Cognition 130 (2014) 174–185

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Working Wonders? Investigating insight with magic tricks

Amory H. Danek [a,*], Thomas Fraps [b], Albrecht von Müller [c], Benedikt Grothe [a], Michael Öllinger [c,d]

[a] Division of Neurobiology, Department Biology II, Ludwig-Maximilians-Universität München, Grosshaderner Straße 2, 82152 Planegg-Martinsried, Germany
[b] Trick 17 magic concepts, Neureutherstr. 17, 80799 Munich, Germany
[c] Parmenides Foundation, Kirchplatz 1, 82049 Munich, Germany
[d] Department Psychology, Ludwig-Maximilians-Universität München, Leopoldstr. 13, 80802 Munich, Germany

A R T I C L E I N F O

Article history:
Received 27 November 2011
Revised 29 August 2013
Accepted 4 November 2013

Keywords:
Insight problem solving
Aha! experience
Constraint relaxation
Magic
Representational change

A B S T R A C T

We propose a new approach to differentiate between insight and noninsight problem solving, by introducing magic tricks as problem solving domain. We argue that magic tricks are ideally suited to investigate representational change, the key mechanism that yields sudden insight into the solution of a problem, because in order to gain insight into the magicians' secret method, observers must overcome implicit constraints and thus change their problem representation. In Experiment 1, 50 participants were exposed to 34 different magic tricks, asking them to find out how the trick was accomplished. Upon solving a trick, participants indicated if they had reached the solution either with or without insight. Insight was reported in 41.1% of solutions. The new task domain revealed differences in solution accuracy, time course and solution confidence with insight solutions being more likely to be true, reached earlier, and obtaining higher confidence ratings. In Experiment 2, we explored which role self-imposed constraints actually play in magic tricks. 62 participants were presented with 12 magic tricks. One group received verbal cues, providing solution relevant information without giving the solution away. The control group received no informative cue. Experiment 2 showed that participants' constraints were suggestible to verbal cues, resulting in higher solution rates. Thus, magic tricks provide more detailed information about the differences between insightful and noninsightful problem solving, and the underlying mechanisms that are necessary to have an insight.

1. Introduction

Sometimes, genius strikes. This moment of sudden comprehension is known as insight and "is thought to arise when a solver breaks free of unwarranted assumptions, or forms novel, task-related connections between existing concepts" (Bowden, Jung-Beeman, Fleck, & Kounios, 2005, p. 322). Insightful problem solving is a fundamental thinking process and nearly one century of psychological research has been dedicated to demystifying it, yet its true nature remains elusive (see Chu & MacGregor, 2011, for a review).

The feeling of suddenly knowing the solution to a difficult problem is generally accompanied by a strong affective response, the so-called Aha! experience, and a high confidence that the solution is correct (Sternberg & Davidson, 1995). Furthermore, insight is thought to be closely linked to processes that restructure the mental representation of a problem (Duncker, 1945; Kaplan & Simon, 1990; Ohlsson, 1992). More specifically, the representational change theory (RCT, Knoblich, Ohlsson, Haider, & Rhenius, 1999; Ohlsson, 1992) assumes that prior knowledge and inappropriate assumptions result in self-imposed constraints that establish a biased representation of the problem and thus prevent a solution. The RCT postulates

* Corresponding author. Tel.: +49 89 21086470; fax: +49 89 452093511.
E-mail address: amory.danek@lmu.de (A.H. Danek).

0010-0277/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cognition.2013.11.003

the process of *constraint relaxation* as one possibility to change the biased problem representation, i.e. the over-constrained assumptions must be relaxed. For example, in Katona's Triangle Problem (1940), participants were asked to build four equilateral triangles with only six matchsticks. The problem cannot be solved if a two-dimensional representation is used, this being the typical approach of most problem solvers. It is necessary to overcome the self-imposed "two-dimension" constraint and search for a three-dimensional solution, that is, by building a tetrahedron.

First empirical evidence for constraint relaxation was provided by Knoblich et al. (1999; see also Knoblich, Ohlsson, & Raney, 2001; Öllinger, Jones, & Knoblich, 2008) who found that the degree of necessary constraint relaxation was mirrored in the differential difficulty of individual problems. However, it remains difficult to directly demonstrate that constraints were actually relaxed or even that they existed before the problem was solved, because the sources of difficulty of a specific problem are often unknown or highly variegated. The classical 9-dot problem is one example for a problem with several different sources of difficulty (Kershaw & Ohlsson, 2004; Öllinger, Jones, & Knoblich, 2013b).

In the past, researchers have confined themselves to investigating insight problem solving mostly in the framework of a small set of insight problems. Reviewing the tasks available so far, MacGregor and Cunningham (2008) identified a need for new sources of insight problems and suggested rebus puzzles as one potential addition. Another relatively new set of problems, already widely used, are compound remote associate problems (e.g. Bowden & Jung-Beeman, 2003, Sandkühler & Bhattacharya, 2008, adapted from the Remote Associates Test by Mednick, 1962). However, like so many classical problem solving tasks, both of these are restricted to verbal material and rely on access to an answer that is already stored in memory (the solution word) rather than on the generation of a truly novel solution. In the spatial domain, matchstick arithmetic tasks (Knoblich et al., 1999) are an important and relatively new contribution. Still, although the use of these tasks has brought forward fruitful results (e.g. Knoblich et al., 2001; Öllinger, Jones, & Knoblich, 2006), it seems appropriate to take a more unconventional approach beyond the current problem domains to better understand insight problem solving.

Here, we propose a new task domain: Magic tricks. We suggest that this more applied domain allows new approaches to reveal the underlying mechanisms (e.g. constraint relaxation) by manipulating particular knowledge aspects in a broader and more natural way than in artificial geometrical or verbal puzzles. We assume that this new domain provides generalized results that show that insightful problem solving is a special type of thinking that can be clearly demarcated from other, more analytical ways of problem solving (see Weisberg & Alba, 1981; Öllinger & Knoblich, 2009). Specifically, we hypothesize that:

(1) Magic tricks allow to differentiate between insight and noninsight problem solving (process hypothesis).
(2) Magic tricks activate constraints that determine the problem solving process (constraint hypothesis).
(3) The time course of the two types of problem solving is different, with insight solutions reached earlier (time course hypothesis).
(4) Participants' confidence in the correctness of their solution differs between insight and noninsight problem solving (confidence hypothesis).

1.1. Magic tricks as a new insight task

The ancient art of conjuring could perhaps be called "applied psychology" in the sense that magicians systematically exploit the limitations of human visual perception and attention. Magicians deliberately evoke inappropriate constraints that hinder the observer from seeing through the magic trick. The experiment begins when the curtain is raised – and, just as any skilled experimenter, the magician keeps improving his methods from performance to performance based on the data (feedback) that is provided by the audience's reactions.

Historically, psychologists' attempts to link magic and psychology date as far back as the 19th century (Jastrow, 1888). More recently, it has been suggested that magic techniques could be adopted as research tools for cognitive science and first studies have already been published in the field of visual attention with special magic tricks as stimuli (e.g. Kuhn, Kourkoulou, & Leekam, 2010; Kuhn & Land, 2006; Kuhn & Tatler, 2005; Kuhn, Tatler, Findlay, & Cole, 2008; Parris, Kuhn, Mizon, Benattayallah, & Hodgson, 2009). These studies demonstrate how magic tricks can be utilized to learn more about human visual perception and attention (see Kuhn, Amlani, & Rensink, 2008, for a thorough discussion).

In the present study, we take this one step further by presenting magic tricks and asking participants to find out how the trick worked, i.e. which method was used by the magician to create the magic effect. We assume that if people overcome the over-constrained problem representation induced by the magician and find the "solution" of a magic trick, they will experience insight. We see two main reasons for that assumption:

First, similar to classical insight problems (Weisberg, 1995), the domain of magic tricks activates self-imposed constraints (Ohlsson, 1992; Öllinger & Knoblich, 2009). Besides sleight of hand, many magic tricks exploit implicit assumptions of the spectator as part of their methods (e.g. if someone performs a throwing motion the spectator expects that he will throw something). The magician benefits from the fact that these constraints are activated highly automatically and that it is almost impossible to overcome them (Tamariz, 1988). Consequently, the subjective search space (Kaplan & Simon, 1990; Newell & Simon, 1972) for possible explanations of an observed trick is fairly constrained. In contrast to insight problems, magic stimuli do not consist of a riddle or a puzzle, but instead the problem is consolidated by the discrepancy between the observed event with unexpected outcome (Parris et al., 2009) and the prior knowledge activated by such an apparently familiar event. This discrepancy often leads the magician's audience into an impasse – a state of mind in which people are completely puzzled and have no idea how this magic effect could possibly have taken place. To overcome such an impasse and find the solution, the over-constrained assumptions must be relaxed (RCT, Fleck & Weisberg, 2013; Jones, 2003; Kershaw, Flynn, & Gordon, 2013; Kershaw & Ohlsson, 2004; Ohlsson, 1992; Thevenot & Oakhill, 2008; Öllinger, Jones, Faber, & Knoblich, 2013a; Öllinger, Jones, & Knoblich, 2013b; Öllinger et al., 2008), as outlined before.

Second, a magic trick can be considered as a highly intriguing problem, which strongly motivates the observer to find a solution. Observing something impossible happening right in front of your eyes poses a challenge for your rationality, and therefore, after the first sensation of wonder and astonishment has passed, the situation is critically analysed. Anyone who has ever witnessed a magic performance, will remember the strong desire to know how the magic effect is achieved (the usual response is "Let me see that again!"). Of course, magicians rarely offer such second chances, but that is exactly what we did in the present work.

We infer from the first point that it might be possible to gain sudden insight into the inner working of a magic trick by relaxing self-imposed constraints (constraint hypothesis). This does not exclude that tricks can also be solved in a more analytical and step-wise way, as also discussed in classical insight problems (Evans, 2008; Metcalfe, 1986; Weisberg, 1995), e.g. by systematically thinking through different solution possibilities. In this case, we assume that the solving process will take longer and that the solution will not be experienced as "sudden" anymore (time course hypothesis). To differentiate between these two solving processes, we will use the subjective Aha! experience as a classification criterion to differentiate between *insight solutions* (solutions accompanied by an Aha!) in contrast to *noninsight solutions* (solutions without Aha!). That is, we adopted the common approach (e.g. Jarosz, Colflesh, & Wiley, 2012; Jung-Beeman et al., 2004; Kounios et al., 2006, 2008) introduced by Bowden and Jung-Beeman (2007) and Bowden et al., (2005) of asking participants directly if they had experienced an Aha! or not. In addition, we assessed participants' feeling of confidence for each solution, expecting that insight solutions would differ from noninsight solutions with regard to these ratings (confidence hypothesis).

For our experimental rationale, it is important to note that each magic trick consists of an *effect* and of a *method* (Ortiz, 2006; Tamariz, 1988). The magic effect is what the observer perceives (e.g. a coin vanishes) and the method is how the trick works, the secret behind the effect (e.g. skill, mechanical devices, misdirection). Conjurers employ a method to produce an effect (e.g. Lamont & Wiseman, 1999). Typically, the magician tries to guide the spectators' attention away from the method and towards the effect. In the present study, participants experienced the effect and were then asked to discover the method.

A second important point to consider is that in contrast to most verbal puzzles or riddles, magic tricks do not have one clear unambiguous solution. Of course, for each magic trick, there exists one *true* solution, that is, the method that was actually used by the magician. Still, other methods to achieve the magic effect might be conceivable (Tamariz, 1988). In fact, almost every conjuring effect can be achieved by several different methods, for example, Fitzkee compiled a list of possible methods for 19 basic effects that comprises 300 pages (Fitzkee, 1944, quoted according to Lamont & Wiseman, 1999, p. 7). Which method the conjurer applies depends on the individual strengths of each method and on the performing situation (e.g. large vs. small audience). Participants might find the true solution, but might perhaps also come up with another plausible solution or alternatively, a solution that is actually impossible (given the information from the video clips), i.e. a false solution.

An example of a magic trick illustrates our account (trick #20, see Appendix A. The full video clip can be found at http://www.youtube.com/watch?v=3B6ZxNROuNw). A coffee mug and a glass of water are presented to the audience. The magician pours water into the mug, as depicted in Fig. 1a. Holding the mug with his arms stretched, the magician snaps his fingers – then he turns the mug upside down and a large ice cube drops out (Fig. 1b). In a few seconds, the water has turned into ice. How does this work?

Most people react with astonishment and disbelief because according to their prior knowledge, this is not possible (Parris et al., 2009). Water can turn into ice, but not in such a short time period (at room temperature), and additionally, it does not turn into a perfect ice cube by itself. Seemingly, causal relationships and laws of nature that were acquired through past experience have been violated (Ohlsson, 1992; Parris et al., 2009). An artful magician induces the impression that he controls the natural laws in a supernatural way and can bend them as he wishes. Besides astonishment, the spectator is faced with the open question of how the magician did the trick: A problem is consolidated that must be solved. In the subsequent problem solving process, the situation is analysed, setting up the initial problem representation. Due to observers' prior knowledge, this representation is often biased and overconstrained (Knoblich et al., 1999). Wrong assumptions turn into constraints that restrict the search space and prevent a solution. In the example trick, the following assumptions are skilfully evoked by the magician:

Fig. 1a. Screenshot from the beginning of the trick.

Fig. 1b. Screenshot from the end of the trick.

1. The mug and the glass are real, ordinary objects.
2. The water is real water.
3. The mug is empty.
4. The water is poured into the mug.
5. It is a real ice cube.
6. There is no water left in the mug after the ice cube has fallen out.

Some of these assumptions may be correct, but others are wrong, and these are the crucial assumptions that create the magic effect. They have become constraints that restrict the search space for a solution. The constraints have to be relaxed to attain a broader search space that includes the solution.

In the present example, only the third assumption is wrong. The "empty" mug is actually filled with a piece of special white napkin, glued to the bottom of the mug, and the ice cube. Because the inner side of the mug is also white, the observer can neither detect the napkin nor the transparent ice cube if the mug is kept in motion while casually showing it empty. The water is indeed poured into the mug, but is fully absorbed by the napkin. And voilà, only the ice cube falls out when the mug is turned upside down – it's magic!

We argue that if the observer achieves to overcome the initial constraint (empty mug), his search space is restructured (Kaplan & Simon, 1990; Öllinger et al., 2013b) and new solution possibilities are opened up allowing him to find the correct solution (napkin) or to think of other possibilities to contain the water (e.g. double bottom).

Taken together, we claim that a magic trick can be regarded as a challenging problem, and that the spectator takes the role of a problem solver who attempts to find explanations for the magic effect.

In Experiment 1, we implement the new domain of magic with the aim of differentiating between two types of problem solving processes, namely insight vs. noninsight problem solving (process hypothesis). If magic tricks actually trigger these two types of problem solving, we expect differences between them with regard to time course (insight solutions reached earlier, time course hypothesis) and subjective appraisal (confidence hypothesis).

2. Experiment 1

2.1. Method

2.1.1. Participants

50 healthy volunteers, most of them students (mean age 24.4 ± 3.3; 16 male), were recruited through announcements at the University of Munich and were paid 32 € for their participation. None of them had any neurological diseases and all had normal or corrected-to-normal acuity. Two participants were excluded because they did not solve any of the presented tricks resulting in a final sample size of 48.

2.1.2. Testing material

With the aid of a professional magician (TF), a careful pre-selection of magic tricks was conducted with regard to sensory as well as cognitive requirements: Only visual effects that could be performed in absolute silence, with no other interactive elements necessary (e.g. assistant, interaction with the audience). We used short tricks, with only one effect and one method. 40 magic tricks were selected and recorded in a standardized setting, again with the magician TF. We ran three pilot studies on a sample of 50 students to ensure that the tricks were understandable, i.e. that participants perceived and were able to report the intended magic effect. Tricks were also rated with regard to the extent of surprise that they caused (see Appendix A). Three tricks that turned out to be not feasible for a filmed performance were removed, and 17 tricks had to be improved in a second recording session (e.g. better camera angle). The final number of stimuli was 34 (plus 3 practice trials). The video clips that ranged from 6 to 80 s were presented on a 17" computer screen displayed by the Presentation® software version 12.1. The tricks covered a wide range of different magic effects (e.g. transposition, restoration, vanish) and methods (e.g. misdirection, gimmicks, optical illusions) and are listed in detail in Appendix A.

2.1.3. Design and procedure

Participants were seated in a distance of 80 cm in front of a computer screen. After filling in an informed consent, participants were orally instructed by the experimenter. Their task was to watch magic tricks and to discover the secret method used by the magician. Following Bowden and Jung-Beeman's approach (2007), participants were asked to categorize their solution experiences into insight and noninsight solutions. The instruction for these judgements (in German) read as follows (adapted from Jung-Beeman et al., 2004): "We would like to know whether you experienced a feeling of insight when you solved a magic trick. A feeling of insight is a kind of "Aha!" characterized by suddenness and obviousness. Like an enlightenment. You are relatively confident that your solution is correct without having to check it. In contrast, you experienced no Aha! if the solution occurs to you slowly and stepwise, and if you need to check it by watching the clip once more. As an example, imagine a light bulb that is switched on all at once in contrast to slowly dimming it up. We ask for your subjective rating whether it felt like an Aha! experience or not, there is no right or wrong answer. Just follow your intuition." The experimenter interacted with participants until they felt prepared to differentiate between these two experiences.

After three practice trials, a randomized sequence of 34 magic tricks was presented. If a trick was solved, participants had to indicate on a trial-by-trial basis whether they had experienced an Aha! during the solution. If participants failed to solve the trick, the video clip was repeated up to two more times while solving attempts continued.

As soon as they had found a potential solution, participants were required to press a button. The button press stopped the video clip and terminated the trial. A dialog with the following question appeared: Did you experience an Aha! moment? Participants indicated Yes or No with a mouse click. Subsequently, they were prompted to type in their solution on the keyboard and gave a rating of how confident they felt about the correctness of their solution on a scale from 0% to 100%. Fig. 2 illustrates the procedure.

Please note that participants never received any feedback about the accuracy of their solutions. To control for familiarity of tricks, at the end of the entire experiment participants received a questionnaire with screenshots from all 34 tricks and were asked to indicate whether the solution to a trick was previously known to them. These tricks were excluded on an individual level and handled as missing data. The entire experiment lasted about 2 h.

Note that there was a second testing session 14 days later, in which participants had to perform an unexpected recall of solutions. These results are reported elsewhere (Danek, Fraps, von Müller, Grothe, & Öllinger, 2013). Furthermore, in each session, an additional quantitative and qualitative assessment of participants' individual Aha! experiences was conducted after the end of the experiment. This data is reported in Danek, Fraps, von Müller, Grothe, and Öllinger (submitted for publication), but not relevant for the present analysis and therefore not considered further.

Trick repetition: In general, magic tricks are fairly difficult. To increase solution rates, each trick was repeated up to three times, thereby breaking the old magicians' rule: Never show the same trick twice! For the reader interested in magic, please consult Lamont, Henderson, and Smith (2010) for a critical discussion of that point. First evidence that trick repetition increases the likelihood of detecting the method was provided by Kuhn and Tatler (2005). In a pilot study, we confirmed this finding and could show that in about 50% of trials, participants were able to detect the method after one repetition of the trick.

2.2. Results of Experiment 1

2.2.1. Response coding

Participants solved magic tricks and categorized their solutions into insight (with Aha!) and noninsight solutions (without Aha!). We use this categorization as our independent variable. The dependent variables are: Solution Rate (number of solved tricks), Solution Accuracy (true or false) and Number of Presentation (number of times a trick was presented until participants solved the trick or until they failed after the third presentation). We applied repeated measures analyses of variance (ANOVA) of the mean

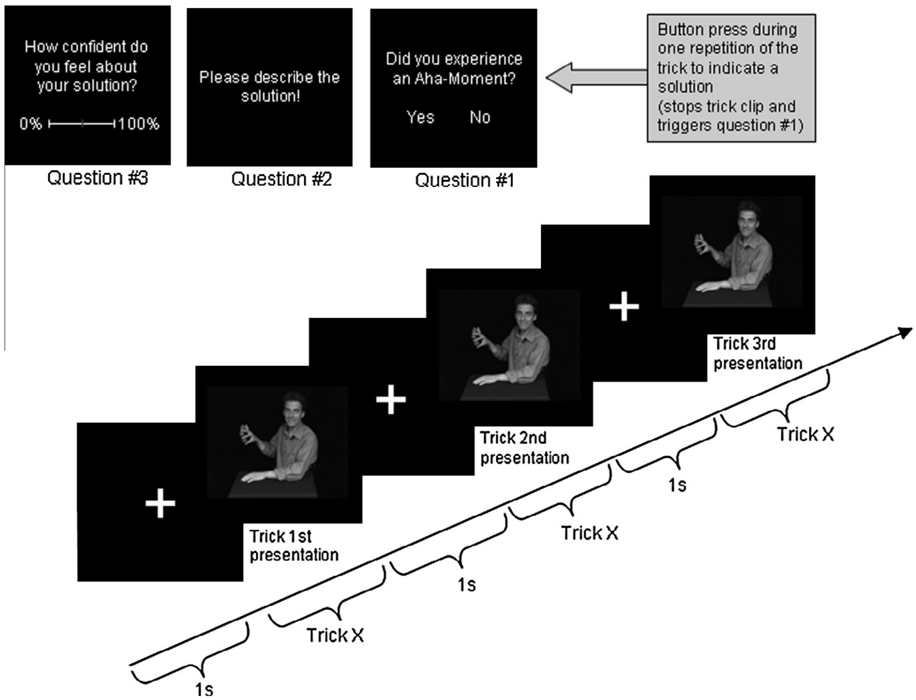

Fig. 2. Procedure of one trial. Different phases and timing are displayed. Note that individual tricks vary in length.

number of solved tricks for statistical analyses. All p-values are Greenhouse-Geisser corrected.

Participants' solutions were coded off-line as true or false by two independent raters, Cronbach's alpha as a measure of inter-rater reliability was 0.99. *True solutions* were identical with the procedure that the magician had actually used. *False solutions* consisted of methods that were impossible with respect to the conditions seen in the video clip. If no solution at all had been suggested, the tricks were coded as unsolved.

In some trials (5.4% of all solutions), participants suggested an alternative, but potentially conceivable method (see introduction). We added those to the true solutions category. 5.2% of the data points had to be discarded because the tricks were already familiar to participants.

2.2.2. Solution rate and accuracy

For this analysis, results were collapsed across repetitions. 45.8% of all trials (34 tricks x 48 participants yielded a total of 1632 trials) were not solved, i.e. participants watched the trick three times without suggesting a solution. Those trials were excluded from further analyses because no insight could occur. In 49%, participants suggested a solution (coded as either true or false). For 41.1% of the solved magic tricks, participants had reported insight. The remaining 58.9% were classified as noninsight solutions. Fig. 3 shows the percentages of true and false insight and noninsight solutions. The ratio of true/false solutions clearly varies between the two solution categories (15.6%/4.6% vs. 16.1%/12.7%), with only few false solutions for insightful problem solving.

The difference between insight and noninsight problem solving is illustrated more pointedly in Fig. 4, depicting the mean number of solved tricks for each solution category. A repeated measures ANOVA with the factors Solution Type

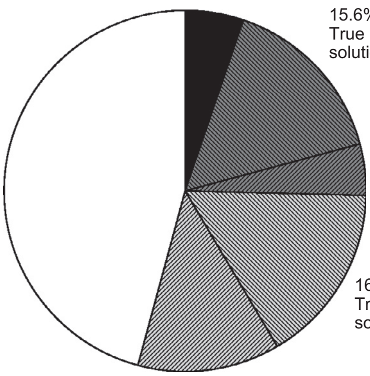

Fig. 3. Overview on the data obtained. Mean percentages of not solved and solved tricks, and their proportion of true and false solutions in the insight and noninsight categories. True insight solution: true or plausible solution + reported Aha! experience; False insight solution: impossible solution + reported Aha! experience; True noninsight solution: true or plausible solution, without Aha! experience; False noninsight solution: impossible solution, without Aha! experience.

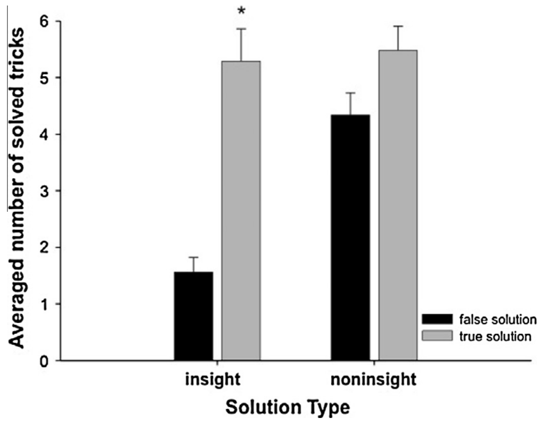

Fig. 4. Mean number of solved tricks (out of 34) as a function of Solution Type and Accuracy. Error bars denote standard errors of the mean. Grey bars indicate true solutions, black bars false solutions. Significant differences are marked with an asterix.

(insight vs. noninsight) and Solution Accuracy (true vs. false) was conducted, with the number of solved tricks as dependent variable. It revealed a significant main effect of Solution Type ($F(1, 47) = 7.18$, $p < .05$, $\eta^2_{partial} = .13$) with more noninsight than insight solutions and a significant main effect of Solution Accuracy ($F(1, 47) = 37.05$, $p < .01$, $\eta^2_{partial} = .44$) with more true than false solutions. There was also a significant interaction ($F(1, 47) = 12.47$, $p < .01$, $\eta^2_{partial} = .21$).

Follow-up t-tests showed that there were significantly ($t(47) = 7.35$, $p < .01$, Cohen's dz = .98) more true insight solutions ($M = 5.29$, $SD = 3.91$, grey bar) than false insight solutions ($M = 1.56$, $SD = 1.83$, black bar). This is in contrast to noninsight solutions with no significant difference between the number of true ($M = 5.48$, $SD = 3.0$) and false ($M = 4.33$, $SD = 2.73$) solutions.

2.2.3. Number of presentations

Tricks were presented up to three times. Therefore, a trick could be solved during the first, second or third presentation. To test hypothesis 3, we investigated the respective time course of insight vs. noninsight solutions, again using the number of solved tricks as dependent variable. Fig. 5 shows differences between insight and noninsight problem solving with regard to time course: Insight solutions occurred most frequently during the second presentation of the trick (bar shaded in light grey) and then during the third presentation (bar shaded in dark grey). For noninsight solutions, this pattern is reversed. Hardly any problems were solved during the first presentation (black bars).

We conducted an ANOVA for repeated measures with the factors Solution Type (insight vs. noninsight) and Number of Presentation (P1, P2, and P3) that revealed significant main effects for both factors (Solution Type, $F(1, 47) = 7.12$, $p < .05$, $\eta^2_{partial} = .13$, and Presentation, $F(2, 94) = 82.42$, $p < .01$, $\eta^2_{partial} = .64$). For the main effect of the factor Presentation, follow-up paired t-tests showed that significantly less tricks were solved in P1 ($M = 1.1$, $SD = 1.6$) than in P2 ($M = 7.8$, $SD = 3.5$) with $t(47) = 14.16$,

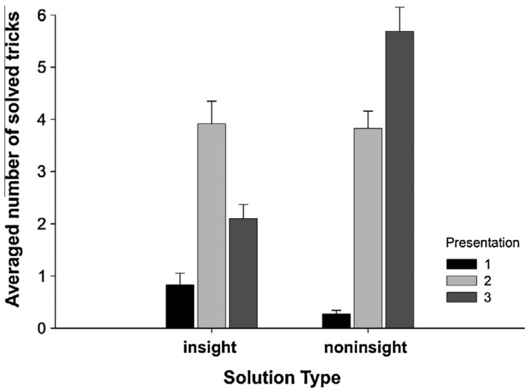

Fig. 5. Mean number of solved tricks (out of 34) as a function of Solution Type and Number of Presentation. Error bars denote standard errors of the mean. Black bars depict the number of solutions during the first presentation of the trick, light grey bars depict solutions during the second presentation and dark grey bars depict solutions during the third presentation.

$p < .01$, Cohen's dz = 1.9 and also significantly less than in P3 ($M = 7.8$, $SD = 3.3$) with $t(47) = 11.97$, $p < .01$, Cohen's dz = 1.8. There was no significant difference between P2 and P3.

The significant interaction, $F(2, 94) = 32.31$, $p < .01$, $\eta^2_{\text{partial}} = .41$, shows the differential time course for the two types of problem solving, with insight solutions reached earlier than noninsight solutions.

2.2.4. Confidence rating

To test hypothesis 4, we compared the mean confidence rating of insight solutions (84.62% on a scale from 0% to 100%) to the mean rating of noninsight solutions (63.08%). A significant difference ($t(45) = 11.22$, $p < .01$) was found, indicating that participants were more confident that their insight solutions were correct than that their noninsight solutions were correct.

2.3. Discussion of Experiment 1

Using magic tricks, we found evidence for two different types of solving processes, with 41.1% of solutions classified as insight solutions and the remaining 58.9% as noninsight solutions. The two solution types differed in their accuracy: Insight solutions were significantly more often true than false, whereas noninsight solutions were equally true or false. Consequently, having an insight results very likely in a true solution. This finding strongly provides evidence for the claim: "To gain insight is to understand something more fully" (Dominowski & Dallob, 1995, p. 37). Solving a problem by insight results in a deeper understanding of the problem (Sandkühler & Bhattacharya, 2008). Without insight, the chances for producing a true or a false solution were nearly even. The differentiation and analysis of true and false solution is, at least to our knowledge, completely new in the realm of insight problem solving. It provides first evidence that there might be a qualitative difference in the comprehension of a problem between step-wise, analytical problem solving, and problem solving by insight. This differentiation is a result of using the new domain of magic tricks that allows a degree of ambiguousness that cannot be found in most of the hitherto used mathematical, verbal or visual-spatial problems that are characterized by clear and unambiguous solutions.

As hypothesized, the data obtained provided a further differentiation between the two solution types, namely with regard to time course: Insight solutions were reached earlier than noninsight solutions, occurring more often during the 2nd presentation (P2) of the video clip than during the 3rd presentation (P3). For noninsight solutions, this pattern was reversed (more often in P3 than P2). This data shows that increasing the number of repetitions reduced insight solutions, and increased analytical, step-wise problem solving strategies. Watching the trick a second time, some participants gained sudden insight into the trick (insight solution). It seems conceivable that if participants did not experience insight during P2, they switched into an analytic mode. Consequently, solutions found during P3 were more seldom experienced as sudden, but based on previous solving attempts and the systematic exclusion of hypotheses. Therefore, if more repetitions than three were included in an experimental paradigm, we would predict even less insight events with increasing repetitions. This points also to a methodological problem of our paradigm: The repetition of the video stimuli might determine a search and exclusion strategy that could be different from working on a static problem outlet.

The present experiment reveals a third difference with regard to participants' subjective appraisal of their performance (confidence hypothesis): The individual certainty of having produced a correct response was significantly higher for insight solutions than for noninsight solutions.

Summing up, insight solutions occurred earlier, participants felt more confident about them and in fact, they were more likely to be true.

The finding of false insights (4.6% of all trials) has interesting theoretical implications. False insights are trials in which participants solved the trick, indicated that they had experienced insight, but suggested a methodically impossible solution. The existence of false insights has been debated, for example Sandkühler (2008, p. 2) states that "a true insight must lead to a correct solution". The Gestalt psychologists assumed that insight "always moves towards a better structural balance", believing in a "certain infallibility in insight" (Ohlsson, 1984, p. 68). This is in accordance with the immediate feeling of certainty (Sternberg & Davidson, 1995) that is often reported after insightful solutions (as it was the case in the present study, too). In contrast, Sheth et al. report the occurrence of incorrect solutions that were rated as highly insightful by problem solvers (2009, p. 1273). Ohlsson (1984, quoted in Ohlsson, 1992, p. 3) originally defined insight as "the sudden appearance in consciousness of the complete and correct solution". Acknowledging the existence of false insights, he later stated in a revision of his theory that the criterion of correctness of a solution is not useful for a definition of insight (Ohlsson, 1992). His conclusion that correctness of solution is a "contingent characteristic which accompanies some insights but not all" (Ohlsson, 1992, p. 3) is clearly supported by our data. We conclude that the present findings prove the existence of false insights, but show that they are far less likely than true insights.

Our first experiment demonstrated that solving magic tricks via insight differs from noninsight problem solving in three important aspects: Accuracy, time course and solution confidence. But one hypothesis remains to be tested: We claimed that magic tricks activate constraints that determine the problem solving process (constraint hypothesis) and the rationale of Experiment 1 is based on the implicit assumption that the subjective Aha! experience stands for the cognitive process of representational change and that constraint relaxation is the reason why the found differences occurred. This assumption is plausible, and it is supported by the existing literature (e.g. Metcalfe & Wiebe, 1987), but asks also for an empirical test showing that (1) constraints play a role in magic tricks and (2) those constraints can be changed. We will address these questions in Experiment 2.

3. Experiment 2

3.1. Introduction

In a second experiment, we address the assumption that magic tricks impose constraints that restrict observers' solution search space (constraint hypothesis). Because the constraints typically encountered by problem solvers are known and exploited by the magician, magic tricks represent an ideal domain to systematically manipulate constraints. For example, if the main obstacle in a trick consists of the fact that a ball is usually perceived as a whole (but is in fact a half-ball), we assume that this constraint can be relaxed by cueing the concept of a half-sphere. Therefore, it seems plausible that the imposed constraints determine the problem difficulty of the magic tricks. We hypothesize that such conceptual constraints can be relaxed by verbal cues and, consequently, solution rates will increase in comparison to an uninformed control group.

Constraint relaxation occurs spontaneously, but can also be triggered by cues, if the constraints are known (Öllinger et al., 2013b). There is evidence that providing cues can facilitate solutions to insight problems (Grant & Spivey, 2003; Thomas & Lleras, 2009), but there are also conflicting findings (Chronicle, Ormerod, & MacGregor, 2001; Ormerod, MacGregor, & Chronicle, 2002). Recently, we could demonstrate that in classical insight problems like the nine-dot problem and Katona's five-square problem, perceptual cues are only helpful if they restrict the initial search space and the relaxed search space at the same time. That is, cues help to navigate the initial search space and increase the likelihood of a representational change. After constraints are relaxed through a representational change, the search space increases even more and then cues are helpful again in order to restrict the larger search space, so that a solution can be found (Öllinger, Jones, & Knoblich, in press; Öllinger et al., 2013b).

3.2. Method

3.2.1. Participants

62 students (26.2 ± 6.3; 17 male) participated for 10 € in the experiment. None of them had any neurological diseases and all had normal or corrected-to-normal acuity. Participants were randomly assigned to either the experimental group (informative cues) or the control group (no informative cues), with 31 participants each.

3.2.2. Testing material

Magic tricks: A set of 12 tricks was selected from the original 34 tricks used in the previous experiment: Tricks # 2, 3, 4, 5, 6, 11, 12, 21, 23, 26, 27, 29 (see Appendix A for a detailed description). The tricks were filtered out using two criteria: (a) Tricks were very unlikely to be solved after the first presentation (solving rate after first viewing <10%). (b) It was possible and plausible to identify one constraint of each trick that might be the main source of problem difficulty (Kershaw & Ohlsson, 2004; Kershaw et al., 2013).

Cues: Three different approaches were used to identify the crucial constraints of each trick: First, the magician who had performed all tricks (TF) identified the main constraint that had to be relaxed in order to "see through the trick", i.e. the main source of difficulty. Second, one of the authors (AD) analyzed participants' written solution attempts from the first experiment, especially the false ones, to identify the ill-defined assumptions participants used. Third, a student who was not familiar with the research question watched all tricks and indicated which kind of cue would have helped her to find out the solution. Finally, based on this information, we created verbal cues (short sentences) that relaxed the putative main constraint, but did not give away the solution. For example, in trick #12, a fake throw from one hand to the other is performed, guiding observers' attention to the wrong hand and thus allowing a coin to vanish and re-appear under a napkin. The main constraint is the fake throw that triggers the wrong assumption that the coin has been transferred to the other hand. Thus, the cue is "transfer to other hand", inviting participants to think about the alleged transfer.

3.2.3. Design and procedure

After providing informed consent, participants were orally instructed by the experimenter to watch the magic tricks and try to discover the secret method used by the magician. The experimental group was told that there would be a hint after the first presentation of the trick. After two practice trials, a randomized sequence of the 12 magic tricks was presented. The procedure was identical to Experiment 1 (see Fig. 2), with the following changes: (1) Cues were presented immediately after the first presentation of the trick and before the fixation cross reappeared and lasted for 3000 ms. The control group was presented with the word "Text" instead of a cue, also for 3000 ms. 2) Participants were asked only question #2 ("Please describe the solution!"). Familiarity of tricks was again checked with a questionnaire. Experiment 2 lasted about 30 min.

3.3. Results of Experiment 2

3.3.1. Response coding and data analysis

Participants' solution attempts were coded off-line as solved or unsolved by two independent raters (Cronbach's alpha as a measure of inter-rater reliability was 0.98). We used the following two solution categories: *Solved* trials comprised solutions that were identical with the procedure that the magician had actually used or an alternative, potentially conceivable method. *Unsolved* trials consisted of methods that were impossible with respect to the conditions seen in the video clip. If no solution at all had been suggested, the tricks were coded as unsolved, too.

The dependent variable was the participants' mean percentage of solved tricks. It was calculated as follows: For each participant individually, the total number of solved tricks (ranging from 0 to 12) was divided by 12, i.e. the total number of presented tricks. When participants already knew a trick, the trick was discarded and the total number was weighted by 12 minus the number of discarded tricks. This applied to 1.5% of trials. We analyzed the data with an univariate ANOVA, with the between-subjects factor Testgroup (experimental vs. control).

3.3.2. Solution rates

The overall solution rate was 27%. On average, the experimental group (with informative cues) solved 33.2%, whereas the control group (not informative cues) solved 20.9%, as depicted in Fig. 6. There was a significant main effect for the factor Testgroup, $F(1,60) = 11.84$, $p = .001$, $\eta^2_{\text{partial}} = .17$.

3.4. Discussion of Experiment 2

Experiment 2 investigated the importance of constraints for the solution of magic tricks. It was assumed that if constraints play a role, cues might help to relax these and consequently would increase the solution rate. It was found that cues increased solution rates in comparison to a control group that received no informative cue. This might be evidence that constraints in magic tricks can be relaxed by pointing out the wrong assumptions that observers have made. It seems plausible to assume that subsequently, the biased problem representation is restructured, allowing the observer to solve the trick. Importantly, we found a significant, but only moderate increase in the solution rate when informative cues were provided (33.2% vs. 20.9%). That is, not all participants could benefit from the provided cue. First, this demonstrates that we did not tell the entire solution, but only a helpful cue. Second, this implicates that we did not resolve all sources of difficulty, a finding that is in line with the multiple-sources of difficulty account of Kershaw and Ohlsson (2004; see also Kershaw et al., 2013; Öllinger et al., 2013a,b), suggesting that having the right information is not sufficient for the solution of a problem if the participant does not know how to integrate the information in order to solve the problem (see Öllinger et al., 2013b). It could also be an indicator that some of our cues did not work in the intended way.

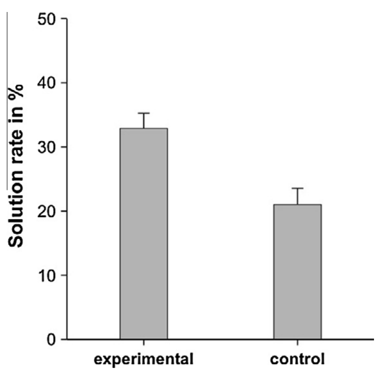

Fig. 6. Solution rates for the experimental and the control group.

In sum, Experiment 2 confirmed our hypothesis that constraints play a role in magic tricks and that those constraints can be relaxed via cues, facilitating a solution. This finding is in accordance with the concept of constraint relaxation postulated by the RCT (Knoblich et al., 1999; Ohlsson, 1992). Thus, magic tricks represent an ideal domain to systematically manipulate constraints.

4. General discussion

The present work provides evidence that the new task domain of magic tricks allows to differentiate between insight and noninsight problem solving, with insight solutions being more accurate, reached earlier and receiving higher ratings of confidence. Further, we could show that magic tricks activate constraints and that proper cues can help to overcome such constraints.

4.1. Theoretical implications

These results have three main theoretical implications: First, with regard to the long-standing debate of the nature of the insight process (e.g. Weisberg & Alba, 1981; and the reply by Dominowski, 1981), our results support the conceptualization of insight problem solving as a special process (Davidson, 1995, 2003) that is qualitatively different from analytical or re-productive thinking (e.g. Weisberg & Alba, 1981). This in accordance with a number of other recent studies (e.g. Jung-Beeman et al., 2004; Knoblich et al., 2001; Kounios et al., 2008; Subramaniam, Kounios, Parrish, & Jung-Beeman, 2009). Differences between insight and noninsight problem solving are not confined to solution accuracy, time course and solution confidence, but also extend to differences in memory processes, with insight solutions remembered better than noninsight solutions, as we could recently demonstrate in a related study (Danek et al., 2013).

Second, the present findings demonstrate the great potential of using magic tricks as a new insight problem solving task. That magic tricks can be solved either with or without insight is advantageous because it allows for a comparison of different problem solving processes (insight and noninsight problem solving), without changing the type of task used. Our results support the idea that any given problem may pose representational obstacles for some solvers, but not for others (Ash, Cushen, & Wiley, 2009) and therefore may be solved through insightful processes or through more analytical processes or a combination of both (Bowden et al., 2005). Another advantage of magic tricks is that the solutions are largely unknown. Only 5.2% (Exp 1) and 1.5% (Exp 2) of all trials had to be discarded in the present work. This is in clear contrast to most of the often used classical insight problems (e.g. the nine-dot problem) that can be found in psychology textbooks, in online resources or puzzle books, leading to a substantial number of participants that must be removed in each study due to familiarity.

Third, the findings from Experiment 2 provide evidence that constraints play an important role in magic tricks, and that they can be manipulated by appropriate cues, resulting in higher solution rates. Therefore, constraint relaxation can be regarded as a general mechanism that is sufficient to gain insight into the inner working of a magic trick. This finding can be integrated within the representational change theory of insight and expands her explanatory power.

4.2. Limitations

A problem of our paradigm is the repetition of video stimuli. This kind of presentation was, at least to our knowledge, never used before in insight problem solving, and therefore it is difficult to directly compare our findings with the existing literature that mostly used static problem displays. In general, a magic trick is a very complex stimulus that is made of a stream of actions. We decided to facilitate the solution process by introducing up to three repetitions of the same video clip to obtain sufficiently high solving rates. We cannot exclude the possibility that participants accumulated additional information during these repetitions, perhaps by attending to different parts of the visual display and therefore "discovering" previously unnoticed events. If participants had implemented such a strategy, this would speak more for an elaboration strategy instead of constraint relaxation as the basis for a solution. Elaboration means that the problem representation is "changed by being extended or enriched" (Ohlsson, 1992, p. 13) and has been proposed as another possibility to gain insight. Although the effectiveness of the cueing manipulation in Experiment 2 strongly supports the constraint relaxation explanation of our results, we cannot fully rule out the other possibility. Further studies that use e.g. only one presentation of the magic trick, and give participants enough time to "mentally simulate" the trick could help to clarify this question.

A further limitation is that the magic tricks might not have only one single constraint or source of problem difficulty (see Kershaw & Ohlsson, 2004; Kershaw et al., 2013). The solution rates from the cueing condition indicate this, since the rates are far from approaching 100%. Our interpretation is that there exist additional constraints that were not relaxed by the implemented cues. Successful solvers might use and integrate additional information. In future experiments, the cues could be improved, perhaps by using pictorial cues instead of verbal ones, and think-aloud protocols could be used to identify possible additional constraints that prevent insight into the problem.

In sum, we offer a new, feasible approach for investigating the complex phenomenon of insight that impacts on existing theories. In the long run, this work might help to further elucidate the process of insight problem solving which is a vital part of human thinking and yet so difficult to grasp.

Acknowledgements

We thank Matus Simkovic for help with programming the experiment. We also thank Eline Rimane, Svenja Brodt and Franca Utz for collecting part of the data and rating the solutions.

Appendix A. List of magic stimuli

	Trick name	Magic effect	Trick description	Solved[a]	With[b] Aha!	Surprise[c]
1	Knives	Transposition	Two differently colored knives change places	14.58	28.57	2.55
2	Orange	Transformation	An orange is transformed into an apple	16.67	50.00	3.57
3	Monte	Transposition	A card swaps places with another one	22.92	27.27	2.82
4	Rope	Restoration	A rope is cut in two pieces and restored to one	25.00	50.00	2.50
5	Coin Trick 1	Vanish	Out of three coins, one vanishes	27.08	23.08	2.91
6	Billiard Balls	Appearance	A little red ball multiplies	29.17	35.71	2.71
7	Coin Trick 2	Appearance and Vanish	A coin is held up in the air, vanishes and reappears	31.25	40.00	2.61
8	Card Trick 1	Telekinesis	Cards turn over by themselves	31.25	33.33	2.54
9	Rubik's Cube	Transformation	Rubik's cube is solved by throwing it up in the air	33.33	50.00	3.17
10	Salt	Vanish	Salt is poured in the fist from where it disappears	33.33	43.75	3.04
11	KetchupBottle	Vanish	A ketchup bottle is put in a bag and disappears	35.42	29.41	3.27
12	Coin Trick 3	Transposition	A coin wanders from the hand under a napkin	37.50	44.44	2.58

(*continued on next page*)

Appendix A (*continued*)

	Trick name	Magic effect	Trick description	Solved[a]	With[b] Aha!	Surprise[c]
13	Bottled Scarf	Vanish	A red scarf disappears from a closed bottle	39.58	36.84	3.00
14	Pen	Penetration	Paper is pierced by a pen, but remains intact	43.75	42.86	2.75
15	Money	Transformation	Sheets of white paper turn into 50 Euro bills	43.75	28.57	3.00
16	Matchsticks	Penetration	One matchstick wanders through another one without breaking it	45.83	50.00	2.59
17	Glass	Vanish	A champagne glass is covered by cloth and disappears	47.92	39.13	2.26
18	Red Scarf	Appearance	A large red scarf appears from nowhere	47.92	60.87	2.73
19	Card Trick 2	Restoration	A card is ripped in pieces and restored	50.00	33.33	3.22
20	Ice Cube	Transformation	Water is poured into a mug and transformed into an ice cube	50.00	25.00	3.14
21	Coin Trick 4	Penetration	A coin penetrates a sealed glass	52.08	20.00	3.00
22	Ball	Transformation	A ball gets transformed into a cube	52.08	36.00	2.50
23	Card Trick 3	Penetration	Cards are chained to each other and unchained without damage	54.17	30.77	3.25
24	Flying ball	Telekinesis (Levitation)	A ball is floating between the magician's hands	54.17	42.31	3.00
25	Card Trick 4	Transformation	Cards in a glass change their colours	58.33	42.86	2.50
26	Coin Trick 5	Transposition	3 coins wander from one hand into the other	62.50	40.00	2.67
27	Salt 'n Pepper	Vanish	Salt and pepper are poured into one hand and the pepper disappears	64.58	32.26	3.13
28	Flying Bun	Telekinesis (Levitation)	A bun is covered by a napkin and starts to fly	66.67	37.50	2.50
29	Bouncing Egg	Physical impossibility	A real egg is bounced repeatedly on the floor without breaking	72.92	25.71	3.05
30	Scarf to Egg	Transformation	A scarf turns into an egg	77.08	70.27	2.67
31	Bowling Ball	Topological impossibility (size)	A large bowling ball is carried in a thin suitcase	81.25	28.21	2.83
32	Coat Hanger	Topological impossibility (size)	A coat hanger is pulled from a small purse	83.33	50.00	2.88
33	Cigarette	Vanish	Cigarette and lighter disappear while the magician tries to light his cigarette	85.42	53.66	3.17
34	Spoon	Transformation	A spoon is put into the magician's mouth and when removed, it has changed into a fork	95.83	65.22	2.88

Tricks are sorted according to their difficulty (starting from the least solved ones).
[a] Percentage of participants who solved the trick (after repeated viewing).
[b] Percentage of participants who indicated an Aha! experience (of those participants who had solved it).
[c] In a pilot study, 50 participants rated their level of surprise caused by the magic effect from 1 (not at all surprised) to 4 (very much surprised). The mean rating for each trick is indicated.

References

Ash, I. K., Cushen, P. J., & Wiley, J. (2009). Obstacles in investigating the role of restructuring in insightful problem solving. *The Journal of Problem Solving, 2*(2), 6–41.

Bowden, E. M., & Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems. *Behavior Research Methods, Instruments, & Computers, 35*(4), 634–639.

Bowden, E. M., & Jung-Beeman, M. (2007). Methods for investigating the neural components of insight. *Methods, 42*(1), 87–99.

Bowden, E. M., Jung-Beeman, M., Fleck, J. I., & Kounios, J. (2005). New approaches to demystifying insight. *Trends in Cognitive Sciences, 9*(7), 322–328.

Chronicle, E. P., Ormerod, T. C., & MacGregor, J. N. (2001). When insight just won't come: The failure of visual cues in the nine-dot problem. *The Quarterly Journal of Experimental Psychology: Section A, 54*(3), 903–919.

Chu, Y., & MacGregor, J. N. (2011). Human performance on insight problem solving: A review. *The Journal of Problem Solving, 3*(2), 119–150.

Danek, A. H., Fraps, T., von Müller, A., Grothe, B., & Öllinger, M. (submitted for publication). It's a kind of magic – new insights into the nature of Aha!.

Danek, A. H., Fraps, T., von Müller, A., Grothe, B., & Öllinger, M. (2013). Aha! experiences leave a mark: Facilitated recall of insight solutions. *Psychological Research, 77*(5), 659–669.

Davidson, J. E. (2003). Insights about insightful problem solving. In J. E. Davidson & R. J. Sternberg (Eds.), *The psychology of problem solving* (pp. 149–175). Cambridge: Cambridge University Press.

Davidson, J. E. (1995). The suddenness of insight. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 125–155). Cambridge, MA: MIT Press.

Dominowski, R. L. (1981). Comment on "An examination of the alleged role of 'fixation' in the solution of several 'insight' problems" by Weisberg and Alba. *Journal of Experimental Psychology: General, 110*(2), 193–198.

Dominowski, R. L., & Dallob, P. (1995). Insight and problem solving. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 33–62). Cambridge, MA: MIT Press.

Duncker, K. (1945). On problem-solving. *Psychological Monographs, 58*. Whole No. 270.

Evans, J. S. B. T. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology, 59*, 255–278.

Fleck, J. I., & Weisberg, R. W. (2013). Insight versus analysis: Evidence for diverse methods in problem solving. *Journal of Cognitive Psychology, 25*(4), 436–463.

Grant, E. R., & Spivey, M. J. (2003). Eye movements and problem solving. *Psychological Science, 14*(5), 462–466.

Jarosz, A. F., Colflesh, G. J. H., & Wiley, J. (2012). Uncorking the muse: Alcohol intoxication facilitates creative problem solving. *Consciousness and Cognition, 21*(1), 487–493.

Jastrow, J. (1888). The psychology of deception. *Popular Science Monthly, 34*(10), 145–157.

Jones, G. (2003). Testing two cognitive theories of insight. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 1017–1027.

Jung-Beeman, M., Bowden, E. M., Haberman, J., Frymiare, J. L., Arambel-Liu, S., Greenblatt, R., et al. (2004). Neural activity when people solve verbal problems with insight. *PLoS Biology, 2*(4), 500–510.

Kaplan, C. A., & Simon, H. A. (1990). In search of insight. *Cognitive Psychology, 22*(3), 374–419.

Katona, G. (1940). *Organizing and memorizing: Studies in the psychology of learning and teaching*. New York: Columbia University Press.

Kershaw, T. C., Flynn, C. K., & Gordon, L. T. (2013). Multiple paths to transfer and constraint relaxation in insight problem solving. *Thinking and Reasoning, 19*(1), 96–136.

Kershaw, T. C., & Ohlsson, S. (2004). Multiple causes of difficulty in insight: The case of the nine-dot problem. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(1), 3–13.

Knoblich, G., Ohlsson, S., Haider, H., & Rhenius, D. (1999). Constraint relaxation and chunk decomposition in insight problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(6), 1534–1555.

Knoblich, G., Ohlsson, S., & Raney, G. E. (2001). An eye movement study of insight problem solving. *Memory and Cognition, 29*(7), 1000–1009.

Kounios, J., Fleck, J. I., Green, D. L., Payne, L., Stevenson, J. L., Bowden, E. M., et al. (2008). The origins of insight in resting-state brain activity. *Neuropsychologia, 46*(1), 281–291.

Kounios, J., Frymiare, J. L., Bowden, E. M., Fleck, J. I., Subramaniam, K., Parrish, T. B., et al. (2006). The prepared mind. *Psychological Science, 17*(10), 882–890.

Kuhn, G., Amlani, A. A., & Rensink, R. A. (2008). Towards a science of magic. *Trends in Cognitive Sciences, 12*(9), 349–354.

Kuhn, G., Kourkoulou, A., & Leekam, S. R. (2010). How magic changes our expectations about autism. *Psychological Science, 21*(10), 1487–1493.

Kuhn, G., & Land, M. F. (2006). There's more to magic than meets the eye. *Current Biology, 16*(22), 950–951.

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., Tatler, B., Findlay, J. M., & Cole, G. G. (2008). Misdirection in magic: Implications for the relationship between eye gaze and attention. *Visual Cognition, 16*(2), 391–405.

Lamont, P., Henderson, J. M., & Smith, T. J. (2010). Where science and magic meet: The illusion of a "science of magic". *Review of General Psychology, 14*(1), 16–21.

Lamont, P., & Wiseman, R. (1999). *Magic in theory*. Hertfordshire: University of Hertfordshire Press.

MacGregor, J. N., & Cunningham, J. B. (2008). Rebus puzzles as insight problems. *Behavior Research Methods, 40*(1), 263–268.

Mednick, S. A. (1962). The associative basis of the creative process. *Psychological Review, 69*, 220–232.

Metcalfe, J. (1986). Feeling of knowing in memory and problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*(2), 288–294.

Metcalfe, J., & Wiebe, D. (1987). Intuition in insight and noninsight problem solving. *Memory and Cognition, 15*, 238–246.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice Hall.

Ohlsson, S. (1984). Restructuring revisited: I. Summary and critique of the Gestalt theory of problem solving. *Scandinavian Journal of Psychology, 25*, 65–78.

Ohlsson, S. (1992). Information-processing explanations of insight and related phenomena. In M. Keane & K. J. Gilhooly (Eds.), *Advances in the psychology of thinking* (pp. 1–44). London: Harvester-Wheatsheaf.

Öllinger, M., Jones, G., & Knoblich, G. (in press). Insight and search in Katona's Five-Square problem, *Experimental Psychology*.

Öllinger, M., Jones, G., Faber, A. H., & Knoblich, G. (2013a). Cognitive mechanisms of insight: The role of heuristics and representational change in solving the eight-coin problem. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39*(3), 931–939.

Öllinger, M., Jones, G., & Knoblich, G. (2006). Heuristics and representational change in two-move matchstick arithmetic tasks. *Advances in Cognitive Psychology, 2*(4), 239–253.

Öllinger, M., Jones, G., & Knoblich, G. (2008). Investigating the effect of mental set on insight problem solving. *Experimental Psychology, 55*(4), 270–282.

Öllinger, M., Jones, G., & Knoblich, G. (2013b). The dynamics of search, impasse, and representational change provide a coherent explanation of difficulty in the nine-dot problem. *Psychological Research, 1–10*. http://dx.doi.org/10.1007/s00426-013-0494-8.

Öllinger, M., & Knoblich, G. (2009). Psychological research on insight problem solving. In H. Atmanspacher & H. Primas (Eds.), *Recasting reality: Wolfgang Pauli's philosophical ideas and contemporary science*. Berlin: Springer.

Ormerod, T. C., MacGregor, J. N., & Chronicle, E. P. (2002). Dynamics and constraints in insight problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(4), 791–799.

Ortiz, D. (2006). *Designing miracles*. El Dorado Hills: A-1 MagicalMedia.

Parris, B. A., Kuhn, G., Mizon, G. A., Benattayallah, A., & Hodgson, T. L. (2009). Imaging the impossible: An fMRI study of impossible causal relationships in magic tricks. *NeuroImage, 45*(3), 1033–1039.

Sandkühler, S., & Bhattacharya, J. (2008). Deconstructing insight: EEG correlates of insightful problem solving. *PLoS One, 3*(1), 1–12.

Sheth, B. R., Sandkühler, S., & Bhattacharya, J. (2009). Posterior beta and anterior gamma oscillations predict cognitive insight. *Journal of Cognitive Neuroscience, 21*(7), 1269–1279.

Sternberg, R. J., & Davidson, J. E. (1995). *The nature of insight*. Cambridge, MA: MIT Press.

Subramaniam, K., Kounios, J., Parrish, T. B., & Jung-Beeman, M. (2009). A brain mechanism for facilitation of insight by positive affect. *Journal of Cognitive Neuroscience, 21*(3), 415–432.

Tamariz, J. (1988). *The magic way*. Madrid: Frakson Books.

Thevenot, C., & Oakhill, J. (2008). A generalization of the representational change theory from insight to non-insight problems: The case of arithmetic word problems. *Acta Psychologica, 129*(3), 315–324.

Thomas, L. E., & Lleras, A. (2009). Swinging into thought: Directed movement guides insight in problem solving. *Psychonomic Bulletin and Review, 16*(4), 719–723.

Weisberg, R. W., & Alba, J. W. (1981). An examination of the alleged role of "fixation" in the solution of several "insight" problems. *Journal of Experimental Psychology: General, 110*(2), 169–192.

Weisberg, R. W. (1995). Prolegomena to theories of insight in problem solving: A taxonomy of problems. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 157–196). Cambridge, MA: MIT Press.