Consciousness and Cognition 48 (2017) 198–211

Contents lists available at ScienceDirect

Consciousness and Cognition

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

Can observing a Necker cube make you more insightful?

Ruben E. Laukkonen *, Jason M. Tangen

Department of Psychology, The University of Queensland, St Lucia, Queensland 4072, Australia

A R T I C L E I N F O

Article history:
Received 9 August 2016
Revised 13 October 2016
Accepted 28 November 2016
Available online 20 December 2016

Keywords:
Insight
Problem-solving
Conflict monitoring
Bistable images

A B S T R A C T

It is a compelling idea that an image as simple as a Necker cube, or a duck-rabbit illusion, can reveal something about a person's creativity. Surprisingly, there are now multiple examples showing that people who are better at discovering 'hidden' images in a picture, are also better at solving some creative problems. Although this idea goes back at least a century, little is known about *how* these two tasks—that seem so different on the surface—are related to each other. At least some forms of creativity (and indeed scientific discoveries) may require that we change our perspectives in order to discover a novel solution to a problem. It's possible that such problems involve a similar cognitive process, and perhaps the same cognitive capacities, as switching perspectives in an ambiguous image. We begin by replicating previous work, and also show metacognitive similarities between the sudden appearance of hidden images in consciousness, and the sudden appearance of solutions to verbal insight problems. We then show that simply observing a Necker cube can improve subsequent creative problem-solving and lead to more self-reported insights. We speculate that these results may in part be explained by Conflict Monitoring Theory.
© 2016 Elsevier Inc. All rights reserved.

1. Introduction

In a 1973 short film, Take the World from Another Point of View, Richard Feynman was asked by esteemed astronomer, Sir Fred Hoyle: "Have you had a moment when, in a complicated problem, where quite suddenly the thing comes into your head and you are almost sure that you have got to be right?" Feynman agreed enthusiastically, and replied, "For example, I worked out the theory of helium once and suddenly saw everything. I had been struggling and struggling for two years and suddenly saw everything." Commenting further on the moment of revelation, Feynman says, "And then afterwards, you wonder why was I so stupid that I didn't see this?" As we will soon see, this exchange between Feynman and Hoyle captures several now well documented features of the insight experience.

On one end of a problem-solving spectrum, there are problems that we solve, or things we learn, where progress is gradual, moving step by step to a solution. Problems solved in this analytic way are characterized by linearity and predictable solutions; from beginning to end, progress is smooth. On the other end of the spectrum we have solutions to problems that are sudden, unexpected, and accompanied by an 'Aha!' moment. These occasions—and Feynman discovering the theory of helium is one example—we may call insights, eureka moments, or revelations. And once an experience like this occurs, the solution seems obviously correct, and like Feynman, we are left to wonder how we were "so stupid" just a moment before. Curiously, the problem of understanding how and why insights occur, and predicting their appearances, has made considerable progress through our understanding of a far simpler stimulus, a bistable image.

* Corresponding author.
E-mail addresses: ruben.laukkonen@gmail.com (R.E. Laukkonen), jtangen@psy.uq.edu.au (J.M. Tangen).

http://dx.doi.org/10.1016/j.concog.2016.11.011
1053-8100/© 2016 Elsevier Inc. All rights reserved.

If you identified both perspectives in Fig. 1, chances are that you experienced a small 'Aha!' moment when the image suddenly appeared quite differently than just a moment before. Here we will begin by describing at least three reasons that we believe bistable images, like the Necker cube, have become so intimately linked to the insight experience in previous research (e.g., Maier, 1930; Schooler, McCleod, Brooks, & Melcher, 1993; Schooler & Melcher, 1995; Schooler, Fallshrore, & Fiore, 1996; Sternberg & Davidson, 1995; Wiseman, Watt, Gilhooly, & Georgiou, 2011; Doherty & Mair, 2012; Ohlsson, 1984, 2011).

Reason 1: ***Phenomenology***. The 'Aha!' experience of solving a bistable image and experiencing an insight is the simplest and perhaps most intuitive reason that the relationship has become so popular. We can see first-hand that the way a "hidden" image appears in consciousness has similar phenomenological characteristics to a sudden insight (Schooler et al., 1996; Metcalfe & Wiebe, 1987). Reason 2: ***Representational Change***. Bistable images and some (but perhaps not all) insight experiences are preceded by a change in representation, or interpretation of problem elements or assumptions (Ohlsson, 1984, 2011; Schooler et al., 1996). When some part of the problem is re-interpreted, or a new perspective is found, then the solution may be immediately obvious, and therefore the insightful solution appears suddenly and unexpectedly. We do not usually have conscious access to our interpretations or awareness of when they change, so all that is experienced is a sudden recognition of a solution that was previously unknown (Ohlsson, 1984, 2011). Reason 3: ***Performance Correlations***. Evidence has also accumulated suggesting that the relationship between bistable images and insight may be more than a simple analogy. That is, the ability to change perspectives in ambiguous images appears to be associated with our ability to solve creative problems (Doherty & Mair, 2012; Jarosz, Colflesh, & Wiley, 2012; O'Brien et al., 2014; Schooler & Melcher, 1995; Wiseman et al., 2011).

Taken together, bistable images and insights feel the same, they may be solved through the same cognitive process of changing perspectives, and successfully reinterpreting an ambiguous image predicts success in creative problems that often lead to insights. It is this third reason—i.e., the empirical relationship between ambiguous images and creative problems—that is particularly not well understood, and as far as we know, there is currently no evidence of a mechanism, cognitive, neuroscientific, or otherwise. To this end, in Experiment 1, we begin by replicating and extending on previous work by testing the association between perceptual switching in ambiguous images and solving insight problems using both accuracy and metacognitive measures. In Experiment 2, we test whether observing the alternations in a Necker cube can trigger cognitive processes that improve subsequent insight problem-solving

1.1. Summary of previous research

In the first and most popular experiment of its kind, Schooler and Melcher (1995) demonstrated that recognizing out-of-focus images was correlated with performance on traditional insight problems. Recognizing blurry images was a better predictor of success with insight problems than analytic problem-solving, remote associate tests, vocabulary, need for cognition, and more. In more recent work, Wiseman et al. (2011) found that self-reported creativity and performance on an alternative uses task correlated with self-reported ease of reversal for one ambiguous figure (the duck-rabbit illusion). Doherty and Mair (2012) found a similar pattern of results, where reversals in three ambiguous figures correlated with performance on a pattern meanings test. Two separate studies also found that insight problems and reversals in ambiguous images were positively influenced by alcohol intoxication, whereas non-insight problems were not (Jarosz et al., 2012; O'Brien et al., 2014). Taken together, the existing research points to a relationship between re-interpreting perceptual stimuli (e.g., blurry or ambiguous images) and re-interpreting conceptual stimuli (e.g., solving insight problems: Doherty & Mair, 2012; Schooler

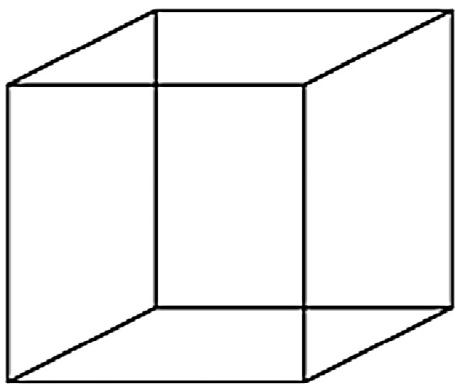


Fig. 1. A Necker cube that can, with sustained attention, alternate between two mutually exclusive interpretations: A cube facing down and left, or a cube facing up and right (Necker, 1832).

& Melcher, 1995; Wiseman et al., 2011; Riquelme, 2002). However, there are reasons to begin with a conceptual replication and extension using a well-known metacognitive measure of insight.

2. Experiment 1

Previous research has not tested for the presence or absence of an insight experience, so it is unclear whether the relationship between insight problems and ambiguous images has anything to do with insight *per se*. If ambiguous images and insight problems are related because they both rely on the same cognitive process of representational change (or shifting perspectives), then we would expect similar metacognitions. In order to measure metacognitive patterns and whether an insight has occurred during problem-solving, a popular method is Metcalfe's (1986) feelings-of-warmth (or simply 'warmth') measure. The warmth measure requires participants to make frequent estimates during problem-solving about how close they are to solving the problem from cold (far) to hot (close). We expect that ambiguous images and insight problems are solved more suddenly and unexpectedly (i.e., moving from a cold state to a solution state) compared to analytic problems, where solutions are more likely to follow from gradually increasing warmth ratings. There is evidence that the warmth measure can reliably signal insights and distinguish between traditional insight and non-insight problems (Metcalfe, 1986; Metcalfe & Wiebe, 1987).

Previous work also relied on a small number of ambiguous images, and occasionally did not include a control condition (Doherty & Mair, 2012; Wiseman et al., 2011). The study conducted by Schooler and Melcher (1995) used blurry instead of ambiguous images, which may not have involved representational change in the way we conceptualize it here. To address these issues, Experiment 1 includes a control condition (an analytic problem-solving task), as well as multiple ambiguous images and insight problems, which have been chosen specifically because there are at least two possible representations to each stimulus. If, under these constraints, we find a positive association between ambiguous images and insight problems, and similar metacognitive patterns, then—combined with the work described above—we ought to take seriously the idea that changing interpretations in ambiguous images is related to, and predictive of, changing interpretations in problem-solving, and perhaps creativity.

2.1. Experiment 1 method

Fifty-one undergraduate students from The University of Queensland participated for course credit (mean age = 20.3; *SD* = 4.9). All of the participants (17 males and 34 females) experienced the same three conditions: ten traditional insight problems, ten analytic problems, and ten ambiguous images. All insight and analytic problems were restricted to verbal problems in order to minimize extraneous differences between the conditions. Insight problems were obtained from either Schooler et al. (1993) and Weisberg (1996), or online sources. An *a priori* 'Taxonomy for Identifying Insight Problems' as outlined in Weisberg (1996) was used to ensure that each insight problem required a re-interpretation of the problem elements. Analytic problems were similarly obtained, but chosen because solutions did not require participants to reinterpret the problem elements (all stimuli are presented in Appendix A).

All video instructions for this experiment were pre-recorded to ensure that each participant received the same information. The experiment was constructed and presented using LiveCode (an open-source programming tool) and conducted in quiet rooms with no more than four participants per session using desktop computers. Each participant began by answering basic demographic questions, and indicated whether their first language was English or not. We suspected that if English was not a participant's first language, difficulties may arise because insight problems required that participants re-interpret specific English words in multiple ways, but no significant differences were identified, so the variable was removed from any further analysis. In the instructions, although participants were not explicitly told about the presence of distinct insight and non-insight problems, they were provided with an example of both in order to prevent any differential practice effects. Participants were also provided with an example of an ambiguous image trial and were shown the two possible interpretations. In the experiment, a correct response for an ambiguous image trial was recorded if both images in the picture were successfully identified within the time limit.

Participants were then told that while they were solving the problems, a warmth rating scale would appear on the right hand side of the screen every fifteen seconds with a tone (see Appendix B for an illustration). When the warmth rating appeared, they were told to indicate how close they were to solving the problem from 1 (cold/far), to 10 (hot/close). For ambiguous image trials, participants were told to indicate how close they were to discovering the second interpretation of the image. When the warmth rating appeared, the response field was disabled and unresponsive to mouse clicks, and participants were shown how to make a rating from one to ten in order to continue working on the problem. They were asked to make a rating as quickly as possible when the rating bar appeared, and were provided with a demonstration of the entire process. Participants were told to finish entering their response and to not change their rating after they had solved the problem (to ensure clarity, they were reminded of these instructions again before beginning the experiment). They were told that each problem would appear for two minutes and then disappear. After the instructions were completed and any questions answered, the experiment began and the stimuli were presented in random order.

2.2. Experiment 1 results

2.2.1. Accuracy and correlations

One of our primary interests was the relationship between the accuracy of the bistable image problems and the insight problems. As in the previous insight demonstrations, we found that participants who correctly identified two images in the bistable image problems ($M = 68\%$) also correctly solved more insight problems ($M = 43.7\%$, $r = 0.39$, $n = 51$, $p = 0.012$). We found a smaller, but significant correlation between analytic problem-solving ($M = 41.6\%$) and ambiguous images ($r = 0.32$, $n = 51$, $p = 0.003$), as well as a correlation between solving insight and analytic problems ($r = 0.48$, $n = 51$, $p < 0.001$). The correlation between analytic problems and ambiguous images was larger than that found in previous research (Schooler & Melcher, 1995), and larger than we expected to find. We elaborate on this relationship further in the discussion of Experiment 1.

2.2.2. Metacognitions

In order to identify the metacognitive pattern preceding solutions, differential warmth ratings were calculated by subtracting each participant's last warmth rating from their first warmth rating for each problem. Negative numbers were converted to positive, so that a higher differential warmth rating indicates a larger increment in warmth preceding a correct answer, and a lower number indicates a smaller increment (i.e., less of a gradual process towards solving the problem). For example, an average score of zero indicates that a participant's warmth ratings were not at all predictive of correct answers, and higher numbers indicate more gradual warmth ratings prior to correct solutions. Each participant was assigned an average incremental warmth rating for each condition for comparison (see Fig. 2A).

Incremental ratings were then used to identify insight problems and bistable image trials that were solved in a way that resembled insight (i.e., suddenly, without any incremental ratings prior to solution). This is considered the most conservative method, as a participant must experience no progress towards the solution before the solution appears (Metcalfe, 1986). The same method was used to identify analytic problems that were solved incrementally (i.e., greater than zero differential warmth ratings preceding solution). Once identified, each participant received an average score for insight and analytic solutions for each of the conditions (see Fig. 2B).

2.3. Experiment 1 discussion

Consistent with previous insight demonstrations (Ohlsson, 1984, 2011; Schooler & Melcher, 1995; Wiseman et al., 2011), participants who were better able to identify two alternative perspectives in ambiguous images (i.e., reinterpret the stimulus) were also more likely to solve insight problems. We also found a positive, although perhaps smaller, relationship between ambiguous images and analytic problem-solving. Previous research has shown that some common factors (e.g., vocabulary) are positively associated with performance in all three conditions—insight, analytic, and image problems (Schooler & Melcher, 1995). Therefore, correlations between each of the conditions were not necessarily surprising. How-

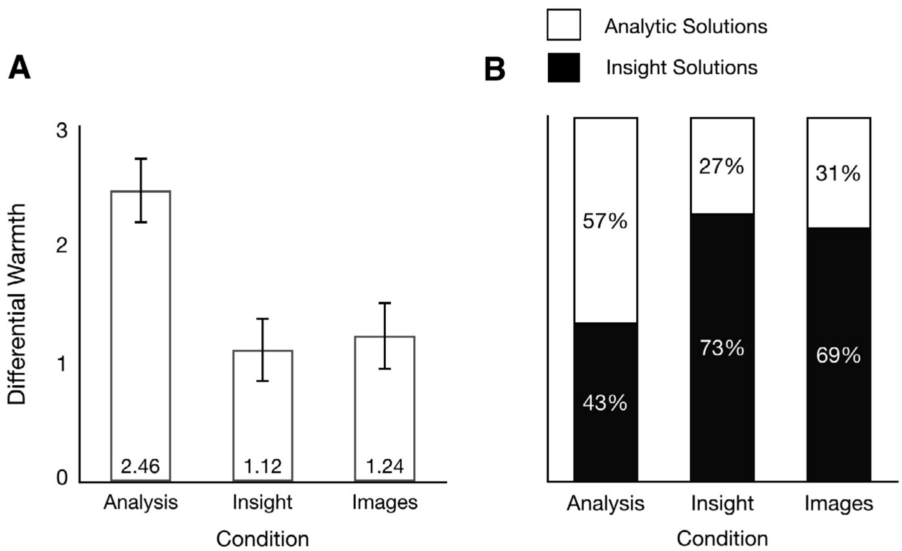


Fig. 2. A (left): Differential warmth ratings by condition (error bars represent the standard error of the mean). B (right): Proportion of insight and analytic solutions by condition.

ever, the relationship between ambiguous images and analytic problems was larger than found in previous research (Schooler & Melcher, 1995). There are two possible explanations. It may simply be that this experiment was not sensitive enough to identify major differences between the conditions, or, it is possible that there is nothing unique about the relationship between ambiguous images and creative problem-solving, and instead, the ability to switch perspectives in ambiguous images is associated with problem-solving generally. We cannot draw a firm conclusion either way, although previous work suggests that the latter conclusion is unlikely. Nevertheless, the accuracy results were in the expected direction, and our primary aim for Experiment 1 was to measure whether the metacognitions observed in the ambiguous images and insight problems were similar to each other, and different from analytic problems.

The metacognitive data support the possibility that there is something unique about the cognitions involved in reinterpreting ambiguous images and solving insight problems. Extending on previous research, we found that insight problems and ambiguous images are solved more suddenly compared to analytic problems. This result suggests that progress on an analytic problem occurs consciously, in the sense that participants are aware of the steps required in the problem and how they are progressing along those steps. For insight problems and ambiguous images, however, the alternative interpretation—and hence the solution—seems to occur to participants spontaneously and unconsciously (most of the time). Therefore, it is also unlikely that the underlying ability is the same in the analytic problems as in insight problems and ambiguous images, since the underlying cognitions appear to be different (i.e., conscious versus unconscious). Considering the results reported here in combination with previous work, we decided to continue with a second experiment and investigate the possibility that a Necker cube would trigger the neuro-cognitive mechanisms required for insight problem-solving, and thereby improve performance.

3. Experiment 2

The finding that conflict leads to activation of the anterior cingulate cortex has become one of the most replicated findings in cognitive neuroscience (Botvinick, Cohen, & Carter, 2004; Weissman, Giesbrecht, Song, Mangun, & Woldorff, 2003). According to Conflict Monitoring Theory, the anterior cingulate cortex functions as a conflict detection center, which upon detecting conflict, triggers cognitive control mechanisms required to overcome the conflict (Botvinick, Braver, Larch, Carter, & Cohen, 2001). The Stroop task, Erikson Flanker Task, and the Simon Task, are classic examples where task difficulty, reaction time, and anterior cingulate activation increases with stimuli that induce conflict compared to non-conflicting versions of the same stimuli (Botvinick et al., 2001; Simon & Wolf, 1963). For example, in Stroop trials (Stroop, 1935) where a word such as blue, is colored in red, naming the color of the word takes longer than if the word blue was also colored blue. The conflict or mismatch induced by the word is responsible for the increased difficulty of the task. Kounios et al. (2006) and Subramaniam, Kounios, Parrish, and Jung-Beeman (2009) hypothesized that conflict monitoring and cognitive control processes are important for insight because they allow individuals to detect competing options other than the prepotent response. Kounios and Beeman (2014) proposed that if the anterior cingulate cortex is sufficiently active before problem-solving, then the participant is better prepared to detect non-dominant—perhaps creative—solutions. This is indeed the very difficulty with traditional insight problems. Insight problems are specifically designed so that the problem is initially represented (interpreted) incorrectly, and therefore to solve the problem, a different, conflicting (non-dominant) interpretation must be discovered. Cognitive control processes and the anterior cingulate cortex are also believed to be important for monitoring competing responses (MacDonald, Cohen, Stenger, & Carter, 2000; Van Veen, Cohen, Botvinick, Stenger, & Carter, 2001), and for shifting attention (Davis, 2005; Dreisbach & Goschke, 2004), which may be other potential mechanisms involved in solving insight problems.

The Necker cube as well as the ambiguous images used in Experiment 1, are visually bistable stimuli that, due to their two competing interpretations, reliably induce conflict (for a review, see Kornmeier & Bach, 2005; Toppino & Long, 2005). Therefore, it seems that the re-interpretation process in both insight problems and ambiguous images benefit—indeed may require—the Conflict Monitoring System as described by Botvinick et al. (2001). It is possible then that the relationships thus far observed in the literature between bistable or ambiguous stimuli and creative problem-solving are partly accounted for by the role that the Conflict Monitoring System plays in switching between competing representations. In support of this hypothesis, there is evidence that activation of the anterior cingulate cortex prior to problem-solving is associated with more insight solutions than analytic solutions (Kounios et al., 2006; Kounios & Beeman, 2014; Subramaniam et al., 2009). Creativity, by definition perhaps, requires a movement from the old to the new. Switching from the old to the new requires that we overcome habitual, prepotent responses driven by past experience. The Conflict Monitoring System may therefore not only partially account for the relationship between insight and ambiguous images, but may play a larger role in creativity than previously thought.

How do we test this hypothesis? It is well known that a conflicting stimulus, which is preceded by another conflicting stimulus of the same category is likely to be solved faster and more often than conflicting stimuli preceded by non-conflicting stimuli (Botvinick et al., 2001, 2004; Kan et al., 2013). According to Conflict Monitoring Theory, this finding—namely the Gratton Effect (Gratton, Coles, & Donchin, 1992)—occurs because conflict in the preceding trial triggers cognitive control, and therefore the participant has control mechanisms prepared for the subsequent trial. Recent evidence suggests that conflict adaptation effects and therefore the Conflict Monitoring System may be domain general. Kan et al. (2013)

showed across three experiments that conflict experienced in one task (e.g., a Necker cube) predicted better performance in overcoming conflict in another task (e.g., Stroop tasks or ambiguous sentences) that followed.

In Experiment 2, we test the possibility that a Necker cube can improve subsequent insight problem-solving. Broadly replicating the design of Kan et al. (2013), we presented participants with either a Necker cube (conflict condition) or an alternating cube (no conflict condition) followed by an insight problem. Our conservative hypothesis was that a Necker cube will elicit some shared cognitive processes, which will improve subsequent insight problem-solving. Our more specific, but also more speculative hypothesis, is that experiencing conflict with the Necker cube would elicit conflict monitoring and cognitive control mechanisms, which would lead to better performance in the subsequent insight problem. If our hypotheses are supported, then it is possible that Conflict Monitoring Theory, and individual differences in conflict monitoring and cognitive control, can at least partially account for the relationship between insight problems and bistable images. At a bare minimum, there are likely to be shared cognitive mechanisms (cognitive control or otherwise). Recent evidence also suggests that engaged cognitive control mechanisms (i.e., preparatory activation in the anterior cingulate cortex) is associated with more self-reported insights (Subramaniam et al., 2009). Therefore, we also expected that participants presented with conflicting Necker cubes would report more insights and less analytic solutions overall than participants presented with normal alternating cubes.

3.1. Experiment 2 method

Eighty undergraduate students (32 males and 48 females) from The University of Queensland participated in exchange for course credit (mean age = 20.1, *SD* = 5.1). Unless indicated otherwise, Experiment 2 was procedurally the same as Experiment 1. Participants were presented with 20 insight problems, preceded by either a Necker cube (conflict condition), or an alternating cube (no conflict condition) for 90 s. In order to make the two conditions as similar as possible (aside from the conflict), the cube in the no conflict condition alternated between the two possible percepts of the Necker cube (as in Fig. 3) at the average rate that reversals tend to be experienced in the Necker cube (i.e., approximately 27 times in 90 s; Kan et al., 2013). In both the conflict and no conflict conditions, participants were instructed to indicate by pressing a key whenever they experienced a reversal in the cube, and were told not to try and change perspectives in either condition, but to observe the images passively. On the left arrow key, a picture of an unambiguous cube pointing left and down was attached, and on the right arrow key, a picture of an unambiguous cube pointing right and up was attached (see Fig. 3). This methodology allows participants to indicate which percept they were currently experiencing by pressing one of the cubes, and each button press indicated a reversal. The insight problems were obtained and presented as in Experiment 1, but participants were provided with only one minute to solve the problem to increase the potential impact of the conflict adaptation from the preceding trial. The insight problems were randomized across the conflict and no conflict conditions.

In order to measure metacognitions and experiences of insight, we used the warmth measure as in Experiment 1, but we also adapted a self-report measure of insight from Bowden and Jung-Beeman (2007). The self-report measure is an alternative to Metcalfe's (1986) warmth rating, and was commonly used in the research reviewed for Experiment 2. Therefore, for consistency with previous research (e.g., Kounios et al., 2006; Kounios & Beeman, 2014, and Subramaniam et al., 2009), and to increase sensitivity in identifying insights, we also included the self-report measure of insight. After each insight problem, participants indicated whether they experienced an insight by providing a rating of 1 (no), 2 (other), or 3 (yes). The important features of an insight were described in detail in the instructions. Participants were instructed to indicate 2 (other) if they simply guessed or did not know the answer, experienced neither insight nor no insight, or if they were unsure. Self-reports of insight compared to no insight or analytic solutions have been associated with different neural activation (e.g., Bowden & Jung-Beeman, 2003; Jung-Beeman et al., 2004; Kounios

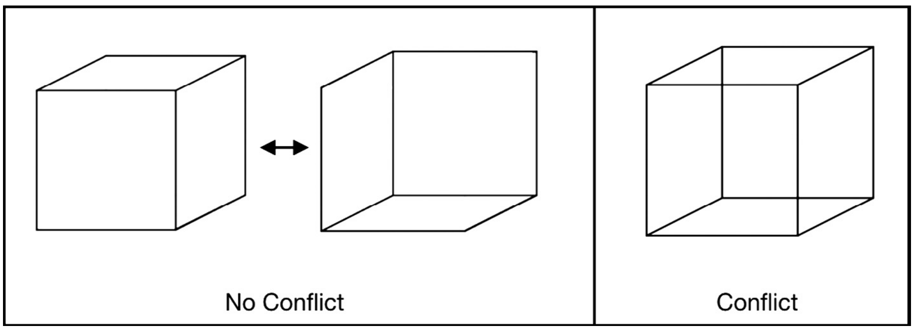


Fig. 3. Left: The two alternating cubes presented intermittently every 2.7 s for 90 s (no conflict condition). Right: Necker cube also presented for 90 s (conflict condition).

et al., 2006), different eye-movements (Salvi, Bricolo, Franconeri, Kounios, & Beeman, 2015), differences in accuracy (Salvi, Bricolo, Kounios, Bowden, & Beeman, 2016), and more. The self-report measure provides several potential advantages to Metcalfe's (1986) warmth measure, however these are discussed elsewhere (see Bowden & Jung-Beeman, 2007). In this experiment, we used both the warmth and self-report measures, and reported them separately. Here, we are specifically interested in how these two measures capture differences in insight problem-solving performance and metacognitions as a result of conflict induction. Because of the shorter presentation times, participants were asked to make warmth ratings more often than in Experiment 1, in this case every ten seconds. Otherwise, the warmth measure was consistent with Experiment 1. After providing an insight rating, participants were asked whether the problem they solved was familiar or not, and any familiar problems were removed from further analysis.

3.2. Experiment 2 results

3.2.1. Accuracy and reaction time

Participants experienced approximately equivalent reversals when observing conflicting Necker cubes ($M = 28.2$, $SD = 26.4$) and alternating cubes ($M = 26.1$, $SD = 4$), although variability in the Necker cube condition was substantially higher, which is consistent with previous research showing individual differences in reversal rates for Necker cubes (e.g., Kan et al., 2013; Shannon, Patrick, Jiang, Bernat, & He, 2011). When participants were presented with a Necker cube, and then an insight problem (conflict condition), they solved an average of 4.24 of 10 insight problems ($SD = 1.87$). When they were first presented with an alternating cube, and then an insight problem (no conflict condition), they solved an average of 3.76 of 10 insight problems ($SD = 1.82$). A paired t-test (one-tailed) showed that participants solved significantly more insight problems in the conflict condition compared to the no conflict condition $t(79) = 1.86$, $p = 0.034$ (see Fig. 4). Therefore, the results suggest that observing a Necker cube increased the likelihood that the subsequent insight problem would be solved correctly.

As in Kan et al. (2013), reaction times between the conflict and no conflict conditions were not significantly different. It is possible that the time constraints in the conditions meant that participants were answering the problems faster than they would naturally, making subtle reaction time differences between the two conditions difficult to detect. As in Kan et al. (2013), we also performed a median split of participants into two groups made up of those who experienced more reversals of the Necker cube in one group (high conflict), and those who experienced less reversals in the other group (low conflict). A one-way ANOVA revealed no significant differences between the two groups in solving insight problems ($p = 0.17$), and no correlation was found between reversals in the Necker cube and performance ($r = 0.02$, $p = 0.82$) or reaction time ($r = 0.08$, $p = 0.32$).

3.2.2. Metacognitions

There are two ways to partition metacognitions in this experiment: they can be localized to correct responses only, or it is possible to explore how participants respond metacognitively to all problems, whether solved correctly or incorrectly across the two conditions. In order to make specific comparisons between metacognitions in the conflict condition

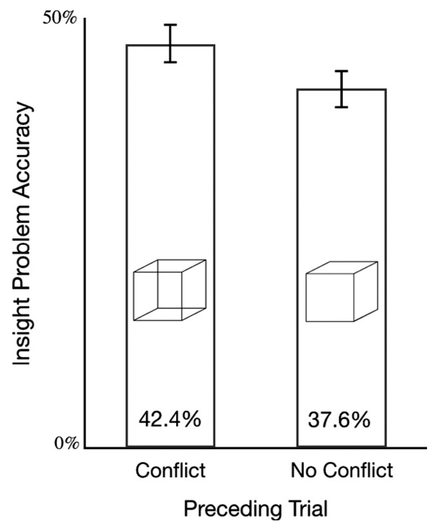


Fig. 4. Average insight problems solved by condition (Conflict trials are insight problems preceded by a Necker cube, whereas No Conflict trials are insight problems preceded by an alternating cube). Error bars represent the standard error of the mean.

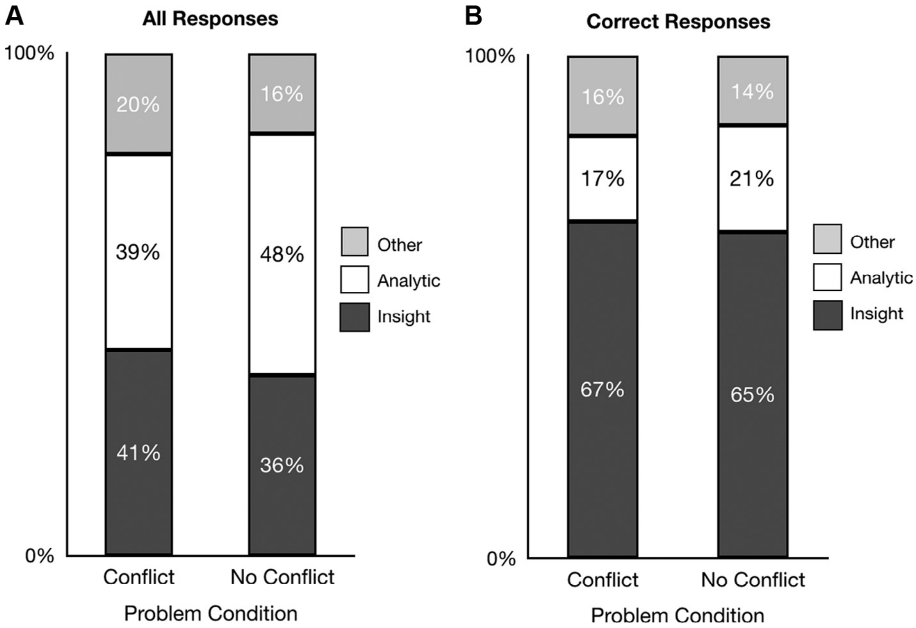


Fig. 5. Average proportion of problems solved through insight, analysis, or other for all responses (A), and for correct responses only (B).

and the no conflict condition, we combined the responses into two variables for each analysis. For instance, to compare insights, we created two variables, either problems solved through insight or problems solved through non-insight (i.e., collapsing over analytic and other solutions). As illustrated in Fig. 5(A) below, when all responses are analyzed, we receive a picture of how participants arrived at solutions to the problem, regardless of whether the solution they found was correct or not. Using a McNemar's test on all responses, we found that when participants solved insight problems preceded by conflict (i.e., a Necker cube), they were significantly more likely to report insights compared to solving insight problems preceded by no conflict (i.e., alternating cubes, $p = 0.017$). Insight problems preceded by conflict were also associated with fewer reports of analytic solutions than the no conflict condition ($p < 0.001$), but no difference was found in reports of 'other' solutions. Also illustrated in Fig. 5(B) below, when only correct responses are analyzed, a McNemar's test revealed fewer analytic solutions, and more 'other' solutions if the problem was preceded by conflict compared to no conflict ($p = 0.003$ and $p = 0.006$, respectively), but there was no difference in the number of insights reported in the two conditions. This may suggest that although participants reported experiencing more insights following Necker cubes (as hypothesized), these insights were not necessarily accurate.

Initially, the differential warmth data for correct responses were surprising. We found that the total warmth ratings appeared larger in the conflict ($M = 0.35$) compared to the no conflict ($M = 0.31$) condition. However, in Experiment 2, we were less interested in the metacognitive patterns (since they ought to be approximately the same across insight problems), but more interested in the number of insights participants experienced. Therefore, as in Experiment 1, the warmth ratings were partitioned into analytic solutions (differential warmth rating greater than zero) and insight solutions (differential warmth ratings of zero or less). The results show a marginally significant difference between insight problems preceded by a Necker cube (conflict condition, $M = 3.80$) and insight problems preceded by alternating cubes ($M = 3.43$), $t(79) = 1.58$, $p = 0.059$, potentially suggesting more sudden solutions when the problem was preceded by a conflicting Necker cube. Warmth measures are less sensitive than the self-report measure because problems that are solved very quickly cannot be analyzed, which may account for the marginal effect. There was also a moderate to strong correlation between the amount of self-reported insights and insights recorded based on the warmth data ($r = 0.61$, $n = 51$, $p < 0.001$).

4. General discussion

While discussing scientific revelations with Fred Hoyle, Richard Feynman expressed a burning curiosity to find the conditions that lead to the kind of breakthrough insights he's had in the past. He goes on to say, "Some man suggested I think about it once because if I could only figure out the formula for what condition to be in to get good ideas, I'd be much more efficient and more happy." One of the implications of this study may be that situations which induce conflict, or conflict experienced during the problem-solving process, may be an important precedent of an insight moment. Once a conflict is experienced between our current interpretations or assumptions and another competing interpretation or assumption, then there is an opportunity to engage control, and step aside from the existing rut to a novel perspective, which if we are lucky, is a vantage point from which we can discover the solution: ‘Aha!’.

Experiment 1 demonstrated a familiar pattern whereby someone who was better at ‘solving’ or re-interpreting a visual stimulus was also better at solving an insight problem. At this stage, there is substantial evidence for the positive relationship between ambiguous or bistable images and insight problems (Doherty & Mair, 2012; Maier, 1930; Ohlsson, 1984, 2011; Schooler & Melcher, 1995; Sternberg & Davidson, 1995; Wiseman et al., 2011). We also found similar metacognitive patterns: both ambiguous figures and insight problems lead to more sudden and unexpected solutions than analytic problems. Our results further indicated that switching perspectives in an ambiguous image may also relate to analytic problem-solving more strongly than previously thought. However, we have assumed—based on previous research and our metacognitive data—that this effect is not equivalent to the relationship between ambiguous images and insight problem-solving. Pending further research, this should be considered a possible caveat to our interpretation of the results that follow. Previous research on the neural correlates of insight indirectly implicate the Conflict Monitoring System as a potential mechanism for resolving conflict in both ambiguous images and insight problems (Botvinick et al., 2001; Kan et al., 2013; Subramaniam et al., 2009; Kounios & Beeman, 2009). Experiment 2 aimed to explore this hypothesis by examining whether it is possible to elicit conflict adaptation in insight problems using a bistable image. As predicted by Conflict Monitoring Theory, in Experiment 2, we found that insight problems were more likely to be solved accurately when they were preceded by a Necker cube, as opposed to two alternating cubes. This result suggests that when the Conflict Monitoring System is engaged through exposure to conflict in the Necker cube, then the associated control mechanisms assist participants in resolving subsequent representational conflict in an insight problem (Kan et al., 2013).

Overall, the metacognitive results of Experiment 2 were also in the expected direction and consistent with previous research showing that experiencing conflict—presumably activating the functions of the anterior cingulate cortex—will lead to more subsequent insights during problem-solving (Kounios et al., 2006; Subramaniam et al., 2009). Overall, participants reported more insights and fewer analytic solutions when preceded by a Necker cube compared to the no conflict control. When analysing the correct responses only, the same results did not entirely emerge, although the direction was the same. It may be that the insights participants indicated experiencing following Necker cubes were not necessarily accurate insights. Nevertheless, even in the ‘correct responses’ subset, the Necker cube condition did encourage fewer analytic solutions and more ‘middle-ground’ solutions, appearing to shift participants in the expected direction (i.e., towards more insight-like solutions).

In order to formalize the proposed role of conflict monitoring with regard to ambiguous images and insight problems, Fig. 6 illustrates a basic schematic representation of the Conflict Monitoring System as a moderating factor in the successful switching from one interpretation to another conflicting interpretation. The model is general enough to capture how the Conflict Monitoring System relates to two tasks as seemingly disparate as insight problems and ambiguous images. It is likely, however, that as the context of the insight becomes increasingly complex (e.g., conflicting interpretations of Feynman’s theory of helium), then domain specific knowledge and experience will be considerably more predictive of insights relative to an engaged Conflict Monitoring System. Nevertheless, if the domain specific information and experiences are exhausted, engaging in active comparisons of one’s assumptions or interpretations, or indeed engaging in an unrelated but conflict inducing task, may be the missing ingredient for an insight moment.

There is some evidence that deliberately comparing conflicting assumptions on a problem will help with solving it. Patrick, Ahmed, Smy, Seeby, and Sambrooks (2015), demonstrated a marked improvement (between 24% and 40%) in insight

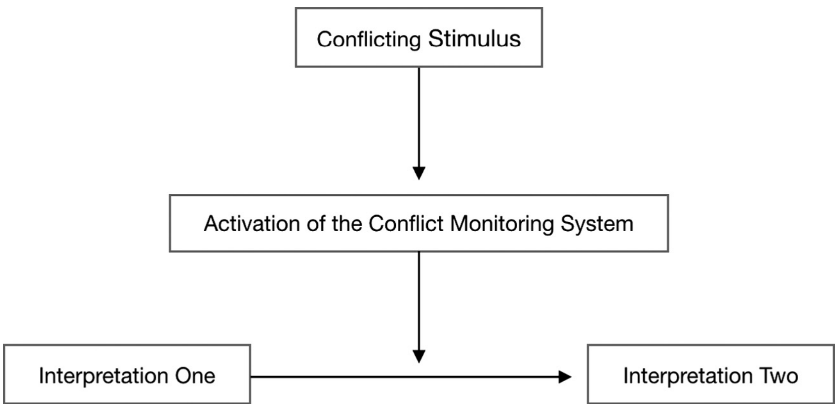


Fig. 6. A proposed moderation model in which the Conflict Monitoring System moderates the likelihood of switching between two interpretations of an insight problem or bistable image. The Conflict Monitoring System can be engaged both by task-relevant or task-irrelevant conflicting stimuli.

problem-solving when participants were instructed to check for inconsistencies between their interpretations of parts of the problem and the problem's specification. Naturally, this technique increases the chances of the participant discovering the correct interpretation simply by virtue of exploring other hypotheses. However, the moderation model in Fig. 6 suggests that in some cases it may be enough to simply engage the system (i.e., the Conflict Monitoring System) in order to boost the likelihood of switching interpretations and experiencing an insight, which may partly explain the effectiveness of this technique.

There are some considerations for interpreting the results of this study. In Experiment 2, we have not included an analytic problem-solving task. It is perhaps important to test whether conflict can improve problem-solving more generally, although this is highly unlikely to be the case given previous research showing that conflict adaption does not improve accuracy with stimuli that do not also have conflict present (Botvinick et al., 2004; Kan et al., 2013). Conceptualizing insight problems as situations of representational conflict is also potentially problematic. We assume that there is conflict occurring below awareness between the initially adopted incorrect (dominant) interpretation, and the correct one, and perhaps on the surface the kind of conflict in an insight problem appears different to the kind of conflict experienced in a Stroop task. However, even in the case of the Stroop task, the conflict between the word and the color does not occur consciously. A participant does not need to read the word "red" in their mind's eye, then notice that the word is in fact blue, before deciding to resolve the conflict between the word and the color. This conflict resolution process occurs below awareness, therefore, it is not a stretch to suggest that a conflict between possible interpretations of an insight problem may also occur below awareness. It is also possible that there is something about the Necker cube, which is unrelated to conflict, that improves subsequent insight problem-solving. However, we believe the hypothesis that a Necker cube can improve subsequent insight problem-solving is sufficiently counterintuitive that the Conflict Monitoring System is the best candidate mechanism at this time. It is also possible that cognitive control elicited by the Necker cube improves insight problem-solving in some way unrelated to the Conflict Monitoring System, but we do not have a competing hypothesis. If cognitive control processes are responsible, it is still unknown precisely how this is aiding in the insight problem-solving process. For example, it may be that cognitive control assists specifically with switching between competing representations, or it may be that cognitive control simply deactivates fixedness on the initial, dominant interpretation (or indeed both). Another possibility, as proposed by Kounios et al. (2006), is that activation of the anterior cingulate cortex is responsible for suppressing irrelevant thoughts such as daydreaming, however, there is some evidence that daydreaming may indeed improve insight problem-solving (e.g., Zedelius & Schooler, 2015).

We do not know how well the effects from Experiment 2 generalize. For example, does observing a Necker cube also improve performance in remote associate problems? To better understand the role of the anterior cingulate cortex, an fMRI study would be informative. For example, if observing a Necker cube does not activate the anterior cingulate cortex, but still improves insight problem-solving, then perhaps this brain region is not as important as we think. On the other hand, if observing a Necker cube improves insight problem-solving only when the anterior cingulate cortex is activated, then this would support the role of the Conflict Monitoring System in both tasks. Purely for the purposes of increasing the number of insights, it may also be interesting to simply identify tasks which most effectively activate the anterior cingulate cortex, and explore the extent to which these tasks promote subsequent insights.

Over a century ago, Jastrow proposed that the duck-rabbit illusion can be used to measure creativity (Jastrow, 1900). We continue to find support for Jastrow's bold claim, and propose that—at least conceptually—the conflict we experience between two interpretations of an image is similar to the conflict we experience between two perspectives in a verbal insight problem. In order to switch perspectives in both tasks (i.e., overcome the conflict), we may be engaging the same cognitive processes and capacities. Indeed, we find that observing a Necker cube can improve insight problem-solving and may lead to more experiences of insight, perhaps because the Necker cube engages the capacities necessary for insight to occur. Future work is necessary to determine the precise mechanism, although the Conflict Monitoring System is one candidate. We also find general support for Schooler et al. (1996) who proposed shared cognitive processes between switching representations of ambiguous images and insight problems, and for Subramaniam et al. (2009), who suggested that cognitive control mechanisms "…could be an important component of what insight researchers variously term cognitive restructuring and flexibility or 'breaking set' and 'overcoming functional fixedness.'"

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

Acknowledgments

The authors thank John McLean for generously assisting on this project.

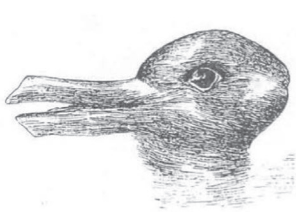
Appendix A. Experiment stimuli

Appendix A: Experiment Stimuli

Insight Problems	Analytic Problems
A man in our town has married 20 women from the town. All of the women are still alive, and the man has never been divorced. Polygamy is illegal in our town, and yet the man has broken no law. How is this possible?	Mary won't eat fish or spinach, Sally won't eat fish or green beans, Steve won't eat shrimp or potatoes, Alice won't eat beef or tomatoes, and Jim won't eat fish or tomatoes. If you are willing to give such a bunch of fussy eaters a dinner party, which items from the following list can you serve: green beans, creamed codfish, roast beef, roast chicken, celery, and lettuce?
An unemployed woman did not have her driver's license with her. She failed to stop at a railroad crossing, then ignored a one-way traffic sign and traveled three blocks in the wrong direction down the one-way street. All this was observed by a policeman, who was on duty, yet he made no effort to arrest the woman. Why?	After a recent spate of home improvements, four couples were having a dinner party to discuss the additions to their houses. Alan had not recently had a new bathroom. Kara had not yet done her kitchen, but perhaps would update it next. Brian, who is married to Maud, had not had new windows. Laura delighted in showing photographs of her new conservatory. Neither Charles nor David had a new kitchen. Julie had not had new windows. Alan, who also had not had windows, is not married to Laura and Charles is not married to Kara. Who is married to whom and what work had they recently undertaken, assuming that each couple had one improvement and no two couples had the same improvement.
Our basketball team won 72-49, and yet not one man scored as much as a single point. How is that possible?	A boy and a girl are sitting on the porch. "I'm a boy," says the child with black hair. "I'm a girl," says the child with red hair. If at least one of them is lying, who is which?
One morning a woman's earring fell into a cup that was filled with hot coffee, yet her earring did not get wet. How could this be?	If you add the age of a man to the age of his wife, the result is 91. He is now twice as old as she was when he was as old as she is now. How old is the man and his wife?
A magician claimed to be able to throw a ping pong ball so that it would go a short distance, come to a dead stop, and then reverse itself. He also added that he would not bounce the ball against any object or tie anything to it. How could he perform this feat?	If the puzzle you solved before you solved this one was harder than the puzzle you solved after you solved the puzzle you solved before you solved this one, was the puzzle you solved before you solved this one harder than this one?
A young boy turned off the lights in his bedroom and managed to get into bed before the room was dark. If the bed is ten feet from the light switch and the light bulb and he used no wires, strings, or other contraptions to turn off the light, how did he do it?	There are three playing cards lying face up, side by side. A five is just to the right of a two. A five is just to the left of a two. A spade is just to the left of a club, and a spade is just to the right of a spade. What are the three cards?
Professor Bumble, who is getting on in years, was driving along in his old car when suddenly it shifted gears by itself. He paid no attention and kept on driving. Why wasn't he concerned?	One train runs from A to B at 105 miles per hour, the other runs from B to A at 85 miles per hour. How far apart were the two trains 30 minutes prior to their crossing?
Mr. Hardy was washing windows on a high-rise office building when he slipped and fell off a sixty foot ladder onto the concrete sidewalk below. Incredibly, he did not injure himself in any way. How is this possible?	You are in the dark, and on the floor there are six shoes of three colours, and a heap of twenty-four socks, black and brown. How many socks and shoes must you take into the light to be certain that you have a matching pair of socks and a matching pair of shoes?

Ambiguous Images



Insight Problems	Analytic Problems
A father and his son get in a car accident. The father is sent to one hospital, and the son is sent to another. When the doctor comes in to operate on the son, the doctor says, "I cannot operate on him. He is my son." How can that be?	Three cards from an ordinary deck are lying on a table, face down. The following information (for some peculiar reason) is known about those three cards: To the left of a queen there is a jack, to the left of a spade there is a diamond, to the right of a heart there is a king, to the right of a king there is a spade. Can you assign the proper suit to each picture card?
A murderer is condemned to death. He has to choose among three rooms. The first is full of raging fires, the second is full of assassins with loaded guns, and the third is full of lions that haven't eaten in 3 years. Which room is safest for him?	A milkman has two empty jugs: a three gallon jug and a five gallon jug. How can he measure exactly one gallon without wasting any milk?

Ambiguous Images

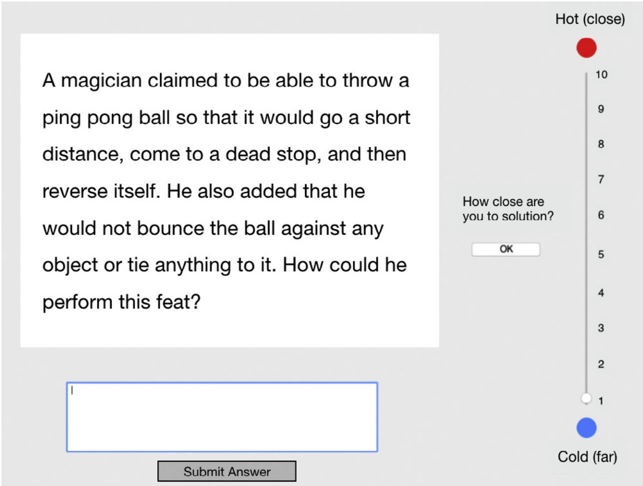



Additional Experiment 2 Stimuli.

Insight Problems
A man pushed a car. He stopped when he reached a hotel at which point he knew he was bankrupt. Why?
1988 pennies are worth more than 1983 pennies. Why?
Sid shady works for a large construction company that was very concerned about employee theft. Someone tipped off the company that Shady was the man to watch. Each night he passed through security with a wheelbarrow full of scrap lumber, discarded electrical wires and chunks of concrete. The security guards checked the contents daily but could find nothing of value. What was Shady stealing?
Bobby had not taken anything and was feeling fine but he couldn't help repeating everything Mr. Jenkins said. Why is that?
A man walked into a bar, and before he could say a word he was knocked unconscious. Why?
While on safari in the wild jungles of Africa, Professor Quantum woke one morning and felt something in the pocket of his shorts. It had a head and tail but no legs. When Quantum got up, he could feel it move inside his pocket. Quantum, however, showed little concern and went about his morning rituals. Why such a casual attitude toward the thing in his pocket?
A prisoner was attempting to escape from a tower. He found in his cell a rope that was half long enough to permit him to reach the ground safely. He divided the rope in half, tied the two parts together, and escaped. How could he have done this?
If you have black socks and brown socks in a drawer, mixed in a ratio of 4 to 5, how many socks will you have to take out to make sure that you have a pair of the same colour?
Two men played five full games of checkers and each won an even number of games, with no ties, draws, or forfeits. How is that possible?
Captain Scott was out for a walk when it started to rain. He did not have an umbrella and he wasn't wearing a hat. His clothes were soaked yet not a hair on his head got wet. How could this happen?

Appendix B. Illustration of warmth ratings

A traditional insight problem was presented on the left of the screen alongside a warmth bar on the right of the screen. Warmth ratings appear every 15 s (Experiment 1) or 10 s (Experiment 2).



The answer to the problem is: The magician throws the ball straight up in the air.

References

Botvinick, M., Braver, T., Larch, D., Carter, C., & Cohen, J. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108*(3), 624–652. http://dx.doi.org/10.1037//0033-295x.108.3.624.

Botvinick, M., Cohen, J., & Carter, C. (2004). Conflict monitoring and anterior cingulate cortex: An update. *Trends in Cognitive Sciences, 8*(12), 539–546. http://dx.doi.org/10.1016/j.tics.2004.10.003.

Bowden, E. M., & Jung-Beeman, M. (2003). Aha! Insight experience correlates with solution activation in the right hemisphere. *Psychonomic Bulletin & Review, 10*(3), 730–737.

Bowden, E., & Jung-Beeman, M. (2007). Methods for investigating the neural components of insight. *Methods, 42*(1), 87–99. http://dx.doi.org/10.1016/j.ymeth.2006.11.007.

Davis, K. (2005). Human anterior cingulate cortex neurons encode cognitive and emotional demands. *Journal of Neuroscience, 25*(37), 8402–8406. http://dx.doi.org/10.1523/jneurosci.2315-05.2005.

Doherty, M., & Mair, S. (2012). Creativity, ambiguous figures, and academic preference. *Perception, 41*(10), 1262–1266. http://dx.doi.org/10.1068/p7350.

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: Reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(2), 343–353. http://dx.doi.org/10.1037/0278-7393.30.2.343.

Gratton, G., Coles, M., & Donchin, E. (1992). Optimizing the use of information: Strategic control of activation of responses. *Journal of Experimental Psychology: General, 121*(4), 480–506. http://dx.doi.org/10.1037/0096-3445.121.4.480.

Jarosz, A., Colflesh, G., & Wiley, J. (2012). Uncorking the muse: Alcohol intoxication facilitates creative problem solving. *Consciousness and Cognition, 21*(1), 487–493. http://dx.doi.org/10.1016/j.concog.2012.01.002.

Jastrow, J. (1900). *Fact and fable in psychology*. Houghton: Mifflin and Company.

Jung-Beeman, M., Bowden, E., Haberman, J., Frymiare, J., Arambel-Liu, S., Greenblatt, R., et al (2004). Neural activity when people solve verbal problems with insight. *Plos Biology, 2*(4), e97. http://dx.doi.org/10.1371/journal.pbio.0020097.

Kan, I., Teubner-Rhodes, S., Drummey, A., Nutile, L., Krupa, L., & Novick, J. (2013). To adapt or not to adapt: The question of domain-general cognitive control. *Cognition, 129*(3), 637–651. http://dx.doi.org/10.1016/j.cognition.2013.09.001.

Kornmeier, J., & Bach, M. (2005). The Necker cube—an ambiguous figure disambiguated in early visual processing. *Vision Research, 45*(8), 955–960.

Kounios, J., & Beeman, M. (2009). The Aha! moment: The cognitive neuroscience of insight. *Current Directions in Psychological Science, 18*(4), 210–216. http://dx.doi.org/10.1111/j.1467-8721.2009.01638.x.

Kounios, J., & Beeman, M. (2014). The cognitive neuroscience of insight. *Psychology, 65*(1), 71.

Kounios, J., Frymiare, J. L., Bowden, E. M., Fleck, J. I., Subramaniam, K., Parrish, T. B., & Jung-Beeman, M. (2006). The prepared mind neural activity prior to problem presentation predicts subsequent solution by sudden insight. *Psychological Science, 17*(10), 882–890.

MacDonald, A. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science, 288*(5472), 1835–1838. http://dx.doi.org/10.1126/science.288.5472.1835.

Maier, N. (1930). Reasoning in humans. I. On direction. *Journal of Comparative Psychology, 10*(2), 115–143. http://dx.doi.org/10.1037/h0073232.

Metcalfe, J. (1986). Feeling of knowing in memory and problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*(2), 288–294. http://dx.doi.org/10.1037/0278-7393.12.2.288.

Metcalfe, J., & Wiebe, D. (1987). Intuition in insight and noninsight problem solving. *Memory & Cognition, 15*(3), 238–246. http://dx.doi.org/10.3758/bf03197722.

O'Brien, C., Harris, M., & Higgs, S. (2013). Effects of alcohol on attentional mechanisms involved in figure reversals. *Human Psychopharmacology: Clinical and Experimental, 28*(5), 484–494. http://dx.doi.org/10.1002/hup.2337.

Ohlsson, S. (1984). Restructuring revisited. *Scandinavian Journal of Psychology, 25*(2), 117–129. http://dx.doi.org/10.1111/j.1467-9450.1984.tb01005.x.

Ohlsson, S. (2011). *Deep learning*. Cambridge: Cambridge University Press.

Patrick, J., Ahmed, A., Smy, V., Seeby, H., & Sambrooks, K. (2015). A cognitive procedure for representation change in verbal insight problems. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*(3), 746–759. http://dx.doi.org/10.1037/xlm0000045.

Riquelme, H. (2002). Can people creative in imagery interpret ambiguous figures faster than people less creative in imagery? *The Journal of Creative Behavior, 36*(2), 105–116.

Salvi, C., Bricolo, E., Franconeri, S. L., Kounios, J., & Beeman, M. (2015). Sudden insight is associated with shutting out visual inputs. *Psychonomic Bulletin & Review, 22*(6), 1814–1819.

Salvi, C., Bricolo, E., Kounios, J., Bowden, E., & Beeman, M. (2016). Insight solutions are correct more often than analytic solutions. *Thinking & Reasoning*, 1–18.

Schooler, J.W., McCleod, C., Brooks, K., & Melcher, J. (1993). Individual differences in solving insight analytic problems. Unpublished Raw Data.

Schooler, J. W., Fallshrore, M., & Fiore, S. M. (1996). Epilogue: Putting insight into perspective. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 559–587). The MIT Press.

Schooler, J. W., & Melcher, J. (1995). The ineffability of insight. In S. Smith, T. Ward, & R. Finke (Eds.), *The creative cognition approach* (pp. 97–133). Cambridge, Mass.: MIT Press.

Shannon, R. W., Patrick, C. J., Jiang, Y., Bernat, E., & He, S. (2011). Genes contribute to the switching dynamics of bistable perception. *Journal of Vision, 11*(3). 8-8.

Simon, J. R., & Wolf, J. D. (1963). Choice reaction time as a function of angular stimulus-response correspondence and age. *Ergonomics, 6*(1), 99–105.

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

Stroop, J. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*(6), 643–662. http://dx.doi.org/10.1037/h0054651.

Subramaniam, K., Kounios, J., Parrish, T., & Jung-Beeman, M. (2009). A brain mechanism for facilitation of insight by positive affect. *Journal of Cognitive Neuroscience, 21*(3), 415–432. http://dx.doi.org/10.1162/jocn.2009.21057.

Toppino, T. C., & Long, G. M. (2005). *Top-down and bottom-up processes in the perception of reversible figures: Toward a hybrid model. Dynamic cognitive processes* (pp. 37–58). Tokyo: Springer.

Van Veen, V., Cohen, J., Botvinick, M., Stenger, V., & Carter, C. (2001). Anterior cingulate cortex, conflict monitoring, and levels of processing. *Neuroimage, 14* (6), 1302–1308. http://dx.doi.org/10.1006/nimg.2001.0923.

Weisberg, R. W. (1996). Prolegomena to theories of insight in problem solving: A taxonomy of problems. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight*. The MIT Press.

Weissman, D., Giesbrecht, B., Song, A., Mangun, G., & Woldorff, M. (2003). Conflict monitoring in the human anterior cingulate cortex during selective attention to global and local object features. *Neuroimage, 19*(4), 1361–1368. http://dx.doi.org/10.1016/s1053-8119(03)00167-8.

Wiseman, R., Watt, C., Gilhooly, K., & Georgiou, G. (2011). Creativity and ease of ambiguous figural reversal. *British Journal of Psychology, 102*(3), 615–622. http://dx.doi.org/10.1111/j.2044-8295.2011.02031.x.

Zedelius, C. M., & Schooler, J. W. (2015). Mind wandering "Ahas" versus mindful reasoning: Alternative routes to creative solutions. *Frontiers in Psychology, 6*.