of memorability and visibility.

In short, the vast majority chose the target card without being aware of the salience forcing, and many confabulated their explanation of why they chose that card.

[1] Square brackets throughout denote 95% confidence intervals (see Cumming, 2014).

2.1.2.4 Limitations

Our methodology had two potential limitations. First, the measurement of participants' awareness of the influence may have been somewhat unreliable. For example, some participants could have been unaware of the influence until they were asked about it. Still, given the low noticing rate, this could only have occurred for a small minority of participants; moreover, this would only cause an underestimate of the effectiveness of the force.

Second, demand characteristics may have led participants to comply with the researcher. During debriefing, several participants reported feeling nervous and pressured throughout the experiment which may have increased compliance. We tried to reduce compliance in several conditions by changing the experimenter's behaviour, appearance, or procedure. Yet, whether the magician acted in a dominant or relaxed manner, whether he dressed more formally or casually, and whether he or a research assistant asked the questions, the influence and subjective free choice rates remained high.

In summary, this study confirms what magicians have long known: the subjective impression of a free choice can dramatically dissociate from reality. To further examine the factors involved, Study 2 attempted to reproduce this effect in a more controlled manner.

2.2 Study 2: Salience forcing in the laboratory

Having established the reliability of forcing in an intermediate environment, we next studied it under more controlled laboratory conditions. In particular, we wanted to determine the extent to which stimulus and personality factors may affect it. For example, playing cards have a range of perceptual and cognitive characteristics. Some of these — such as the visibility of a card — may affect how often it is chosen. To measure visibility, participants searched for a given card as a series of them appeared on a computer; we averaged then compared the results for each card (Olson et al., 2012). For instance, the Ace of Spades was the easiest to perceive and remember in a rapid series, with its unique pip (spot) and markings. We used similar procedures to measure other characteristics of cards. Here we investigate five of them:

- *visibility*, how easily a card is discriminated from others in a rapid display;
- *visibility bias*, the bias in declaring the card absent in a detection task, wherein a higher bias means more likely to declare the card absent (this is independent of how visible the card is; cf. Green & Swets, 1966);
- *memorability*, how easily the card is remembered in a slower display;
- *memorability bias*, the bias in declaring the card absent when remembering (this is independent of memorability); and
- *likeability*, how often the card is preferred relative to others.

We predicted that cards with higher visibility and memorability (d' in Signal Detection Theory) would be chosen more often, since they would have a greater effect on perception and memory. We also predicted that cards with lower bias (c) would be chosen more often, since they have a lower threshold for being declared present.

We also examined personality characteristics. Some magicians believe certain people are more susceptible to magic tricks involving forcing, such as opposite-sex participants or those in a particular age range. We examined two personality measures that may predict salience forcing:

- *Locus of control* is the amount of control one believes to have over one's life (Duttweiler, 1984). People with an internal locus tend to believe in responsibility and autonomy; those with an external locus tend to believe in luck and fate.
- *Transliminality* is the threshold for stimuli to enter conscious awareness (Lange, Thalbourne, Houran, & Storm, 2000). People with higher transliminality respond to more subtle internal and external stimuli, such as fleeting thoughts or faint smells, near the threshold of conscious detection. Transliminality measures openness to experience, warmth, absorption, and magical beliefs.

We predicted that people with a more external locus of control would be easier to influence. Presumably those who *feel* that external factors control their lives would more likely let such factors influence their decisions. We also predicted those with high transliminality would be more sensitive to the target and thus more easily influenced. A previous study found that people with high transliminality were better able to identify briefly-presented playing cards (Crawley, French,

& Yesson, 2002); since we had similar stimuli and procedures we expected a similar effect.

2.2.1 Methods

We recreated a simple version of the visual riffle force using a series of images of cards sequentially presented on a computer. Participants were asked to watch this sequence and silently choose one of the cards then enter it at the end of the trial. Each trial contained one target card shown about three times longer than the rest. Based on the results of Study 1, we expected that participants would often choose this card without noticing that it was shown longer. At the end of the experiment, we probed whether participants were aware of this influence.

2.2.1.1 Participants

Fifty-two undergraduates completed the experiment for course credit or money. All had normal or corrected-to-normal vision. Nine participants did not complete all of the questionnaires in the study and so were excluded. Thus, our final sample comprised 43 participants.

These participants were most often female (70%), 23 years old ($SD = 3.2$), and spent most (Mdn = 75%) of their lives in Canada. They primarily spoke (74%) and wrote (65%) English, spent 5.9 hours on the computer each day ($SD = 3.6$), and used glasses or contacts for vision correction (74%).

2.2.1.2 Materials

The experiment used the same deck of cards as in Study 1, but scanned and displayed on an Apple eMac G4/700 (Cupertino, CA, USA). The computer setup resembled the one described by Olson et al. (2012). The experiment was coded in GNU Octave 3.2.3 (Eaton, Bateman, & Hauberg, 2008) with Psychtoolbox 3.0.9 (Brainard, 1997). Statistics used R 3.1.2 (R Core Team, 2014) with the ggplot2 1.0.0 (Wickham, 2009) and lme4 1.1-7 packages.

2.2.1.3 Procedure

Participants signed up through the participant pool to complete a task ostensibly involving telepathy. The experimenter did not explain anything about telepathy but simply told the participant that this would be explained afterwards. Neither the experimenter nor the task instructions mentioned magic. We framed the task in this way because an unpublished study found that participants were more sceptical of magic tasks than telepathy ones (O. Crofton, 2010, personal communication).

2.2.1.3.1 Personality measures Next, participants filled out questionnaires measuring demographics, locus of control, and transliminality. Locus of control was measured with the Internal Control Index (Duttweiler, 1984), a 28-item paper questionnaire. An example item is: "I always like jobs where I can make my own decisions and be responsible for my own work." A higher score (maximum: 140) indicates a more internal locus; a lower score (minimum: 28) a more external one. This scale usually has fairly high internal consistency reliability (Cronbach's α = .84; Duttweiler, 1984); it was slightly lower in our sample (.79). Participants had an average Internal Control Index of 85.31 ($SD = 10.54$).

Transliminality was measured with the Revised Transliminality Scale, a 29-item true-false paper questionnaire (J. Houran, Thalbourne, & Lange, 2003; Lange et al., 2000). An example item is: "I have gone through times when smells seemed stronger and more overwhelming than usual." Labelling this statement 'true' would increase the transliminality score and would suggest higher sensitivity — that more near-threshold material enters awareness. The scale has fairly high internal consistency reliability (Cronbach's $\alpha = .82$; Lange et al., 2000); it was lower in our sample (.67). Participants had an average Revised Transliminality Scale score of 6.46 ($SD = 3.11$). This measure was unrelated to the Internal Control Index ($r = -0.02$).

2.2.1.3.2 Behavioural measures At the beginning of the task, the computer gave the following instructions: "You will see a series of playing cards. Choose *any* one you want. Stare at the cross at the beginning of the trial. If you don't know, guess." The participants then completed 28 trials (see Figure 2.2 for an overview).

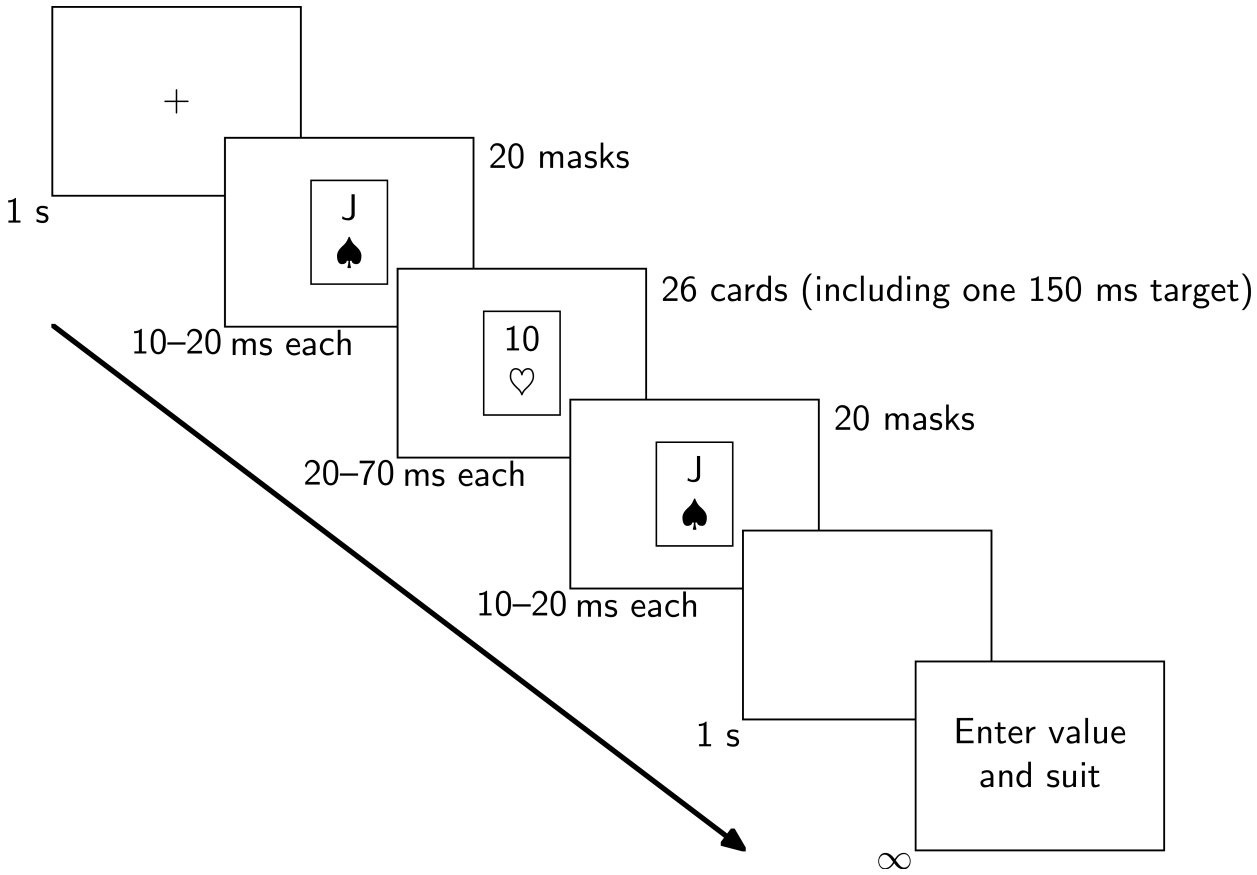

Fig. 2.2 Design of each trial.

Each trial began with a 1-second fixation cross centered at where the top left pip of the playing card would appear. Ten masks consisting of random coloured squares then appeared for 20 ms each, followed by ten playing card masks for 10 ms each. The latter consisted of cards not displayed in the main series. All were presented with a 0 ms inter-stimulus interval.

A main series of 26 cards then followed. Each of the 25 non-target cards was displayed for a random duration of 20 to 70 ms, and the target for 150 ms.[2] The whole series (including the masks) required approximately 1.7 s. The target card appeared at a random position in the series, counter-balanced across the first and last half. It never appeared in the first or last four positions in case these were less adequately masked. The target differed each trial but each participant saw

[2]Pilot studies found these durations effective for salience forcing on a computer, though they diverged somewhat from the durations used in Study 1.

the same set of targets; trial order was balanced with a Latin square.

After the main series, ten cards followed by ten random-square masks provided backwards masking. After a 1 s blank screen, participants entered the value and suit of the card they chose; this became the main dependent variable.

We used 28 possible target cards, selected to create a high range of values on each stimulus factor (see Table 2.1). For example, for likeability, two cards (Q♠, 2♡) were highly liked and two (2♢, 7♢) were liked relatively little. (For the values of each card, see Olson et al., 2012.) Non-target cards were selected randomly in each trial and generally had intermediate values on these measures.

Factor	Target cards
Visibility	K♠, 7♡, 2♣, 8♢
Visibility bias	2♠, 3♠, 6♡, 3♣
Memorability	4♡, 8♡, 9♡, A♣
Memorability bias	7♠, 8♣, J♢, K♢
Likeability	Q♠, 2♡, 2♢, 7♢
(Other target cards)	5♠, J♠, 5♡, 5♣, A♢, 3♢, 5♢, 9♢

Table 2.1: Stimulus factors and target cards. Each set of cards showed a high range of values on the factor.

After 28 trials — one for each target — participants completed another questionnaire (Table 2.2) which probed whether they were aware that one card was shown longer than the rest. The participants classified as *aware* either spontaneously reported that one card was shown longest (Question 1 or 2) or stated that they noticed that one card was shown longest after they were asked (Question 6). We decided on this operationalisation before analysing the data (cf. Simmons, Nelson, & Simonsohn, 2011). Three participants responded ambiguously to Question 6 and so were excluded from the analyses involving awareness.

Question	Common responses
1. During the task, when you were choosing playing cards, how did you make your choices? Did you use any strategies?	No strategy (26%); chose last card (14%); chose card that stood out (12%); stared at pip of card (9%); chose first card (9%); chose card shown longest (9%).
2. Did you notice anything during the task?	The same cards repeated each trial (23%); some cards were shown longer (5%); one card was shown longest (2%).
3. Did you feel that you had a free choice over which cards you chose?	Yes (66%).
4. Did you feel that you were being influenced to choose any particular cards?	No (52%).
5. Did you notice that any cards were shown longer than the others?	Yes (67%).
6. Each trial, one card was shown longer than all of the rest of the cards. Did you notice this?	Yes (60%).
7. Whether or not you noticed it, about how many times do you think you chose the card shown the longest? (There were 28 trials.)	$M = 9.43$ (SD=7.47, Mdn = 7).

Table 2.2: Common responses to post-test questionnaire items. $N = 43$.

2.2.1.4 Analysis

We used mixed-effect logistic regression. This method assumes there is neither perfect multicollinearity nor specification error. Variance inflation factors showed little evidence of multicollinearity. The absence of specification error occurs when all and only relevant predictors are included in the model (Meyers, Gamst, & Guarino, 2006). Because this was an exploratory study, we could only model a subset of relevant factors, so some degree of specification error was present. Thus, p values are likely not trustworthy; instead, we focus primarily on effect sizes (Cumming, 2014; Kline, 2013).

2.2.2 Results and discussion

2.2.2.1 Choice of target

Overall, participants chose the target card on 30% [28%, 33%] of the 28 trials. Though reasonably high, this rate was lower than in Study 1 (98%), possibly because many of the social and situational factors central to magic tricks were absent; alternatively, the timing parameters may not have been optimal. In any event, among target cards in our sample, people chose Aces the most and the Eight of Diamonds the least (Figure 2.3). Relatedly, Aces are among the most visible, memorable, and accessible cards, and the Eight of Diamonds is among the least (Olson et al., 2012).

2.2.2.2 Awareness of influence

After 28 trials, 40% [23%, 77%] of participants still reported being unaware that the target was shown the longest in each trial (cf. Question 6 of Table 2.2). Personality measures poorly predicted awareness (Table 2.3). Aware participants had an Internal Control Index of 84.07 $\pm$ 1.91 (mean $\pm$ standard error [SE]) and the unaware ones 89.29 $\pm$ 2.56; the groups in our sample therefore differed by 0.5 standard deviations (d_{unb}; see Cumming, 2014). Transliminality had almost no effect (Table 2.3).

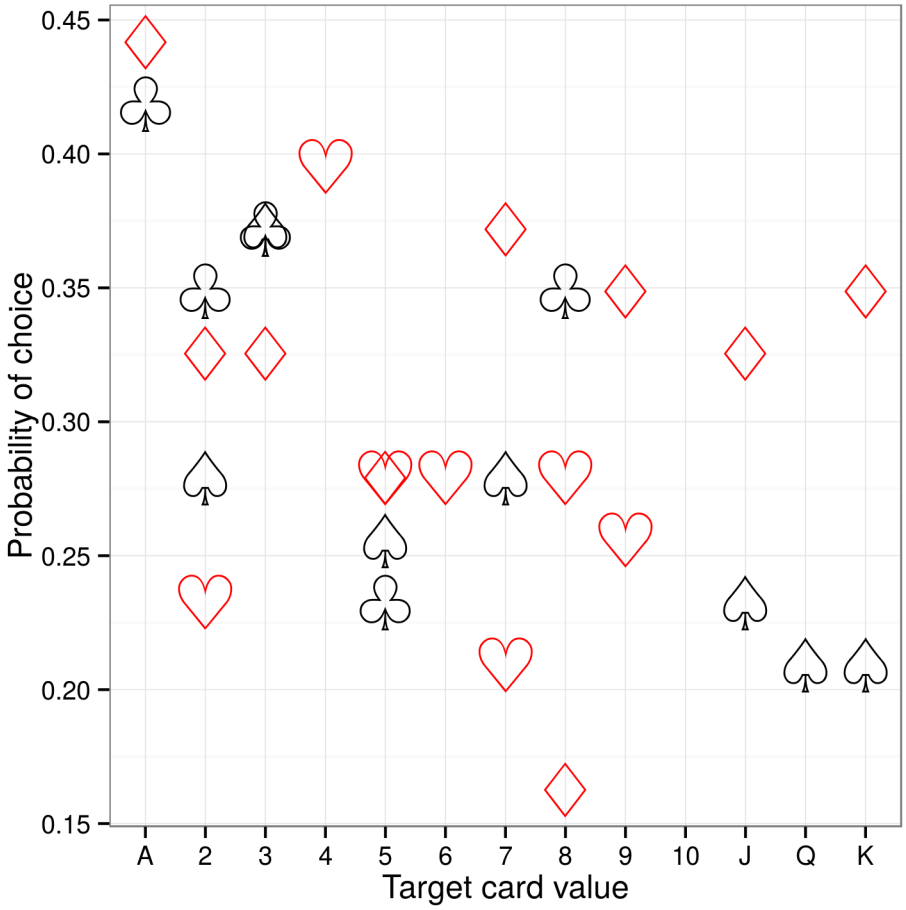

Fig. 2.3 Probability of choosing each of the 28 target cards tested. Based on 1204 trials with each card equally tested. Each data point averages 43 trials.

	B	SE	*z*	*p*	OR
(Model y-intercept)	4.747	2.947	1.611	0.107	
Locus of control	-0.051	0.032	-1.577	0.115	0.951
Transliminality	0.023	0.103	0.221	0.825	1.023

Table 2.3: Personality predictors of noticing. B is the change in odds for each unit increase in the predictor and OR is the odds ratio. $N = 40$ participants.

2.2.2.3 Choice of target by aware participants

Aware participants — those who noticed one card was shown longest — chose the target card on 23% [19%, 26%] of the trials. Their choice was based on stimulus characteristics but not personality measures (Table 2.4). For each unit increase in visibility and visibility bias, the odds of choosing the target card increased by a factor of 5.54 and 7.82, respectively. We did not expect the latter result: people were more likely to choose target cards that had a higher bias — that is, those more likely to be declared *absent* in a detection task. This effect applied only when aware participants (but not unaware ones) chose target cards (not other cards). Since target cards with a high visibility bias are difficult to detect, when they *are* detected, they may become more salient or visible than average. If this conscious perception influences choice, it would show a particularly strong effect for these high visibility bias cards. This effect did not occur for non-target cards perhaps simply because they were not displayed long enough to generate such high levels of visibility.

For each unit increase in memorability, the odds of choosing the target increased by a factor of 4.77. In contrast, memorability bias had relatively little predictive power (odds ratio [OR] = 1.26). Likeability weakly predicted choice: unexpectedly, people seemed to choose less likeable cards. For a full unit increase in likeability, the odds of choosing the target decreased by a factor of 0.11, controlling for other predictors. There were no large learning or fatigue effects (see Trial in Table 2.4).

	B	SE	*z*	*p*	OR
(Model y-intercept)	-3.387	2.473	-1.369	0.171	
Visibility	1.713	0.832	2.058	0.04	5.544
Visibility bias	2.057	0.917	2.244	0.025	7.823
Memorability	1.563	0.649	2.409	0.016	4.772
Memorability bias	0.23	0.688	0.334	0.738	1.259
Likeability	-2.222	1.235	-1.799	0.072	0.108
Locus of control	0.008	0.025	0.322	0.747	1.008
Transliminality	-0.122	0.086	-1.42	0.155	0.885
Trial	0.017	0.011	1.493	0.135	1.017

Table 2.4: Predictors of target card choice among aware participants. $N = 672$ trials.

2.2.2.4 Choice of target by unaware participants

Unaware participants chose the target card on 30% [27%, 33%] of the trials, slightly (7%) higher than the aware participants. Unlike the situation for the aware participants, choice was now better predicted by personality than stimulus factors (Table 2.5). In our sample, people with a more external locus of control tended to choose the target card slightly more. Restated, those who believed that external factors influence their lives were easier to influence. A one-unit increase in the Internal Control Index decreased the odds of choosing the target by a factor of 0.96. However, this effect was small and may be unreliable.

	B	SE	*z*	*p*	OR
(Model y-intercept)	5.262	2.991	1.759	0.079	
Visibility	-1.222	1.08	-1.132	0.258	0.295

	B	SE	z	p	OR
Visibility bias	-0.938	1.153	-0.813	0.416	0.391
Memorability	0.417	0.817	0.511	0.609	1.518
Memorability bias	0.119	0.878	0.136	0.892	1.127
Likeability	-1.709	1.578	-1.083	0.279	0.181
Locus of control	-0.044	0.026	-1.7	0.089	0.957
Transliminality	-0.157	0.075	-2.086	0.037	0.854
Trial	0.04	0.015	2.722	0.006	1.041

Table 2.5: Predictors of target card choice among unaware participants. $N = 448$ trials.

Transliminality had a stronger effect. People with a higher score (i.e., those more sensitive to faint stimuli) chose the target less often than those with a lower score. A one-unit increase in transliminality decreased the odds of choosing the target by a factor of 0.85. Perhaps those with higher transliminality could identify more of the non-target cards and so would choose these more often. Indeed, high transliminality participants seemed to choose non-target cards of shorter durations. Based on a median split, these participants chose cards shown 48.82 ± 1.21 ms (mean $\pm$ SE) compared to low transliminality participants at 53.23 ± 0.92 ms, a 0.27 standard deviation difference (d_{unb}). The probability of choosing the target card increased slightly as the trials progressed (OR = 1.04).

Importantly, then, different factors predicted target card choice depending on whether participants noticed the influence. For those who were aware, choice was predicted by stimulus factors; for those who were unaware, it was predicted by personality factors. This suggests participants may have used different strategies for choosing cards depending on their awareness. Of the aware participants, 27% reported knowingly choosing the longest card; of the unaware, none reported this strategy. This difference in strategies may explain why aware participants tended to choose cards that were more visible and memorable.

2.2.2.5 Choice of non-target card

When people did not choose the target card (i.e., the one presented longest), they often chose cards near the beginning or end of the trial (Figure 2.4). We see the usual primacy and recency effects (Murdock, 1962); cards at the beginning and the end of the stream may also have been less adequately masked. Consistent with the tendency found for targets, people chose cards that were shown longer (Figure 2.5) likely because they had more time to process these cards. In addition, perhaps stimuli shown longer had more apparent contrast (see Bloch's Law; Kahneman & Norman, 1964) and so may have had greater salience, drawing more attention.

People also seemed to preferentially choose Aces and lower number cards (Figure 2.6), which are easier to perceive, remember, and verbally access (Olson et al., 2012). In particular, choice of non-target card related to memorability (Figure 2.7). After removing extreme scores,[3] for each unit increase in memorability, there was a 16.32 raw frequency increase in choice (out of 842 non-target choices), $r_{46} = 0.4$, $p = .005$. There were no other strong relationships between choice and stimulus factors.

2.2.2.6 Limitations

An important — though unavoidable — limitation of this study was its operationalisation of awareness. We measured awareness primarily via the question: "Each trial, one card was shown longer than all of the rest of the cards. Did you notice this?" (cf. Question 6 of Table 2.2). Because noticing is a subjective activity, assessing whether people actually did notice something is difficult (Newell & Shanks, 2014). In any event, given the tendencies we have found between groups, our operationalisation may have been at least somewhat effective. Future studies may use more recent measures such as the Sense of Agency Rating Scale (Polito, Barnier, & Woody, 2013) or follow the instructions of Newell and Shanks (2014).

[3] Based on a previous analysis of atypical cards, these were the Ace of Spades, and the Ace, Queen, and King of Hearts (Olson et al., 2012).

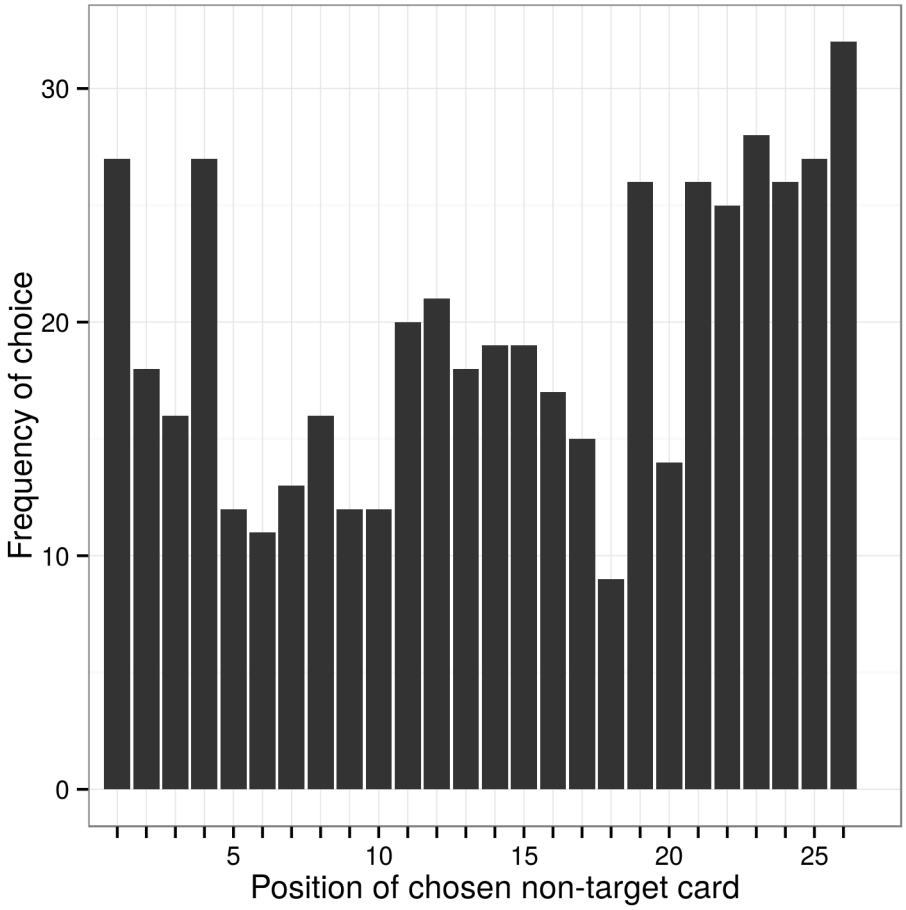

Fig. 2.4 Non-target cards chosen by position in stream (1 to 26). Based on 506 trials in which present non-targets were selected.

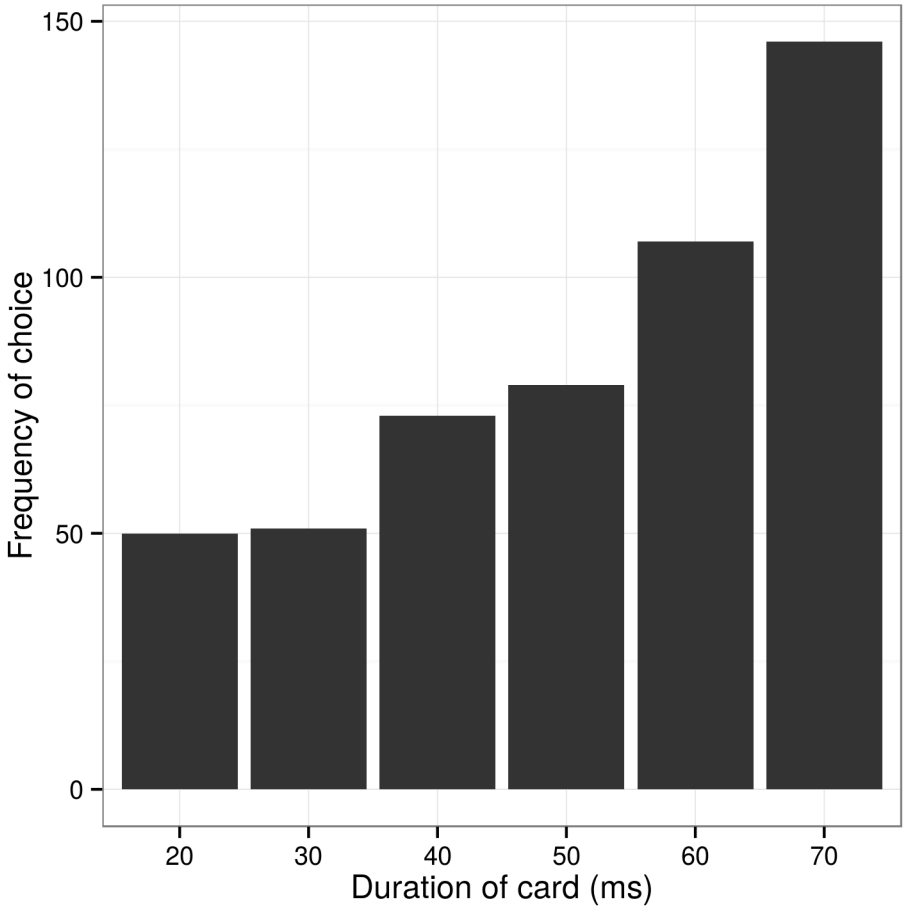

Fig. 2.5 Frequency of choice by non-target card duration. $N = 506$.

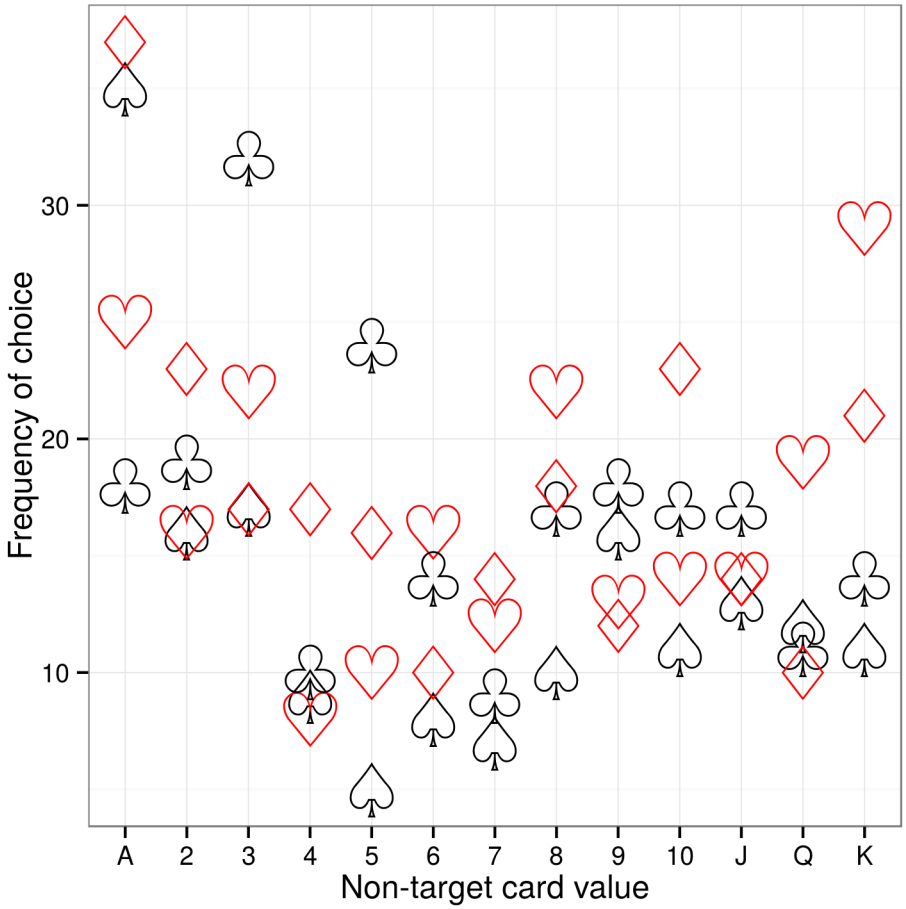

Fig. 2.6 Non-target cards chosen. $N = 842$.

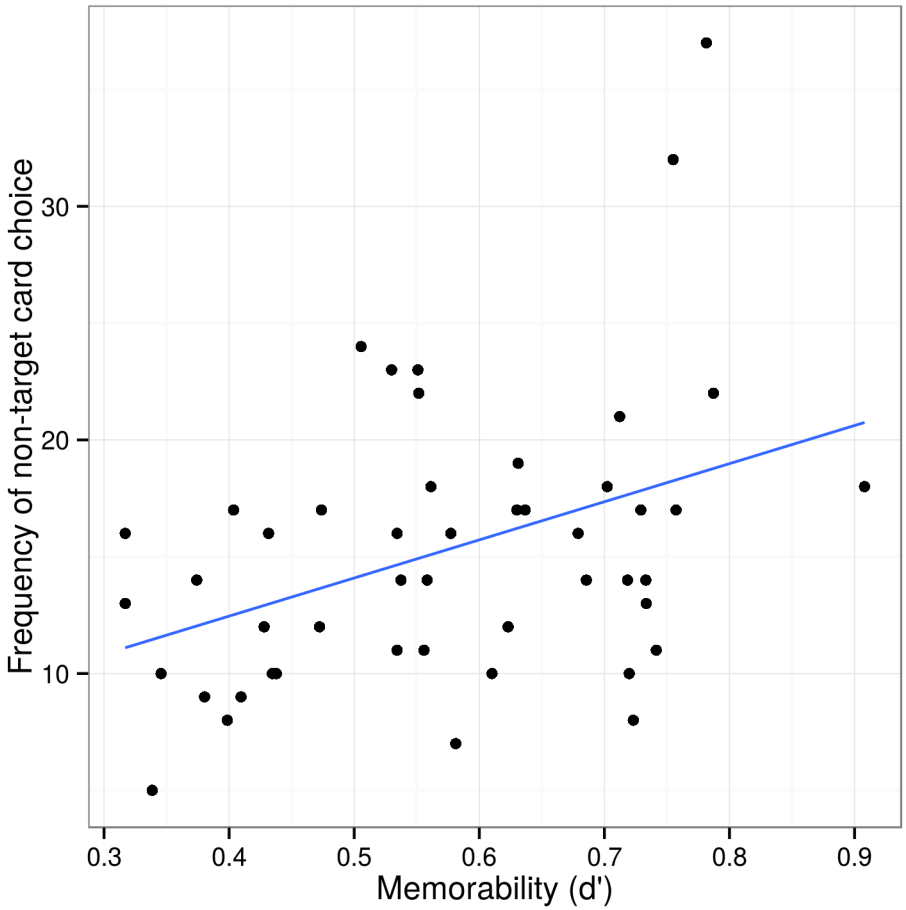

Fig. 2.7 Frequency of choosing each non-target card by memorability, $r_{46} = .4$, $p = .005$.

2.3 Discussion

For centuries, magicians have amazed audiences by subtly yet powerfully influencing their decisions. Here we harnessed this technique to study how people choose a particular card without awareness of an objective influence on their choice. Among other things, we discovered that stimulus and personality characteristics both predicted choice, depending on whether or not the influence was noticed. Specifically, participants aware of the influence chose visible, memorable, and unlikeable target cards, while personality factors mattered little. Conversely, for unaware participants, stimulus factors mattered little, while personality factors — in particular, transliminality — better predicted the degree of forcing. This suggests that different decision-making mechanisms may be at play for the different states of consciousness.

One of the mechanisms underlying salience forcing may be exogenous attention capture. Stimuli with particular features, such as a different colour from the background, can automatically capture attention; in some cases, this can occur without awareness (Mulckhuyse, Talsma, & Theeuwes, 2010). In our experiment, perhaps the longer duration of the target card captured attention automatically, so people chose that card without knowing why.

Salience forcing is only one method of dozens that magicians use to influence audiences. Exploring such methods could reveal new ways to present choices or modify environments in order to encourage better decision-making (Thaler & Sunstein, 2008; Wansink & Sobal, 2007). Beyond its practical benefit, understanding forcing and the impression of a free choice may also help the study of the sense of agency and decision-making. The present studies demonstrate that people can be influenced by external forces yet feel their choice is free. In other situations, such as when using a Ouija board (Gauchou, Rensink, & Fels, 2012), the converse holds: people are not influenced by such forces, yet believe their choice is constrained. In a sense, this shows a double dissociation between objective and subjective free choice. Such a dissociation may relate to distortions in the sense of agency seen in disorders of mental control, such as schizophrenia and alien hand syndrome (cf. Haggard, Martin, Taylor-Clarke, Jeannerod, & Franck, 2003). Experimentally distorting the sense of agency in the more accessible non-clinical population could also lead to insights about these symptoms (Olson, Landry, Appourchaux, & Raz, in progress).

Forcing may also shed light on the nature of higher-level cognition, such as the ability of humans to account for the decisions they have made. Especially in our first study, participants that were influenced often created confabulations that had little to do with the actual constraints on their behaviour. Forcing could thus provide a reliable way to examine this phenomenon. It might also help with related effects, such as the introspective illusion, in which people overestimate the accuracy of their thoughts (Nisbett & Wilson, 1977; Pronin & Kugler, 2007).

As a magician, precise knowledge of forcing could improve performances. Some types of forcing — especially psychological forcing — have relatively low success rates (e.g., Shalom et al., 2013). Greater success might be obtained by using cards that are more often chosen (cf. Figure 2.6) or participants who are more susceptible. Currently, magicians tend to choose target cards and participants arbitrarily or based on heuristics which have yet to be formally tested. Just as the careful study of playing cards can refine magicians' intuitions (Olson et al., 2012), the careful study of forcing may likewise help magicians improve the effectiveness of their magic tricks.

Of interest to both magicians and scientists, we recommend researchers also focus on the situational factors that influence the effectiveness of forcing. As we have seen, stimulus and personality factors have limited effect; other factors — in particular, situational ones — may have a larger influence. For example, when offering a choice of card, magicians often pressure spectators to choose one quickly and may touch or rush participants to increase compliance (e.g., Kleinke, 1977). Indeed, some magicians believe the spectator's personality is largely irrelevant to forcing: a skilled performer should be able to make almost anyone conform on stage.

In any event, the present studies outline a methodology for analysing magic effects in a controlled environment. The ideal methodology may be to start with an in-person magic trick (Study 1), followed by a video representation of the same effect, and finally a reproduction using stimuli on a computer (Study 2). Such a progression could isolate the factors that enable the trick while retaining much of its power.

To make it easier for researchers to study forcing and the factors that influence choice, we have made our data available online.[4] By doing so, we hope to help researchers participate in this growing field. In particular, we hope that similar methodologies which combine the realism of the

[4]See https://github.com/jayolson/card-influence-data.

performing environment with the control of the laboratory will foster collaboration between the art of magic and the science of psychology.

3. Interlude: Views of magicians

Studying phenomena like forcing can help psychology by revealing subtle effects on decision-making. Such findings may also help magicians increase the effectiveness of forcing (Olson, 2012). Could similar studies of the science of magic help magicians improve their performances?

Some magicians think not. Teller (2012) argues that, compared to magicians, scientists have millennia less experience with deception and conjuring; they will thus unlikely discover new practical findings. Artificial environments and small sample sizes may further prevent studies from offering useful advice to performers (Teller, personal communication, 2013). Other magicians claim that key phenomena in magic are too subtle to easily dissect in the laboratory (Jamy Ian Swiss, personal communication, 2014).

Scepticism of the usefulness of a science of magic seems reasonable given the incipient field. However, some research questions clearly benefit magicians. For example, magicians have noticed patterns in the types of playing cards people select when asked to verbally choose one (Banachek, 2000). In a previous study, we recorded the responses of a thousand people asked to choose a card (Olson et al., 2012). The results confirmed some of magicians' intuitions (e.g., many people chose the Ace of Spades or Queen of Hearts); we also discovered new effects, such as how the wording of the question influences choice. We can now rank the 52 playing cards by how often people choose them, and combined with related studies, can measure their visibility, memorability, and likeability (Olson et al., 2012). Such findings are useful in magic, particularly for mind reading (Olson, 2012) and tricks that depend on the audience forgetting certain cards (e.g., Farmer, 2014). Thus, at least some studies benefit magicians; the value of other applications remains to be seen (e.g., Williams & McOwan, 2014). At least, no necessary barriers prevent magic research from helping magicians (Rensink & Kuhn, 2014).

Perhaps other magicians hold views not represented by the vocal minority. To assess this, Amir Raz and I surveyed a larger sample of magicians with an online questionnaire.[1] A popular magic magazine, *Genii*, published a link to the questionnaire which drew most of the respondents.

In total, 127 magicians completed the survey. Most respondents — like most magicians — were male (94%). The average age was 39 years (median: 35, mode: 18; Figure 3.1). The respondents had practised magic for a median of 15 years and performed for 2 (Figure 3.2). Most respondents reported good (51%) or excellent (22%) knowledge of magic.

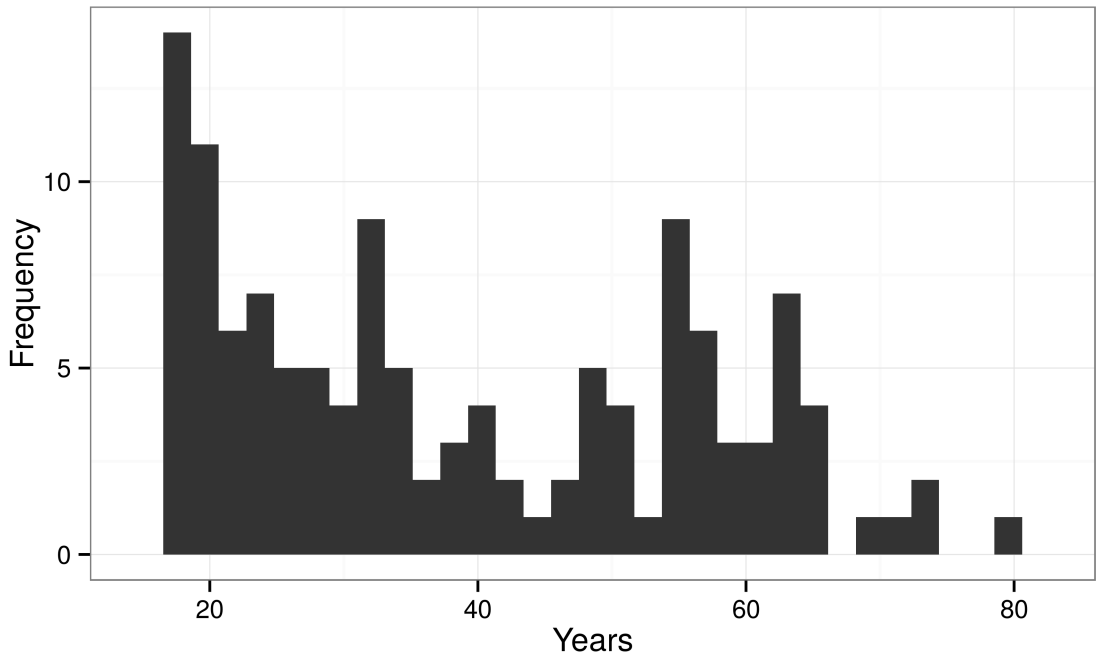

Fig. 3.1 Age of respondents.

When asked whether magic can help science, respondents were generally optimistic: 48% said "definitely" and 25% said "probably" (Figure 3.3). Few (8%) claimed that science would probably not help and none said it definitely would not.

When asked the converse — whether science can help magic, such as by coming up with new effects or improving existing ones — people were even more optimistic. Here, 77% said "definitely" and only 2% claimed that science would "probably not" or "definitely not" help (Figure 3.3).

This informal survey outlined magicians' views but had obvious limitations. Presumably those

[1] See Appendix A for the questionnaire. Thanks to Genii editor Richard Kaufman for promoting the survey.

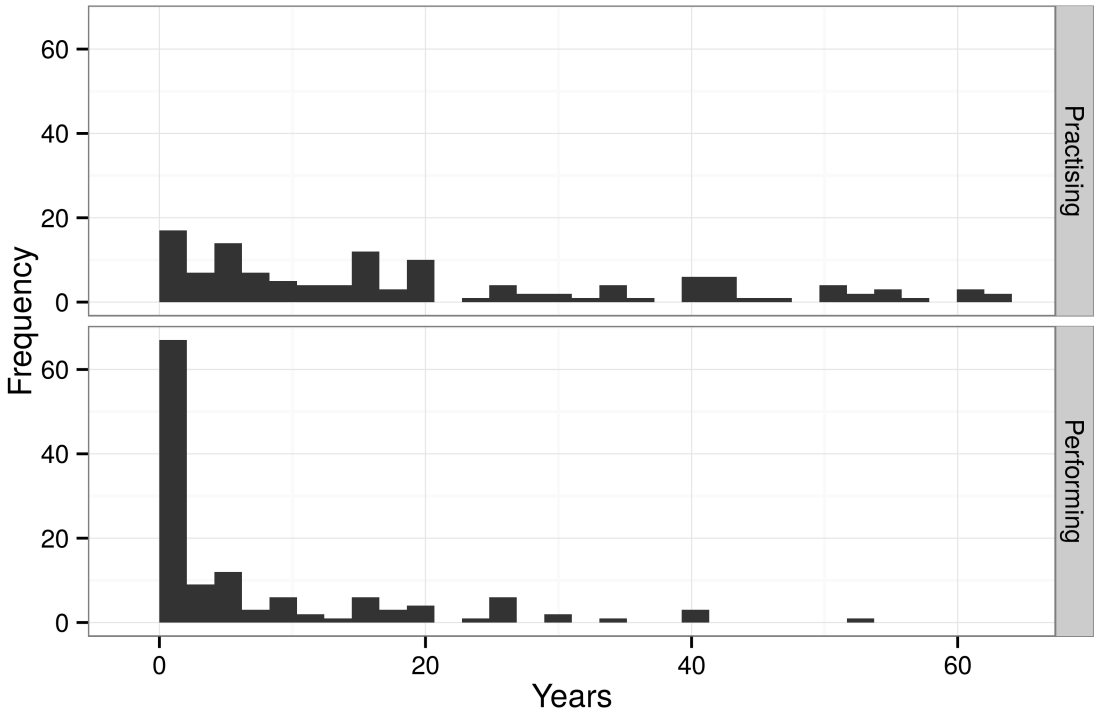

Fig. 3.2 Years spent practising and performing magic.

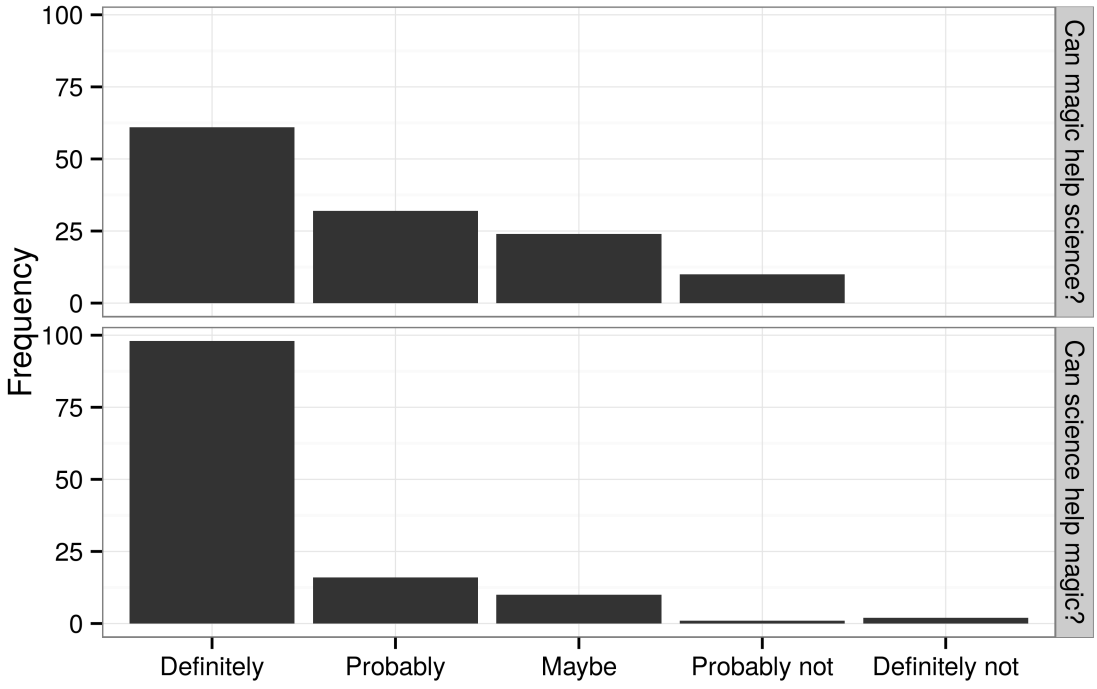

Fig. 3.3 Whether magic and science can help each other.

interested in — and optimistic about — the science of magic were more likely to participate. The survey also attracted younger and less experienced magicians. Still, we can conclude that at least some magicians are optimistic about the interaction between magic and science.

Whether studying magic can help scientists or magicians, it can still benefit scientists as a method. Magic enables experimental methods that would be impossible without deception and conjuring. One study, for example, examined how social influence affects the interpretation of paranormal events (K. Wilson & French, 2014). A conjurer bent a metal key seemingly by psychokinesis, and a confederate's verbal comments could influence whether participants saw the event as paranormal. Another study used magic to convince participants that a brain scanner could read their minds (Ali, Lifshitz, & Raz, 2014). In it, participants privately chose numbers that the brain scanner correctly guessed ostensibly by reading neural activity. Eventually participants believed the machine could read their thoughts; in reality, a magic trick enabled the correct guesses. Such methodologies would be impossible without magic. In the next chapter we similarly use magic as a method, in this case to test hypotheses of cognitive development.

4. Cognitive development

Magic tricks depend on assumptions about the world. Magicians skillfully violate these assumptions to create mysteries (Rensink & Kuhn, 2014). Since assumptions change with age, magicians perform differently for children and adults. Children, for example, may prefer watching physical magic such as vanishing objects, while adults can understand psychological magic such as mind-reading. To keep performances suitable, magicians have developed intuitions about which tricks work best for which ages (e.g., Ginn, 2004; Kaye, 2005). Examining these intuitions could lead to new insights or methods in the study of cognitive development.

Scientists have leveraged magic to explore other areas in psychology (Kuhn et al., 2008) including attention, perception, decision-making, and problem solving. Some have used both children and adults in their samples to compare cognitive development (e.g., Subbotsky, 2001). Few, however, have explored developmental differences with a large sample over a wide age span. Combined with previous research on adults (Demacheva et al., 2012), we present a feasibility study of 1175 participants aged 4 to 90 years.

Due to their level of maturation, children have different expectations and assumptions than adults; magicians thus cater to them with a specific set of effects (Rissanen et al., 2014; Sharpe, 1988). Around four years of age, children begin to understand that other people have distinct beliefs and intentions — that is, they begin to form a Theory of Mind (Apperly, Samson, & Humphreys, 2009). Around the same time, the distinction between appearance and reality becomes clearer (Flavell, 2000). When executive attention develops around three to seven years of age, logical thinking and sustained attention improve (Posner & Rothbart, 2007). With these developments, children are better able to make assumptions about what is going to happen and thus become more receptive to magic tricks.

Magical beliefs — such as beliefs about the existence of events which violate physical laws — also change with age (Subbotsky, 2014). Young children tend to believe in fantasy figures (such as fairies; Phelps & Woolley, 1994; Woolley, 1997) and many preschool children believe magicians have supernatural powers (Evans, Milanak, Medeiros, & Ross, 2002). During school age, children start to develop a more scientific perspective which can override magical beliefs (Subbotsky, 2010). Even so, these beliefs can persist into adulthood. In one study, more than half of college students ascribed psychic abilities to someone performing tricks resembling clairvoyance and psychokinesis, even if he was introduced as an amateur conjurer (Benassi, Singer, & Reynolds, 1980). In another study, adults who claimed not to believe in supernatural abilities were reluctant to let the experimenter cast a spell on their identification cards (Subbotsky, 2001). Though some magical beliefs decrease with age, they continue to play an important role throughout the life span (Subbotsky, 2014).

In this paper we present a preliminary study of magical beliefs in children and adults. Participants watched a magician make a pen vanish then they tried to explain the trick. This "non-permanence magic" (Subbotsky, 2001) surprises most people over four years old (K. S. Rosengren & Rosengren, 2007). We had three hypotheses:

1. Confidence in one's explanation of the secret will decrease with age. This is consistent with magicians' observations and with studies showing that young children feel overconfident in their cognitive abilities (Lipko, Dunlosky, & Merriman, 2009; Shin, Bjorklund, & Beck, 2007).
2. Younger children (aged 4 to 8 years), compared to older ones, will show more magical beliefs when explaining the trick (see Phelps & Woolley, 1994).
3. Younger children (aged 4 to 5 years) will more often take observed events at face value, since the appearance–reality distinction is still developing (Flavell, 2000). Specifically, they will more often believe that the pen broke or dissolved in the magician's hands.

4.1 Methods

The experimenter led participants to a testing room with individual computers. The participants watched a recorded magic trick, tried to explain it, then rated their confidence in the explanation. Next, the experimenter prodded for alternative explanations using a questionnaire. Finally, participants explained the trick again and re-rated their confidence level. The entire procedure took under 30 minutes for each participant.

4.1.1 Participants

We recruited 167 children from a summer camp in Montréal, Canada. They were 8.8 $\pm$ 2.3 years old (mean $\pm$ SD, range 4 to 13) and around half (54%) were male. Each age group had at least ten participants (Table 4.1). The procedure conformed to the guidelines of the Jewish General Hospital Research Ethics Committee and we obtained parental consent.

Age	4–5	6	7	8	9	10	11	12	13	14–17	18–19	20–29	30–39	40+
N	10	20	31	22	17	23	16	18	10	37	225	655	62	29
% Male	10	35	55	86	35	65	56	72	40	46	25	30	55	52

Table 4.1: Sample sizes and gender proportions for each age group. Participants aged 13 and under completed the child version of the questionnaire; the rest did the adult version (Demacheva et al., 2012).

Previously we recruited a sample of 1008 participants 22.3 $\pm$ 6.6 years old (14 to 90, 31% male; see Table 4.1) which we used as a comparison group (Demacheva et al., 2012). They completed an analogous questionnaire online.

4.1.2 Materials

4.1.2.1 Magic trick

The experimenter explained that we were studying how people think about magic tricks. On a computer, a 15-second silent video clip showed a magician making a pen vanish. In the video, the magician begins by showing a pen then appears to break it. When his hands open, the pen has vanished (Figure 4.1). We chose this minimal magic trick because it can fool both children and adults without needing patter, interaction, or explicit social cues (Demacheva et al., 2012; cf. Joosten et al., 2014). Participants could watch the video as many times as they wanted. Throughout the study, the experimenter referred to the magic trick in the video as a trick and avoided mentioning "real magic".

There are several methods of performing this trick. Here, the secret involved the pen quickly moving inside the magician's jacket. A small cue in the video of an object hitting the magician's shirt hinted at this method. For a full description of the mechanism behind the trick, see M. A. Wilson (1988, p. 279, "The Vanish of the Handkerchief").

Fig. 4.1 Participants watched a silent video of a magician making a pen vanish.

4.1.2.2 Questionnaire

The experimenter then led the children through a questionnaire (Appendix B); we used the same one as Demacheva et al. (2012) after a developmental psychologist adapted the wording for children. Most children tried to explain the secret of the trick. A magician who was unaware of

our hypotheses later rated these explanations on a scale from 1 (i.e., completely wrong) to 5 (i.e., complete grasp of the method). Children rated their confidence in the explanations on a similar 5-point scale (1: not at all, 2: a bit, 3: some, 4: a lot, 5: a whole lot). The questionnaire then probed for alternative explanations by asking about required materials and possible methods to perform the trick. Some materials and methods were accurate (e.g., rubber bands, the pen moves quickly to a different location) and others were not (e.g., mirrors, the magician still holds the pen but it cannot be seen). Finally, children revised their initial explanations and re-rated their confidence.

4.2 Results and discussion

Consistent with our hypotheses, younger children gave more supernatural interpretations, more often took the magicians' actions at face value, and felt more confident in their explanations. Inconsistent with our hypotheses, confidence also increased with age among adults.

Secret Although most children (62%, CI [54%, 69%][1]) tried to explain the secret, none correctly identified it. The magician gave 96% [92%, 99%] of the initial explanations the lowest accuracy rating: completely inaccurate. (We considered the explanation correct if the magician rated it 3 or more out of 5.) Even after being probed for alternative explanations, participants performed only marginally better: 2% [0%, 6%] guessed it correctly. Adults similarly had little success in guessing the secret (5% were correct in their first explanation and 9% in the second; Demacheva et al., 2012). The trick was thus effective in that few people figured it out. We excluded these few from the rest of the analyses.

Explanations Attempts to explain the trick were broad. The 4- to 6-year-olds usually remarked the pen "just disappears" or the magician "just breaks it". Indeed, the younger children more often took the magician's actions at face value. Specifically, they more often believed that the pen broke or dissolved in the magician's hands (Figure 4.2). Thus, age related to reports that the pen broke ($\chi^2(8) = 22.459, p = .004$) or dissolved ($\chi^2(8) = 25.54, p = .001$).[2] These reports largely

[1] Square brackets denote 95% confidence intervals (see Cumming, 2014).

[2] Statistical tests used data from participants four to thirteen years old. Four- and five-year-olds were combined due to their small sample sizes (see Table 4.1).

flattened out after the teenage years (Figure 4.2).

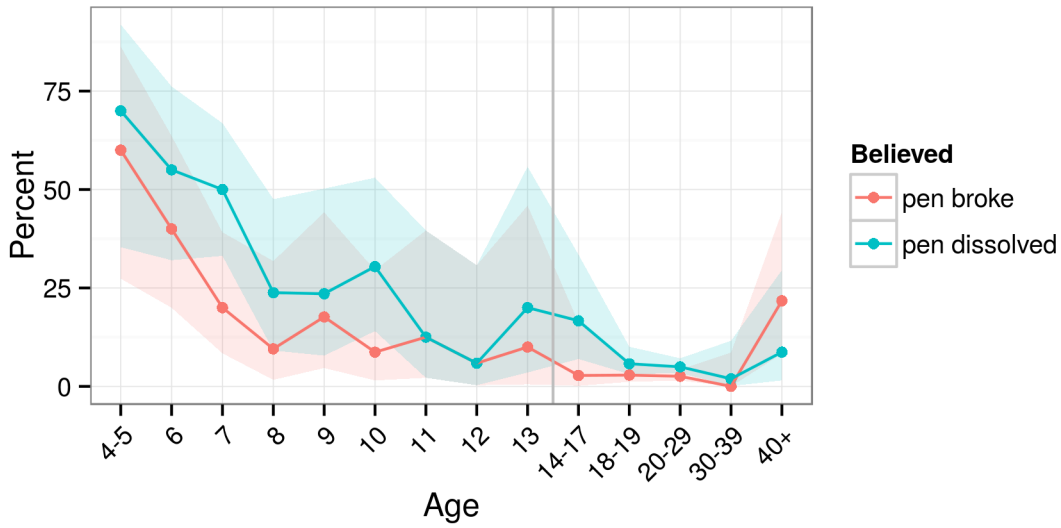

Fig. 4.2 Percent of participants believing that the pen broke or dissolved. The vertical line separates those who took the child versus adult version of the questionnaire. Shaded areas show bootstrapped 95% confidence intervals.

The 7- to 9-year-olds began to develop possible yet implausible explanations. Some suggested the magician hid the pen in his sleeves (which were rolled up in the video) or hid it in his skin. Others suggested the pen crumbled into smaller and smaller pieces until nothing remained. One suggested that the torso in the video was actually a mannequin and the magician hid the pen in the empty torso. The 10-year-olds and older children started to develop plausible explanations, such as a trick pen, camera tricks, or a hidden pocket. These progressive changes in the explanations presumably reflect both increased verbal ability and cognitive development.

Consistent with previous studies (e.g., Evans et al., 2002), many of the younger children showed magical beliefs. Some suggested that the pen vanished simply because "the pen is magic". When asked in the questionnaire, younger children more often believed the secret involved superpowers or a magic potion (e.g., "there is secret invisible stuff on his hands that makes [the pen] disappear"; Figure 4.3). There were thus relationships between age and the frequency of beliefs that the trick used a potion ($\chi^2(8) = 24.008, p = .002$) or superpowers ($\chi^2(8) = 32.74, p < .001$). The adult version of the questionnaire used different wording ("chemical reaction" rather than "magic potion") which prevented a comparison to the children.

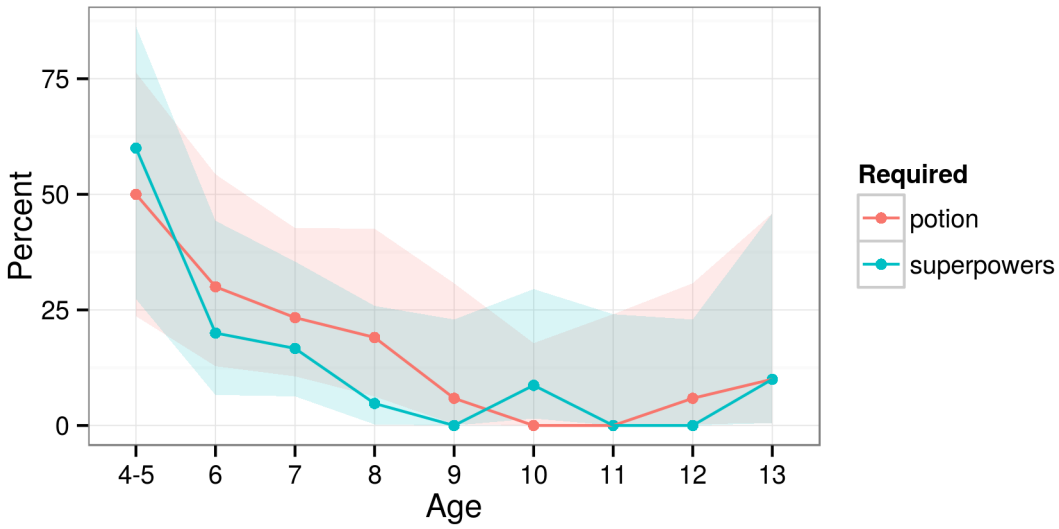

Fig. 4.3 Percent of participants believing that the magic trick required a magic potion or superpowers. Shaded areas show bootstrapped 95% confidence intervals.

Confidence Despite their lack of accuracy, children felt confident in their explanations: 84% reported at or above the midpoint of confidence. The majority (73%) reported "some" or "a lot" of confidence in their explanation. Adults reported roughly similar levels of confidence (57%).

Among children, confidence seemed to decrease with age (Figure 4.4); there was a relationship between age and confidence in the explanation of the trick (first explanation: Kruskal-Wallis $H(8) = 15.509, p = .05$; second: $H(8) = 19.176, p = .014$). This general pattern is consistent with the finding that younger children are particularly overconfident (Lipko et al., 2009). Indeed, when presenting a deck of cards to young children, magicians (e.g., co-authors J.O. and A.R.) often hear, "Oh! I know that trick!"

Among adults, confidence seemed to *increase* with age (Figure 4.4). This seems inconsistent with findings that younger adults are generally more overconfident than older ones (Pliske & Mutter, 1996; Zell & Alicke, 2011). In our sample, gender differences may have contributed to this effect. Some studies have found that men are more overconfident in their abilities than women (Barber & Odean, 2001; Bengtsson, Persson, & Willenhag, 2005). Our sample included more men as age increased above 18 (see Table 4.1) and overall males were more overconfident than females (Figure 4.5). The increase in males among older adults could have likewise increased confidence at older ages. Still, this could only explain part of the effect. Zell and Alicke (2011) found

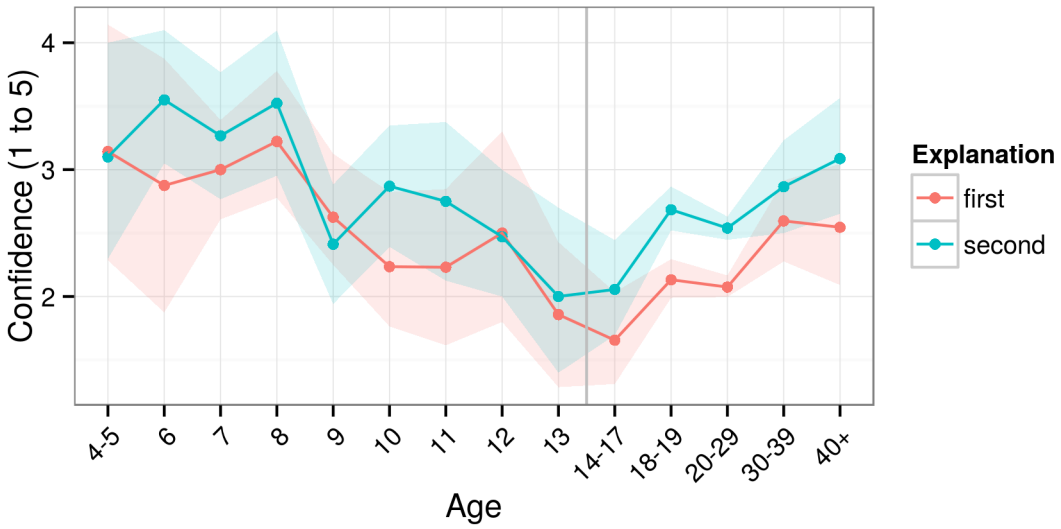

Fig. 4.4 Confidence in one's inaccurate explanation of the magic trick. Shaded areas show bootstrapped 95% confidence intervals.

an interaction between age and overconfidence depending on which dimension was measured. For example, older adults were more confident about their sociability but less so about their athleticism. Perhaps, then, explaining magic tricks is a dimension showing more overconfidence with age. It remains unknown whether similar results apply to other magic tricks or cognitive tasks among adults.

Limitations This study had three potential limitations. First, the questionnaires for children and adults differed slightly in wording (compare Appendix B here with Demacheva et al., 2012). Although we consulted a developmental psychologist to help ensure analogous wording, different results between children and adults could be partly due to inconsistencies in wording. To account for this, we minimised comparisons between those who took the child versus adult version of the questionnaire. Second, the magic trick was recorded rather than performed live, which complicated the explanations of the trick. When young children claimed that the pen dissolved or vanished, they could have either intended that the pen actually vanished (in reality) or simply that it appeared to vanish (in the video); we could not differentiate these with certainty. Third, our methodology was insensitive to different interpretations of other questionnaire items. For example, when asked whether the trick needed "superpowers", perhaps some children thought of

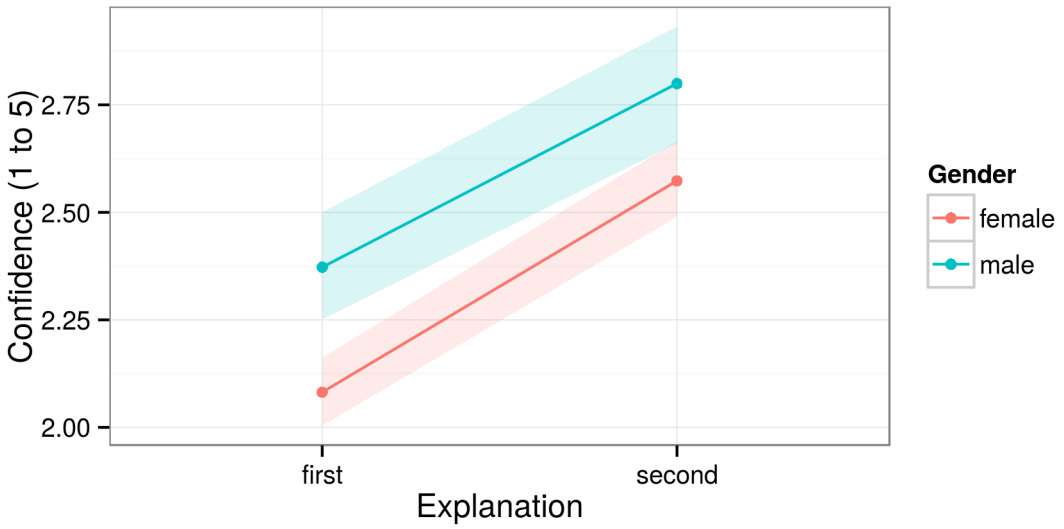

Fig. 4.5 Confidence in one's inaccurate explanation of the magic trick by gender. Shaded areas show 95% bootstrapped confidence intervals.

supernatural abilities while others thought of specialised skills. One potential solution would be to perform the trick live each time followed by a more in-depth interview; in our case, this would have prevented such a large sample.

Implications Using magic tricks may have several advantages for studying cognitive development across the life span. Traditional illusions in developmental psychology often require props such as boxes, screens, or backdrops (e.g., Baillargeon, 2002). These illusions can make the prop itself seem magical, such as when transforming objects inside a special box (e.g., Subbotsky, 2004). Using magic, as in the current study, the experimenter can make a person look magical rather than a prop. Shifting the locus of magic from props to people could help clarify differences in the development of magical beliefs regarding people versus objects.

Further, unlike many of the illusions used to test phenomena like object permanence, magic tricks are robust across age: they amaze a large majority of people (here, 95%) over a wide age span. Many tricks work in diverse environments (e.g., Kuhn & Tatler, 2005) and can be translated for use in controlled experiments (Danek, Fraps, Müller, Grothe, & Ollinger, 2013; Olson et al., 2015a). Children and adults can thus view the same stimuli, which allows researchers to make more direct comparisons across different age groups. Such comparisons may be particularly useful to

examine phenomena like magical beliefs or overconfidence which change their presentation across the life span (Benassi et al., 1980; Subbotsky, 2014; Woolley, 1997; Zell & Alicke, 2011). Similarly, magic tricks work across different cultures (Kiev & Frank, 1964) and thus could shed light on intercultural differences in magical beliefs.

In sum, our feasibility study demonstrated a method to test developmental hypotheses with large and diverse samples. Such a method combining video stimuli and online surveys is particularly useful to explore age-based changes in magical beliefs and overconfidence in children and adults. Magic may thus offer a useful tool to gain new insights in developmental psychology across the life span.

5. Conclusion

This thesis aimed to show the usefulness of studying magic to explore the mind. We first used magic as a subject to study decision-making in the context of a card trick. Results showed that magicians can heavily influence spectators' decisions without their awareness. Further, personality characteristics of the spectator as well as properties of the card predicted choice. Combining real-world and laboratory studies allowed us to examine the mechanisms underlying the trick while initially retaining its realism. The manuscript (Chapter 2) has now been published in *Consciousness and Cognition* (Olson et al., 2015a).

Next we used magic as a method rather than a subject. We showed children and adults a magic trick and asked them to explain it. Consistent with findings in developmental psychology, we saw differences in magical beliefs and overconfidence throughout the life span. The manuscript (Chapter 4) has now been published in *Frontiers in Psychology* (Olson et al., 2015b) as part of a special issue on the psychology of magic.[1]

Moving forward, the science of magic may follow two routes. First, researchers can continue to study magicians' intuitions that psychology has not yet tested. For example, magicians find laughter relaxes the audience's attention and critical thinking (Macknik et al., 2008), even if the laughter occurs *after* the secret move (Teller, personal communication, 2013). Or, magicians have intuitions about the amount of naturalness required for an action to appear inconspicuous (Rensink & Kuhn, 2014). Exploring these and other intuitions (cf. Kelley, 1980; Sharpe, 1988) may uncover new effects in psychology.

Second, researchers can study how these findings in magic translate to other environments. Salience forcing (Chapter 2), for example, coheres with findings that people tend to choose more

[1] See http://journal.frontiersin.org/ResearchTopic/2464.

attention-grabbing objects. Namely, people eat more visually-salient food (Wansink, 2004) and choose items from memory-salient locations on restaurant menus (Dayan & Bar-Hillel, 2011), without being aware of these influences. Perhaps other factors that affect forcing — or other phenomena in magic — likewise apply to other environments.

In sum, magicians and scientists have similar interests but different methods. Magicians test intuitions to predict behaviour and amaze audiences; scientists test hypotheses to predict results and build theories. This thesis demonstrated that studying magic can uncover new phenomena and methods in psychology. Nevertheless, we only examined one type of forcing and one method of vanishing a pen. Magicians have dozens of methods of influence, hundreds of ways to vanish objects, and thousands of intuitions about the mind. The vast majority of these remain unexplored by scientists. Continued collaboration between scientists and magicians can retain the secrets of magic while revealing the secrets of the mind.

6. References

Ali, S., Lifshitz, M., & Raz, A. (2014). Empirical neuroenchantment: From reading minds to thinking critically. *Frontiers in Human Neuroscience*. doi:10.3389/fnhum.2014.00357

Apperly, I. A., Samson, D., & Humphreys, G. W. (2009). Studies of adults can inform accounts of theory of mind development. *Developmental Psychology*, *45*(1), 190–201. doi:10.1037/a0014098

Baillargeon, R. (2002). The acquisition of physical knowledge in infancy: A summary in eight lessons. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development*. Malden, MA: Blackwell Publishers.

Banachek. (2000). *Psychological Subtleties*. Houston, TX: Magic Inspirations.

Barber, B. M., & Odean, T. (2001). Boys will be boys: Gender, overconfidence, and common stock investment. *Quarterly Journal of Economics*, *116*(1), 261–292.

Benassi, V. A., Singer, B., & Reynolds, C. B. (1980). Occult belief: Seeing is believing. *Journal for the Scientific Study of Religion*, *19*(4), 337–349. doi:10.2307/1386128

Bengtsson, C., Persson, M., & Willenhag, P. (2005). Gender and overconfidence. *Economics Letters*, *86*, 199–203. doi:10.1016/j.econlet.2004.07.012

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision*, *10*, 433–436. doi:10.1163/156856897X00357

Bruno, N., Martani, M., Corsini, C., & Oleari, C. (2013). The effect of the color red on consuming food does not depend on achromatic (Michelson) contrast and extends to rubbing cream on the skin. *Appetite*, *71*, 307–13. doi:10.1016/j.appet.2013.08.012

Crawley, S. E., French, C. C., & Yesson, S. A. (2002). Evidence for transliminality from a subliminal card-guessing task. *Perception*, *31*(7), 887–892.

Cumming, G. (2014). The new statistics: Why and how. *Psychological Science*, *25*(1), 7–29. doi:10.1177/0956797613504966

Danek, A. H., Fraps, T., Müller, A. von, Grothe, B., & Ollinger, M. (2013). Working wonders? Investigating insight with magic tricks. *Cognition*, *130*(2), 174–185. doi:10.1016/j.cognition.2013.11.003

Dayan, E., & Bar-Hillel, M. (2011). Nudge to nobesity II: Menu positions influence food orders. *Judgment and Decision Making*, *6*(4), 333–342.

Demacheva, I., Ladouceur, M., Steinberg, E., Pogossova, G., & Raz, A. (2012). The applied cognitive psychology of attention: A step closer to understanding magic tricks. *Applied Cognitive Psychology*, *1*, 541–549. doi:10.1002/acp.2825

Duttweiler, P. C. (1984). The Internal Control Index: A newly developed measure of locus of control. *Educational and Psychological Measurement*, *44*(2), 209–221. doi:10.1177/0013164484442004

Eaton, J. W., Bateman, D., & Hauberg, S. (2008). *GNU Octave Manual Version 3*. Network Theory Limited.

Evans, D. W., Milanak, M. E., Medeiros, B., & Ross, J. L. (2002). Magical beliefs and rituals in young children. *Child Psychiatry & Human Development*, *33*(1), 43–58. doi:10.1023/A:1016516205827

Farmer, B. (2014). *The Bammo Ten Card Deal Dossier*. (M. Field & M. Vance, Eds.). Toronto: Magicana.

Filevich, E., Vanneste, P., Brass, M., Fias, W., Haggard, P., & Kühn, S. (2013). Brain correlates of subjective freedom of choice. *Consciousness and Cognition*, *22*(4), 1271–84. doi:10.1016/j.concog.2013.08.011

Flavell, J. H. (2000). Development of children's knowledge about the mental world. *International Journal of Behavioral Development*, *24*(1), 15–23. doi:10.1080/016502500383421

Gauchou, H. L., Rensink, R. A., & Fels, S. (2012). Expression of nonconscious knowledge via ideomotor actions. *Consciousness and Cognition*, *21*(2), 976–982. doi:10.1016/j.concog.2012.01.016

Ginn, D. (2004). *Professional magic for children*. Loganville, GA: Scarlet Green.

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics* (Vol. 1). Wiley. doi:10.1901/jeab.1969.12-475

Haggard, P., Martin, F., Taylor-Clarke, M., Jeannerod, M., & Franck, N. (2003). Awareness of action in schizophrenia. *Neuroreport*, *14*(7), 1081–5. doi:10.1097/01.wnr.0000073684.00308.c0

Houran, J., Thalbourne, M. A., & Lange, R. (2003). Methodological note: Erratum and comment on the use of the Revised Transliminality Scale. *Consciousness and Cognition*, *12*(1), 140–144.

Johansson, P., Hall, L., Sikstrom, S., Olsson, A., & Sikström, S. (2005). Failure to detect mismatches between intention and outcome in a simple decision task. *Science*, *310*(5745), 116–119. doi:10.1126/science.1111709

Joosten, A., Girdler, S., Albrecht, M. A., Horlin, C., Falkmer, M., Leung, D., ... Falkmer, T. (2014). Gaze and visual search strategies of children with Asperger syndrome/high functioning autism viewing a magic trick. *Developmental Neurorehabilitation*, 1–8. doi:10.3109/17518423.2014.913081

Kahneman, D., & Norman, J. (1964). The time-intensity relation in visual perception as a function of observer's task. *Journal of Experimental Psychology*, *68*(3), 215–220.

Kaye, D. (2005). *Seriously silly: How to entertain children with magic and comedy*. Washington: Kaufman & Company.

Kelley, H. (1980). The management of causal attributions. In D. Gurlitz (Ed.), *Perspectives on attribution research and theory* (pp. 19–35). Cambridge, MA: Ballinger Publishing Company.

Kiev, A., & Frank, J. D. (1964). *Magic, faith, and healing: Studies in primitive psychiatry today*. Free Press of Glencoe.

Kleinke, C. L. (1977). Compliance touching to requests made by gazing and experimenters in field settings. *Journal of Experimental Social Psychology*, *13*, 218–223.

Kline, R. B. (2013). *Beyond significance testing: Reforming data analysis methods in behavioral research* (Second). Washington, DC: American Psychological Association.

Kuhn, G., & Martinez, L. M. (2012). Misdirection – past, present, and the future. *Frontiers in Human Neuroscience*, *5*. doi:10.3389/fnhum.2011.00172

Kuhn, G., & Tatler, B. W. (2005). Magic and fixation: Now you don't see it, now you do. *Perception*, *34*(9), 1155–1161.

Kuhn, G., Amlani, A. A., & Rensink, R. A. (2008). Towards a science of magic. *Trends in Cognitive Sciences*, *12*(9), 349–354. doi:10.1016/j.tics.2008.05.008

Lange, R., Thalbourne, M. A., Houran, J., & Storm, L. (2000). The Revised Transliminality Scale: Reliability and validity data from a Rasch top-down purification procedure. *Consciousness and Cognition*, *9*(4), 591–617.

Libet, B., Gleason, C. A., Wright, E. W., & Pearl, D. K. (1983). Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential). The uncon-

scious initiation of a freely voluntary act. *Brain: A Journal of Neurology*, *106*, 623–642. doi:10.1093/brain/106.3.623

Lipko, A., Dunlosky, J., & Merriman, W. (2009). Persistent overconfidence despite practice: The role of task experience in preschoolers' recall predictions. *Journal of Experimental Child Psychology*, *103*(2), 152–166. doi:10.1016/j.jecp.2008.10.002

Macknik, S. L., King, M., Randi, J., Robbins, A., Teller, Thompson, J., & Martinez-Conde, S. (2008). Attention and awareness in stage magic: Turning tricks into research. *Nature Reviews Neuroscience*, *9*(11), 871–879.

Meyers, L., Gamst, G., & Guarino, A. (2006). *Applied multivariate research: Design and interpretation*. Sage Publications.

Mulckhuyse, M., Talsma, D., & Theeuwes, J. (2010). Grabbing attention without knowing: Automatic capture of attention by subliminal spatial cues. *Journal of Vision*, *7*(7), 1081–1081. doi:10.1167/7.9.1081

Murdock, B. B. (1962). The serial position effect of free recall. *Journal of Experimental Psychology*, *64*(5), 482–488. doi:10.1037/h0045106

Newell, B. R., & Shanks, D. R. (2014). Unconscious influences on decision making: A critical review. *Behavioral and Brain Sciences*, 1–19. doi:10.1017/S0140525X12003214

Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review*, *84*(3), 231–259. doi:10.1037/0033-295X.84.3.231

Olson, J. A. (2012). Pick a card, not any card. *Genii: The Conjurors' Magazine*.

Olson, J. A., Amlani, A. A., & Rensink, R. A. (2012). Perceptual and cognitive characteristics of common playing cards. *Perception*, *41*(3), 268–286. doi:10.1068/p7175

Olson, J. A., Amlani, A. A., Raz, A., & Rensink, R. A. (2015a). Influencing choice without awareness. *Consciousness and Cognition*. doi:10.1016/j.concog.2015.01.004

Olson, J. A., Demacheva, I., & Raz, A. (2015b). Explanations of a magic trick across the life span. *Frontiers in Psychology*, *6*(219), 1–5. doi:10.3389/fpsyg.2015.00219

Phelps, K. E., & Woolley, J. D. (1994). The form and function of young children's magical beliefs. *Developmental Psychology*, *30*(3), 385.

Pliske, R. M., & Mutter, S. A. (1996). Age differences in the accuracy of confidence judgments. *Experimental Aging Research*, *22*, 199–216. doi:10.1080/03610739608254007

Polito, V., Barnier, A. J., & Woody, E. Z. (2013). Developing the Sense of Agency Rating Scale (SOARS): An empirical measure of agency disruption in hypnosis. *Consciousness and Cognition*, *22*(3), 684–96. doi:10.1016/j.concog.2013.04.003

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology*, *58*, 1–23. doi:10.1146/annurev.psych.58.110405.085516

Pronin, E., & Kugler, M. B. (2007). Valuing thoughts, ignoring behavior: The introspection illusion as a source of the bias blind spot. *Journal of Experimental Social Psychology*, *43*(4), 565–578. doi:10.1016/j.jesp.2006.05.011

R Core Team. (2014). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.r-project.org

Rensink, R. A., & Kuhn, G. (2014). A framework for using magic to study the mind. *Frontiers in Psychology*, *5*(1508). doi:10.3389/fpsyg.2014.01508

Rissanen, O., Pitkänen, P., Juvonen, A., Kuhn, G., & Hakkarainen, K. (2014). Expertise among professional magicians: An interview study. *Frontiers in Psychology*, *5*(1484).

Rosengren, K. S., & Rosengren, E. C. (2007). Discovering magic. In N. Mulholland (Ed.), *The psychology of Harry Potter: An unauthorized examination of the boy who lived* (pp. 123–134). Dallas, TX: Ben Bella Books Inc.

Rozin, P., Scott, S., Dingley, M., Urbanek, J. K., & Kaltenbach, M. (2011). Nudge to nobesity I: Minor changes in accessibility decrease food intake, *6*(4), 323–332.

Shalom, D. E., de Sousa Serro, M. G., Giaconia, M., Martinez, L. M., Rieznik, A., & Sigman, M. (2013). Choosing in freedom or forced to choose? Introspective blindness to psychological forcing in stage-magic. *PLoS ONE*, *8*(3), e58254. doi:10.1371/journal.pone.0058254

Sharpe, S. H. (1988). *Conjurers' Psychological Secrets*. Calgary, AB: Hades Publications.

Shin, H. E., Bjorklund, D. F., & Beck, E. F. (2007). The adaptive nature of children's overestimation in a strategic memory task. *Cognitive Development*, *22*, 197–212. doi:10.1016/j.cogdev.2006.10.001

Shiv, B., & Fedorikhin, A. (2011). Heart and mind in conflict: The interplay of affect and cognition in consumer decision making. *Journal of Consumer Research*, *26*(3), 278–292. doi:10.1086/209563

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2011). False-positive psychology: Undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychological Science*, *22*(11), 1359–66. doi:10.1177/0956797611417632

Subbotsky, E. (2001). Causal explanations of events by children and adults: Can alternative causal modes coexist in one mind? *British Journal of Developmental Psychology*, *19*(1), 23–45. doi:10.1348/026151001165949

Subbotsky, E. (2004). Magical thinking in judgments of causation: Can anomalous phenomena affect ontological causal beliefs in children and adults? *British Journal of Developmental Psychology*, *22*, 123–152.

Subbotsky, E. (2010). *Magic and the Mind: Mechanisms, Functions, and Development of Magical Thinking and Behavior*. New York: Oxford University Press.

Subbotsky, E. (2014). The belief in magic in the age of science. *SAGE Open*, *4*, 1–17. doi:10.1177/2158244014521433

Teller. (2012). *Teller Talks: The Science Behind Magic Tricks*. Talk of the Nation.

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: Improving decisions about health, wealth, and happiness*. Yale University Press.

Wansink, B. (2004). Environmental factors that increase the food intake and consumption volume of unknowing consumers. *Annual Review of Nutrition*, *24*(217), 455–479. doi:10.1146/annurev.nutr.24.012003.132140

Wansink, B. (2007). *Mindless eating: Why we eat more than we think*. Random House LLC.

Wansink, B., & Sobal, J. (2007). Mindless eating: The 200 daily food decisions we overlook. *Environment and Behavior*, *39*(1), 106–123. doi:10.1177/0013916506295573

Wegner, D. M. (2003). *The illusion of conscious will*. MIT press.

Wickham, H. (2009). *ggplot2: Elegant graphics for data analysis*. Springer.

Williams, H., & McOwan, P. (2014). Magic in the machine: A computational magician's assistant. *Frontiers in Psychology*, *5*(1283). doi:10.3389/fpsyg.2014.01283

Wilson, K., & French, C. C. (2014). Magic and memory: Using conjuring to explore the effects of suggestion, social influence and paranormal belief on eyewitness testimony for an ostensibly paranormal event. *Frontiers in Psychology*, *5*(1289). doi:10.3389/fpsyg.2014.01289

Wilson, M. A. (1988). *Mark Wilson's Complete Course in Magic*. Philadelphia: Courage Books.

Woolley, J. D. (1997). Thinking about fantasy: Are children fundamentally different thinkers and believers from adults? *Child Development*, *68*(6), 991–1011.

Zell, E., & Alicke, M. D. (2011). Age and the better-than-average effect. *Journal of Applied Social Psychology*, *41*(5), 1175–1188.

A. Questionnaire for magicians

Magicians completed the following questionnaire online.

1. What is your age?
2. What is your gender?
3. What country do you live in?
4. What city?
5. How many years have you been studying/practising magic?
6. How many years have you been performing professionally?
7. How would you rate your knowledge of magic?[1]
    - Excellent
    - Good
    - Satisfactory
    - Poor
    - None
8. Beyond performing magic, how would you rate your knowledge of deception, con-artists, cheats, scams, and other such hustle 'skills'?[1]
    - Excellent
    - Good
    - Satisfactory

[1] Respondents could select one option.

- Poor
- None

9. Do you think science can help magic (e.g., by coming up with new effects or improving existing ones)?[1]

    - Definitely
    - Probably
    - Maybe
    - Probably not
    - Definitely not

10. Why or why not?

11. Do you think knowledge of magic can help advance science?[1]

    - Definitely
    - Probably
    - Maybe
    - Probably not
    - Definitely not

12. Why or why not?

13. Can you think of any outstanding magicians who were also reputable scientists? They can be historic or current.

B. Developmental questionnaire

The experimenter showed the children the magic trick then asked them the following questions. Common answers are shown in square brackets.

1. Have you seen this trick before? [88% no]
2. Do you think you know how magicians do this trick? [74% no]
3. Please tell us how magicians could do this trick. [62% offered an explanation other than "I don't know"]
4. How confident are you of this explanation? (1: not at all, 2: a bit, 3: some, 4: a lot, 5: a whole lot) [$M = 2.64$]
5. Do you think this is a camera trick? [54% yes]
6. Please watch the video and write the specific TCG time [shown in the video] the pen leaves the magician's hands. [$M = 6.92$ s; secret around 4–5 s, 17% answered within this range. Children had difficulty answering this question so it was kept only for consistency with the adult version of the questionnaire.]
7. What would you need to do this trick?[1]
    - String [14%]
    - *Safety pin(s)* [11%]
    - Magnets [19%]
    - Special lights [16%]

[1] None or multiple can be selected. Emphasis here shows correct (or plausible) items.

- *Special clothing (for example: certain colour, with pockets)* [38%]
- *Stickers* [7%]
- *Rubber bands* [11%]
- Magic potion [17%]
- Mirrors [7%]
- *Pen* [81%]
- Other (specify) [1 answered "a hidden accomplice"]

8. How does the magician do it?[1]

- He makes you look in the wrong spot. [19%]
- He uses superpowers. [11%]
- He still has the pen in his hands, but you cannot see it. [28%]
- His magic potion eats up the pen. [15%]
- He lets the pen fall. [35%]
- He makes you forget what you saw. [14%]
- *He quickly moves the pen from one location to another.* [43%]
- Other (specify). [0%]

9. Please check what you think is **true**:[1]

- *The magician is using a real pen.* [41%]
- The pen actually breaks. [19%]
- The magician drops the pen. [34%]
- This special pen dissolves in magician's hands. [32%]
- The magician hides the pen between his fingers. [21%]
- None of the above. [13%]

10. How many times did you watch this video altogether? [$M = 5.42$]
11. Do you think that your first explanation for this trick is still good? [66% yes]
12. Please try to explain the trick in a better way.
13. How confident are you of this explanation? (1: not at all, 2: a bit, 3: some, 4: a lot, 5: a whole lot) [$M = 2.96$]