Running Head: MAGIC AND PROBLEM SOLVING

It is magic! How impossible solutions prevent the discovery of obvious ones?

Cyril Thomas[1], André Didierjean[2] and Gustav Kuhn[1]

[1] Department of Psychology
Goldsmiths University of London
New Cross, London SE14 6NW
United Kingdom

[2] Laboratoire de Psychologie & MSHE
Université de Bourgogne-Franche-Comté,
30 rue Mégevand, 25030 Besançon
France

Address for correspondence: Cyril Thomas, Department of Psychology, Goldsmiths University of London, New Cross, London SE14 6NW, United Kingdom

E-mail: Cyril.thomas@univ-fcomte.fr

Abstract: When confronted with an insight problem, some factors limit our capacity to discover the optimal solution. Previous research on problem solving has shown that the first idea that **comes to participants' minds** can inhibit them from finding better alternative solutions. We used a magic trick to demonstrate that this mind fixing effect is more general than previously

thought: a solution that participants knew to be incorrect and impossible inhibited the discovery of an easy alternative. We show that a simple exposure to an obvious false solution (e.g., the magician hides the card in the palm of his hand to secretly transfer it to his back pocket) can inhibit participants from finding the real secret of the trick (e.g., he used a duplicate card), even if the magician proves that this false solution is impossible (e.g., he shows his hand is empty). We discuss the psychological processes underlying this robust fixing effect.

Keywords: Magic, Fixing effect, Einstellung effect, Insight problem solving, Misdirection, False Solution, Illusion.

Word count: 4527.

Introduction

Our progress and evolution are closely linked to our ability to develop innovative ideas, and the best solutions are often found by stepping outside the box. However, our minds can often become fixated on one solution, which can inhibit us from discovering alternative, and

possibly better solutions. This fixing phenomenon is known as the *Einstellung effect* and has typically been studied in the problem solving literature (Luchins, 1942; for other studies on fixing effect, see also Chrysikou & Weisberg, 2005; Duncker, 1945; Smith, Ward & Schumacher, 1993).

Luchins (1942) discovered the Einstellung effect by conducting experimental studies in problem solving. He gave his participants water jar problems that could be solved using a fixed solution that was quickly learnt. After a few training trials, participants were invited to solve a final problem that had two solutions: the familiar solution and a less familiar but quicker alternative (optimal solution). Participants typically found the familiar solution, but failed to discover the optimal one. In contrast, participants who were not trained on the "familiar solution" discovered the optimal solution more readily. This result illustrates that exposure to the "familiar solution" inhibited them from discovering the alternative. Moreover, when participants were asked to solve a problem that could not be solved with the previously learnt familiar solution (the extinction problem), they were more likely to fail to find the solution. It is important to note that these original experiments involved a **strict time limit**, and those participants previously exposed to the familiar solution failed to solve the extinction problem because they were retesting the familiar solution instead of searching for alternatives, and they simply ran out of time (they had only 2 minutes and 30 seconds to solve it). According to Luchins (1942), the similarity between the new problem and the previous one enhanced the activation of the familiar solution in participants' mind, making them blind to alternatives.

Several decades later, Bilalić, McLeod and Gobet, (2008a, 2008b, 2010) demonstrated that the Einstellung effect also affects people who are experts within their field. Chess masters were given a number of chess problems in which they had to find the shortest way to achieve checkmate. In the first condition, there were always two solutions: a familiar one, which took

five moves, and an unfamiliar one, which took fewer moves. Most of the experts found the familiar solution, but failed to find the optimal one. However, they were perfectly capable of discovering the solution in chess configurations where only the optimal solution was possible. Moreover, eye movement recordings revealed that the chess masters continued to fixate on the elements related to the familiar solution, even when they claimed to be searching for alternatives.

Recently, Thomas and Didierjean (2016) used a new type of insight problem, a magic trick (Danek, Fraps, von Müller, Grothe & Öllinger, 2013; 2014), to investigate the Einstellung effect. Manipulating people's reasoning process is an important element of magicians' misdirection principles (Kuhn, Caffaratti, Teszka & Rensink, 2014), and magicians have arguably spent centuries developing their intuitive knowledge of human cognitive limitations (Kuhn, Amlani, & Rensink, 2008; Rensink & Kuhn, 2014, 2015; Thomas, Didierjean, Maquestiaux, & Gygax, 2015). Whilst many misdirection principles involve manipulating spectators' attentional and perceptual strategies, some of the most effective techniques involve manipulating reasoning, i.e., how the spectators subsequently interpret what they have just seen. Beyond their use in magic performances, these principles can provide intriguing insights into every day problem solving processes. Among all the psychological tools often used by magicians to mislead people's mind, one in particular seems to be closely linked to a fixing effect: the false solution (Kuhn, et al., 2014; Lamont & Wiseman, 2005; Tamariz, 1988). The false solution corresponds to any method other than the one used to produce the magical effect. During a magic trick (e.g., a magical transposition, where a playing card appears to vanish from the top of a deck and then reappear in the magicians' back pocket), the performer can suggest a false explanation of the trick (e.g., the card is secretly hidden in the palm of his hand) to divert participants' suspicion away from the real secret of the trick (e.g., he uses a duplicate queen of clubs).

Thomas and Didierjean (2016) presented participants with a short magic trick. The participants freely selected a playing card from an array of six facedown cards. When their card was turned over, the magician revealed that he had correctly predicted the identity of the card that they had chosen. The secret of the trick was simple; all the cards were identical. Before they were presented with the magic trick, some participants were exposed to an unlikely false solution: "I can influence your choice with my gestures". Participants who were exposed to this suggestion were less likely to correctly identify the real secret compared to those participants who simply watched the magic trick. This effect persisted even when participants were explicitly instructed for a conditional alternative ("if your solution was not the correct one, could you find another solution?"). These results demonstrated that a single exposure to a false solution can inhibit participants from discovering the real secret. The authors attributed this mind fixing effect to the concept of cognitive economy. That is to say, it can be more economic and efficient to direct our attention towards an apparently available solution (in this case, a false solution) than to investigate a hypothetical alternative that may not even exist. However, once this unlikely false solution was explicitly ruled out, most of the participants were able to identify the alternative solution, i.e. the true secret. In other words, after the participants considered the false solution to be incorrect, they ceased to fixate on it and were able to easily discover the true secret.

This last result contradicts magicians' assumptions about the false solution, because a false solution should prevent observers from discovering the secret method even once this solution has been ruled out and considered impossible (see Kuhn, Caffaratti, Tezka & Rensink, 2014; Lamont & Wiseman, 2005; Thomas & Didierjean, 2016). According to Thomas and Didierjean (2016), the nature of the false solution used in their experiment could explain the contradiction between their results and **magicians' assumptions**. Thomas and Didierjean (2016) used an unlikely false solution ("he will use his gesture to influence my choice"), and

the experimenter explicitly informed participants about this solution. Instead, magicians typically use very obvious false solutions, which are implicitly implied through specific actions (e.g., I guess that an object is hidden in the magician's hand). It is likely that an obvious, and internally generated false solution will be more trusted/activated and thus **harder to abandon compared to** an unlikely/implausible false solution.

The aim of the present study was to investigate this hypothesis and to test whether an obvious false solution can prevent people from discovering a simple alternative, even when this false solution has been shown to be impossible. In our experiment, observers were led to believe an obvious false solution to a magic trick ("he concealed the card in his hand and he will secretly place it into his pocket") that was later shown to be impossible ("he shows his hand empty"). We predict that this false solution will prevent participants from discovering a relatively simple solution, even though they know that their initial solution was false/impossible.

Method

Participants

One hundred twenty students (67 female, 53 male[1], mean age: 22 years, SD: 2,9) from Goldsmiths, University of London, United-Kingdom, took part in the experiment. All participants had normal or corrected-to normal visual acuity and provided informed consent and signed the ethic forms. All the participants were debriefed at the end of the experiment.

Stimuli and procedure

Three versions of a magic trick were performed live by the same performer (first author), and each participant was tested individually (see Figure 1 for a visual description and see

[1] 18 males and 22 females for the false solution control trick, 17 males and 23 females for the no false solution trick, 18 males and 22 females for the false solution extinction trick.

Appendix A for video links), watching only one version of the trick. The first version was intended to establish whether participants would discover and report the false solution in the absence of an extinction (false solution control trick). The aim of the second version of the trick was to establish the extent to which participants would discover the correct solution when it was presented without this false solution (no false solution trick). The aim of the third version of the trick was to establish the extent to which participants discovered the solution when the false solution was activated, but immediately and unquestionably ruled out (false solution extinction trick). Each of our 120 participants were randomly allocated to watch one of these tricks, after which they were asked a question about how they thought the trick was done.

In the false solution control trick, the performer (with his sleeves up) held a red-backed deck of cards in his right hand and spread it face up to show that all the cards were different. He then removed the queen of clubs and placed it face up on the top of the face down deck. He explained that he would magically transpose the queen of clubs from the top of the deck into his back pocket. Unbeknownst to the participants, the magician already had a *duplicate* queen of clubs in his back pocket. The magician then openly proceeded to turn the queen of clubs face down on top of the deck and pantomimed the action of "secretly" concealing the queen of clubs in the palm of his left hand (this palming action is exaggerated, unnatural so as to be easily detected by the participants) (see Figure 1a). The aim of this fake palming action was to highlight the likely and obvious false solution, namely that the magician might palm the card from the packed and secretly place it into his pocket. He then put this "suspicious" hand in his left back pocket and produced the queen of clubs (see Figure 1e). After completing the trick, the magician asked participants to verbally answer the following question: ''what is the secret of the trick?". The real secret of the trick was that the magician had a duplicate queen of clubs in his pocket. Participants had unlimited time to give their answer.

In the no false solution trick, the magician carried out the same actions as in the false solution control trick with one exception. The magician did not go through the actions of pretending to palm the card. Instead, he showed that his left hand was empty (from both sides with his fingers spread) (see Figure 1b), before producing the queen of clubs from his back pocket (see Figure 1e). After the trick, participants were asked the same question as outlined above. Additionally, they were asked to rate their confidence in their answer on a scale from one to seven (1=not confident, 7=very confident)[2]. The aim of these confidence ratings was to establish whether the false solution only influenced the discovery of the real secret, or whether it also influenced participants' confidence in this solution.

The final version of the trick, the false solution extinction trick, was likewise identical to the false solution control trick, with one exception. The magician initiated the fake palming pantomime with his left hand, just like in the false solution control trick (see Figure 1c). However, instead of reaching directly into his pocket, the magician suddenly froze, and then spread the fingers of his left hand and turned it palm up, showing it be completely empty (see Figure 1d). This simple gesture proved that no card was hidden in his hand and that the false solution "palming the card" **was impossible**. This version was designed to be visually simple and as similar as possible to the no false solution trick condition (approximately the same duration, with similar moves) to avoid any effect of the perceptual complexity. The only visual difference between the two versions is the closed fingers (palming action) in the false solution extinction trick while these fingers are open in the no false solution trick. After the trick was completed, participants were asked the same set of questions as outlined in the no false solution trick.

[2] The confidence score was not measured in the false solution control trick because the only aim of this first version was to control that the false solution we used in the false solution extinction trick was sufficiently obvious to pop-up **in most participants' minds**.

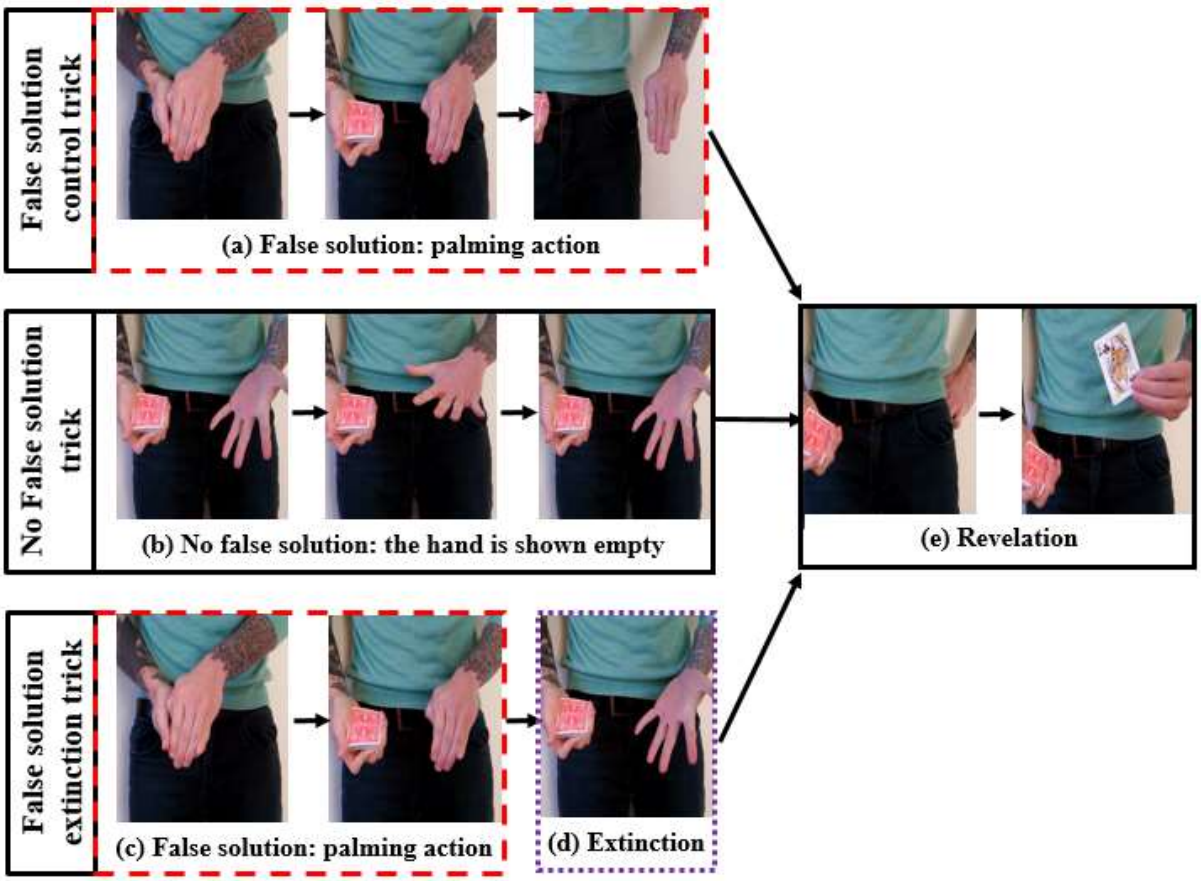

Fig. 1. Visual description of each condition (false solution control trick, no false solution trick, false solution extinction trick).

Results

In the false solution control trick, 82,5% of the participants suggested that the magician palmed the card, illustrating that the false solution was sufficiently obvious to pop into most of the participants' mind (see Figure 2 for more details about participants' answers).

Our main interest lay in the different responses provided by participants who watched the false solution extinction trick compared with those who watched the version without the false solution (see Figure 3a). As predicted, a significantly smaller percentage of participants discovered the correct solution in the false solution extinction trick (60%), compared to the no

false solution trick (87,5%, χ^2= 7,81, p < .01). It is important to highlight that, unlike in Luchins' (1942) extinction problem, in the false solution extinction trick, most of the participants who failed to discover the secret did not propose the false solution as a potential solution (see Figure 2 for more details about participants' answers).

There was no significant difference in confidence level between those participants who discovered the correct solution in the no false solution trick (N=35, *M* = 5,29, *SD* = 1,53) and those who discovered it in the false solution extinction trick (N= 24, *M* = 4,92, *SD* = 1,50), *t*(57) = 0.92, *p* = .36 (see Figure 3b).

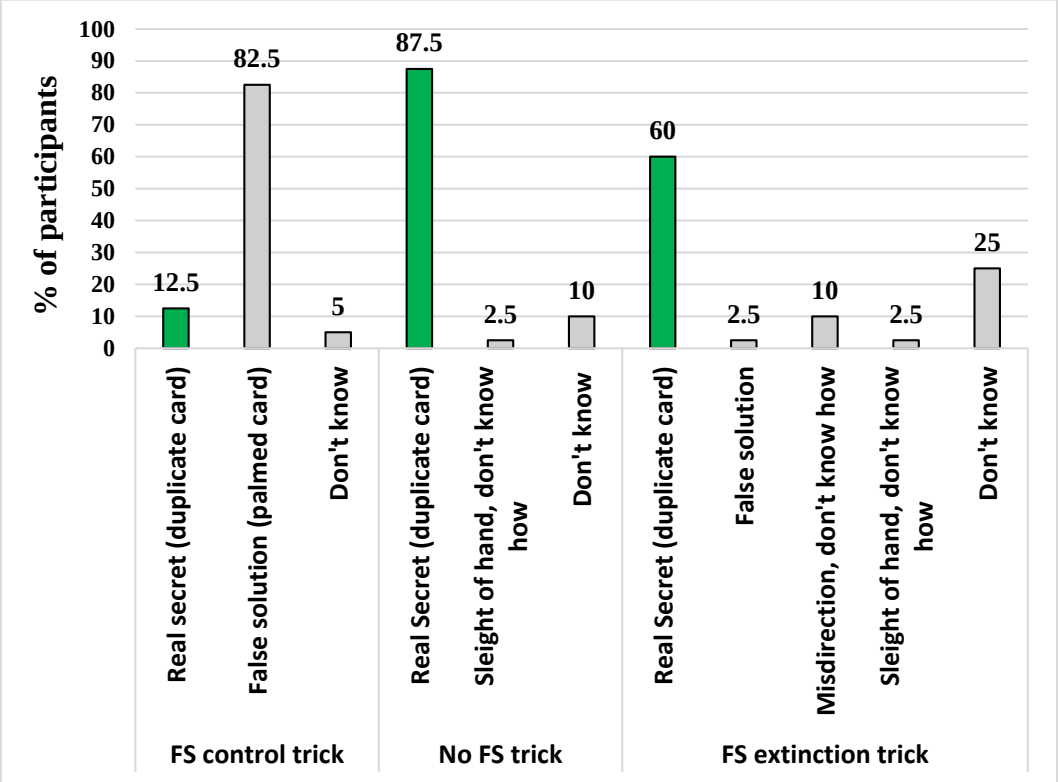

Fig. 2. Percentage of participants as a function of the type of solution and the condition (false solution (FS) control trick, no false solution (no FS) trick, false solution (FS) extinction trick).

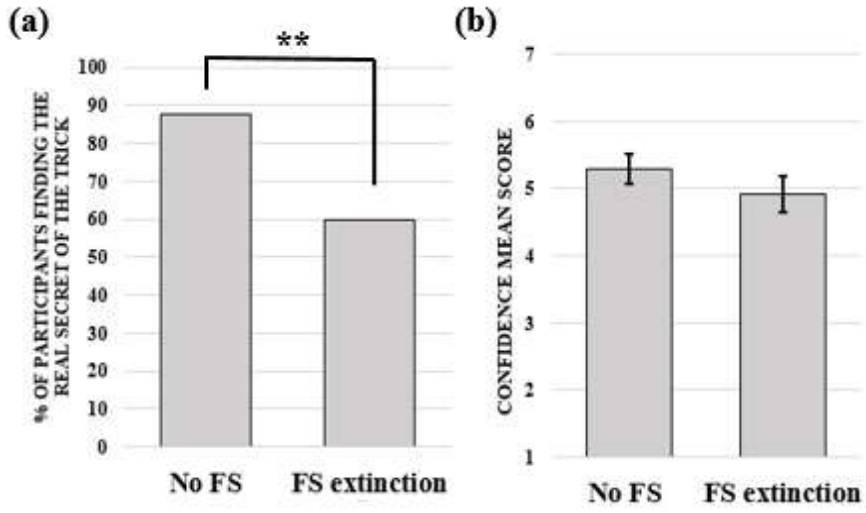

Fig. 3. (a) Percentage of participants who found the real secret of the trick (duplicate card) as a function of the condition (no false solution (no FS) trick, false solution (FS) extinction trick). **(b)** Confidence mean score for participants who found the real secret of the trick as a function of the condition (no false solution (no FS) trick, false solution (FS) extinction trick). Error bars represent the standard errors of the mean.

Discussion

It can be difficult to relinquish old ideas to discover new ones, and we investigated whether a potential solution to a problem can prevent people from discovering the true solution, even though they know that the first solution is impossible and wrong. To do that, we used an original type of insight problem: a magic trick (Danek, et al., 2014). We showed that if observers were given an obvious solution about how the trick can be done, they were significantly less likely to discover the true solution, even after the first solution was shown to be impossible. Previous research on problem solving has shown that the first idea that comes to mind can prevent a better alternative from being discovered (see Bilalić, McLeod and Gobet,

2008a, 2008b, 2010; Luchins, 1942; Thomas & Didierjean, 2016). Our results are novel and surprising in that even when participants were fully aware that their solution was wrong, and that an alternative solution must exist, they were still inhibited from discovering plausible alternatives. We will now discuss in more detail how this false solution could influence participants' reasoning, even when it is ruled out.

Previous studies on misinformation have shown that participants can maintain and recall information after its retraction (e.g., Ecker, Lewandowsky, Swire, & Chang, 2011; van Oostendorp & Bonebakker, 1999; for a review, see Lewandowsky, Ecker, Seifert, Schwarz & Cook, 2012). However, our study goes one step further. We show that, in the context of problem solving, this false information continues to exert its influence. This effect can persist following a deliberate extinction, even if participants do not endorse the false information themselves (see Figure 2). Unlike most of the other studies in this field, the event and the retraction happened in front of participants' eyes and not in an imaginary/artificial context (e.g., a printed text). Thus, the retraction was sufficiently salient not be ignored, which is illustrated by the fact that hardly any of our participants proposed the false solution after it had been ruled out. Moreover, in most of the studies on misinformation, participants are invited to recall some parts of a story, rather than actively search for a solution to a problem. Thus, we assume that the continuous influence of misinformation relies on different cognitive processes than those involved in the mind fixing effect we observed here.

According to Knoblich and colleagues' Representational Change Theory (Knoblich, Ohlsson, Haider, & Rhenius, 1999, Knoblich, Ohlsson, & Raney, 2001), to find the optimal/only solution to an insight problem, it is often necessary to think "outside of the box," outside of a first representation of the problem. Along similar lines, we propose a peripheral representation hypothesis, whereby a false solution can activate a peripheral representation of the problem. This (false) peripheral representation can remain active, even after the central false

solution has been ruled out, and thus it can continue to activate implicit constraints and false assumptions (Danek et al., 2014). For example, in the case of our experiment, pantomiming the action of palming the card might activate a specific representation of the problem in which "a *unique queen of clubs* will travel from the top of the deck to the magician's back pocket hidden in his hand". Even after the false solution is ruled out, the peripheral part of the false representation might still be active: "*the queen of clubs is unique* and it will travel from the top of the deck to the magician's back pocket hidden behind a mask (*not his hand*)". Because this peripheral representation does not contain the true solution (the queen of club is not unique/duplicated), participants face an impasse (Ohlsson, 1992) (see Figure 4). This peripheral representation hypothesis can explain why most of the participants who struggled to discover the secret of the trick did not propose the central false solution as a potential secret of the trick. To find the correct solution, the false representation of the problem needs to be changed by, for example, relaxing some crucial constraints (e.g., the card is *not* unique) (Knoblich, Ohlsson, Haider & Rhenius, 1999). However, it may be more economical to focus our attention on the activated representation/**constraints** of the problem (even if it is closely linked to the ruled out solution) than to relax these **constraints** and investigate a hypothetical better alternative representation (Simon, 1990; Thomas & Didierjean, 2016).

Our results differ **from those of Thomas and Didierjean** (2016) in that the false solution exerted its influence even after participants **knew** it was impossible. One of the main differences between the current experiment and the previous study is that our false solution was simply implied, rather than explicitly stated. Unlike in the previous study, our participants were required to construct the false solution (i.e. the magician hides the card in the palm of his hand) based on their own observation (i.e. hand looks as if it is concealing a card), and thus our false solution will have engaged a deeper and more complex level of processing. It is likely that this deeper level of processing results in stronger activation of the peripheral representation of the

problem space, which may explain its persistent influence, even once the main false solution has been ruled out.

Moreover, during a problem solving task, an unlikely solution (see Thomas and Didierjean, 2016) can be accepted simply because it is "better than nothing". Participants therefore accept the solution, but are not necessarily confident in its authenticity and thus easily abandon it (and its peripheral representations) once they are informed it is wrong.

Our results also suggest that the fixing effect only influenced the discovery of the correct solution, but not **participants'** confidence in the solution. When participants discover the real secret of the trick, it could create an "Aha! Experience" that is linked to a strong and sudden feeling of pleasure, certainty and obviousness (see Danek et al., 2013; Danek et al., 2014; Danek & Wiley, 2017; Thomas et al., 2015). This "Aha! Experience" might facilitate the total deactivation of the false solution and increase participants' confidence in the new alternative.

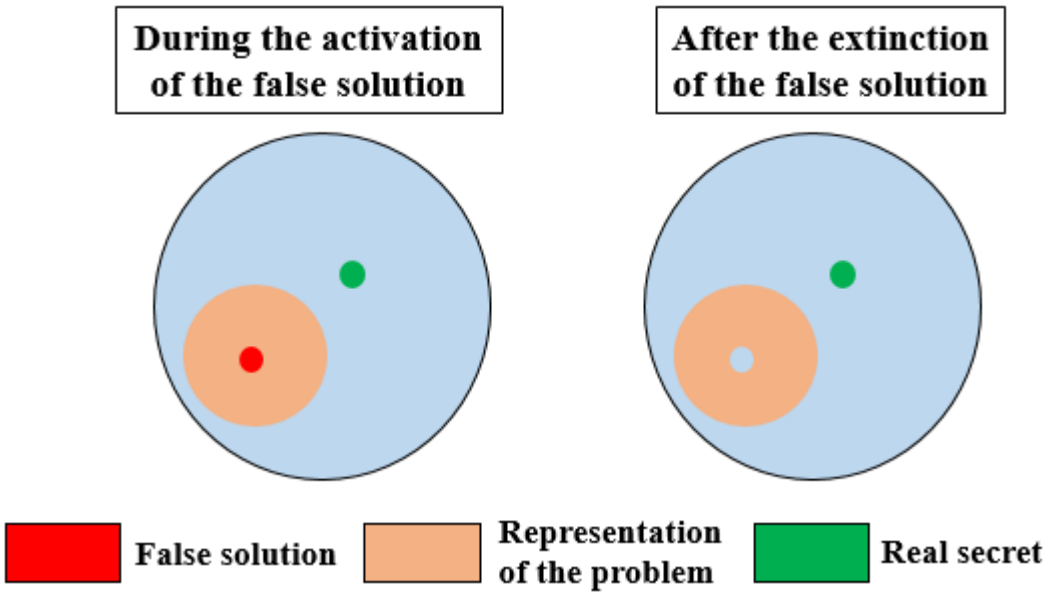

Fig. 4. Visual representation of the peripheral representation hypothesis.

Magic tricks provide us with a toolkit to explore powerful failures in cognition, and whilst the false solution is typically used in conjuring tricks, we believe that mind fixing effects play an important role in non-magical problems and everyday reasoning. Our results raise an important, and potentially alarming issue on how we solve everyday problems: if the simple exposure to an idea that is unquestionably ruled out can actively influence the way we represent a simple problem, how do our everyday **erroneous** beliefs influence our reasoning capacity? It is likely that representations linked to maladaptive ideas that have been **activated** for years can have profound and detrimental impacts on our ability to find better solutions.

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Appendix A.

- False solution control: https://youtu.be/jbgXTWQAnkk
- No false solution: https://youtu.be/-EOXweY5oUE
- False solution extinction: https://youtu.be/pgnO3IYdhPc

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