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Short Communication

The dark side of Eureka: Artificially induced Aha moments make facts feel true

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ABSTRACT

Some ideas that we have feel mundane, but others are imbued with a sense of profundity. We propose that Aha! moments make an idea feel more true or valuable in order to aid quick and efficient decision-making, akin to a heuristic. To demonstrate where the heuristic may incur errors, we hypothesized that facts would appear more true if they were artificially accompanied by an Aha! moment elicited using an anagram task. In a preregistered experiment, we found that participants (n = 300) provided higher truth ratings for statements accompanied by solved anagrams even if the facts were false, and the effect was particularly pronounced when participants reported an Aha! experience (d = .629). Recent work suggests that feelings of insight usually accompany correct ideas. However, here we show that feelings of insight can be overgeneralized and bias how true an idea or fact appears, simply if it occurs in the temporal 'neighbourhood' of an Aha! moment. We raise the possibility that feelings of insight, epiphanies, and Aha! moments have a dark side, and discuss some circumstances where they may even inspire false beliefs and delusions, with potential clinical importance.

1. Introduction

John Nash, a mathematician and Nobel laureate, was asked why he believed that he was being recruited by aliens to save the world. He responded, "…the ideas I had about supernatural beings came to me the same way that my mathematical ideas did. So I took them seriously" (Nasar, 1998). Although Nash was diagnosed with Schizophrenia in 1959, the example exposes a basic human conundrum. In everyday life humans need to discern the difference between a true and useful idea and a false one, and sometimes must do so quickly in order to respond in conversation, give advice, or solve a problem under pressure. How is the validity of a new idea evaluated, especially when time is of the essence? Perhaps the metacognitive process described by Nash is correct, and humans turn to the phenomenology that accompanies their ideas—their Aha! moments.

Ideas that are called 'insights' are defined by metacognitive suddenness (Metcalfe & Wiebe, 1987) and an immediate sense that the idea is correct or valuable despite its unexpected appearance in mind (Ohlsson, 1984; Kounios & Beeman, 2014; Danek & Wiley, 2017; Laukkonen & Tangen, 2017). Recent empirical work suggests that when participants report an Aha! experience—the subjective marker of insight—then the solution they provide tends to be correct (Danek, Fraps, von Müller, Grothe, & Öllinger, 2014; Hedne, Norman, & Metcalfe, 2016; Salvi, Bricolo, Kounios, Bowden, & Beeman, 2016; Webb, Little, & Cropper, 2016; Danek & Wiley, 2017). For example, Salvi et al. (2016) presented participants with four different problems to solve: compound remote associates, anagrams, rebus puzzles, and degraded images. For each of the problems, when participants reported a feeling of Aha! they were more likely to provide a correct response (nearly twice as likely in some cases). This insight-accuracy effect appears to be robust across a number of laboratory problems, and effect sizes are consistently large (e.g., Hedne et al., 2016; Webb et al., 2016; Danek & Wiley, 2017).

1.1. Why are Aha! moments usually correct?

There is currently no generally accepted explanation for why the feeling of insight should predict accurate solutions to problems, but there are theoretical frameworks for which it is not so surprising. According to Feelings-as-Information Theory (Schwarz, 2011), subjective experiences in the forms of emotions, bodily sensations, and metacognitive experiences are sources of information that humans regularly rely on to make judgments and decisions (see also Bechara, Damasio, & Damasio, 2000; Slovic, Finucane, Peters, & MacGregor,

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2007). Obvious examples include hunger, fear, pleasure, and tiredness, which signal something about the organism's internal state, or an automatic appraisal of some external phenomenon. The role of feeling in guiding decision-making has been demonstrated in far-reaching domains including risk judgments (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978), stock market investments (Alter & Oppenheimer, 2006; Hirshleifer & Shumway, 2003), gambling and probability judgments (Loewenstein, Weber, Hsee, & Welch, 2001), truth and memory judgments (Reber & Schwarz, 1999; Dougal & Schooler, 2007; Schwarz, Sanna, Skurnik, & Yoon, 2007), and jury decision-making (Semmler & Brewer, 2002). It is feasible that the Aha! experience—like the many other feelings and sensations that guide decision-making in productive ways—is a source of information for the problem solver. Moreover, if the feeling of insight carries information about the veracity of a new solution—as it subjectively purports to—then it would not be surprising that it predicts accurate solutions.

How might Aha! moments carry information about the veracity of a new idea? When a scientist, an inventor, or an artist has a new idea, they may be drawing on a vast repository of knowledge and expertise. Therefore, one possibility is that the insight experience signals that the new idea is highly coherent with the individual's existing knowledge and experiences. It's well known that experts can automatically and intuitively bring their expertise to bear in their domain, often without explicitly knowing why their intuitions are correct (Ericsson & Charness, 1994; Kahneman, 2015). New ideas may be evaluated through a similar mechanism, the only difference being that the idea occurs 'in the head' for the problem solver, whereas the stimulus is 'in the world' for the expert. Therefore, when a solution to a problem appears in mind, the problem solver can use the Aha! experience as a heuristic shortcut—a quick appraisal of whether the idea is consistent with what they know—instead of engaging in a slow and effortful evaluation (Slovic et al., 2007; Gigerenzer & Gaissmaier, 2011). So long as the person's existing knowledge is valid, then the Aha! experience will likely signal a correct solution. For a detailed theoretical discussion of our theory—termed the Eureka Heuristic—see Laukkonen, Schooler, and Tangen (2018), and Laukkonen (2019).

1.2. The experiment

This experiment is based on a specific prediction that arises from the view described above. If humans are being guided by their Aha! experiences as signals of veracity, then presumably artificially induced Aha! phenomenology ought to bias judgments. Similar effects have been found using feelings of surprise (Whittlesea & Williams, 2001), fluency (Reber & Schwarz, 1999, addressed further in the discussion), and familiarity (Whittlesea, Jacoby, & Girard, 1990). To test this prediction, we borrowed the "discovery misattribution" paradigm used by Dougal and Schooler (2007) in which participants confused the experience of successfully deciphering scrambled words with that of having previously studied them. Here we presented participants with claims such as: 'ithlium is the lightest of all metals', where the scrambled word is 'lithium' (Reber & Unkelbach, 2010). Participants needed to solve the scrambled word before the proposition is complete, and then they rated the extent to which they believe that the proposition is true. We expected that successfully solving the anagram will induce an Aha! experience that would be misattributed to the proposition, leading to biased truth judgments.

Our main interest was comparing truth judgments within-participants for solved and unsolved anagrams (with and without Aha!). However, we also included a between-subjects variable so that we could investigate baseline truth judgments without the presence of an anagram. If we find a baseline difference between the presence of the anagram and no anagram, this is equivalent to finding the 'Revelation Effect' (see Watkins & Peynircioglu, 1990; Bernstein, Whittlesea, & Loftus, 2002). We also included a condition where the key word—the same word that was scrambled in the anagram condition—was presented after a short delay. Solving an anagram inevitably leads to a delayed presentation of the key word that completes the proposition, and we wanted to ensure that the delayed presentation (which may itself elicit a miniature Aha! moment) was not accounting for any effects we observe. In the interest of a brief report, we provide detailed hypotheses, prespecified decision rules, instruction transcripts, and exploratory analyses on the Open Science Framework (OSF): https://osf.io/up98z.

2. Methods

2.1. Design & materials

This experiment was approved by the University of California, Santa Barbara, Human Subjects Committee, clearance number: 81-18-0543, in accordance with the Declaration of Helsinki. The experiment had three within subject variables: 2 (Proposition: true or false) × 2 (Problem: solved or unsolved) × 2 (Aha! Experience: yes or no), and one between subjects factor (Anagram: present, absent, and absent with delay). The dependent measure was truth judgments on a 12 point scale ranging from 1 (definitely false), to 12 (definitely true). All participants were presented with the same 26 propositions (13 true and 13 false) and those in the anagram condition were also presented with 26 anagrams derived from the propositions (materials can be found on the OSF). The propositions were adapted from Fenn, Newman, Pazdek and Garry (2013), and a key word from the proposition was used as the anagram (i.e., a word that is necessary for the proposition to make sense—see procedure for an example). Keywords were initially reorganised into anagrams using a random scramble function. These anagrams were then pilot tested and the combinations of letters adjusted manually until they were neither too difficult or too easy (we aimed for 50% solving rates). In the delay condition, the missing word in the proposition was presented with a 15 s delay in order to mimic the anagram condition as closely as possible.

2.2. Participants and procedure

Based on Dougal and Schooler (2007), we determined that 300 participants (100 in each condition) would provide sufficient power (.8) to detect an effect size of .4, which they observed in Experiment 1. Participants were recruited using Amazon Mechanical Turk. All participants were provided with written instructions, and randomly assigned to either the anagram, no anagram, or delay condition. Instructions provided to participants in the anagram condition are illustrated in Fig. 1 below.

Each trial proceeded as follows. The participants were first presented with the incomplete proposition, for example: "There are more than 100,000 craters on the…". Below the incomplete proposition participants were presented with an anagram that completes the claim, in this case they see the word "*nomo*" (moon). When the anagram is resolved, participants see the completed proposition as: "There are more than 100,000 craters on the moon." If the anagram was not solved within 20 s then the solution, "moon", was presented. Participants then made a truth judgment about the claim, after either solving it themselves or having the solution presented to them. Finally, on a new screen, participants reported whether they experienced an Aha! moment (yes or no).

In the No Anagram condition, participants were simply presented with the completed proposition: "There are more than 100,000 craters on the moon." They then made a truth judgment about it, and then, for consistency, also reported on their Aha! experience. The delay condition was the same, except that participants were presented with the key word after 15 s, which was approximately the same time it took to solve the anagrams.

Please read the following instructions carefully:

In the following experiment you will be presented with a claim such as "Lithium is the lightest of all metals." One of the words in the claim will be scrambled, as follows:

"**ithlium** is the lightest of all metals"

Your first task is to unscramble the word in the box provided below it in order to complete the proposition. Once you've completed the proposition by unscrambling the word "lithium", you will be asked whether the claim is true. In this case, you would be deciding whether the proposition: "Lithium is the lightest of all metals", is true or false.

Your task will be to rate whether or not the claim is true or false on a 12 point scale, where 1 is *definitely false* and 12 is *definitely true*. Please make the truth judgment as quickly as possible. You may need to rely on your intuition and trust your own judgment. Please DO NOT google the answer or search for it elsewhere, make the rating on your own.

Fig. 1. Instructions provided to participants in the Anagram condition. The instructions were similar in the other conditions except that we removed any mention of the anagram.

3. Results

3.1. Descriptives

After applying our decision rules, 268 of the 300 participants were included in the analyses. On average, participants solved the anagrams 59.6 % of the time (SD = .3), and the mean accuracy for individual anagrams is shown in Fig. 2. Unsurprisingly, participants provided higher truth ratings for true claims (M = 6.92, SD = 1.39), and lower ratings for false claims (M = 5.9, SD = 1.44), and the difference was significant, $t(267) = 13.8$, $p < .001$, $d = .84$. The anagrams elicited insights 39 % of the time, and consistent with previous work (Salvi et al., 2016), we found that anagrams accompanied by insight were more likely to be correctly solved (M = .71, SD = .3) compared to anagrams not accompanied by insight (M = .5, SD = .56), $t(67) = 3.94$, $p < .001$, $d = .48$.

The following analyses deviate slightly from the preregistration. We couldn't run the between- and within-subjects factors together (as planned) because the within-subjects factors are only present in the anagram condition, and not the others. Therefore, we ran separate analyses for the within-subjects factors, and then an ANOVA to evaluate the between-subjects manipulation.

3.2. Truth judgments in the within-subjects anagram condition

We predicted that when a participant successfully solves an anagram, rather than being presented the solution, they would be more likely to believe that the associated proposition is true. We also predicted that Aha! moments occasioned by solving the anagram would increase truth judgments. The results are illustrated in Fig. 3. As predicted, solved anagrams resulted in higher truth ratings than unsolved anagrams, $t(68) = 5.06$, $p < .001$, $d = .609$. Moreover, if participants reported experiencing an Aha! moment when solving the anagram, they provided higher truth ratings than on trials without Aha!, $t(68) = 5.23$, $p < .001$, $d = .629$.

We also explored whether Aha! moments resulted in higher truth judgments specifically for anagrams that were solved. We found that they did: solved anagrams accompanied by Aha! resulted in higher truth ratings (M = 7.2, SD = 1.94) than solved anagrams without Aha! (M = 6.31, SD = 1.87), $t(64) = 2.59$, $p < .006$, $d = .321$.

It's possible that solving anagrams has a differential effect on truth judgments for propositions that are true versus false. To test this possibility, we subjected the data to a two-way repeated measures ANOVA, but did not find a significant interaction $F(1,63) = 1.3$, $p = .259$ (see Fig. 4 below). This finding suggests that successfully solving anagrams

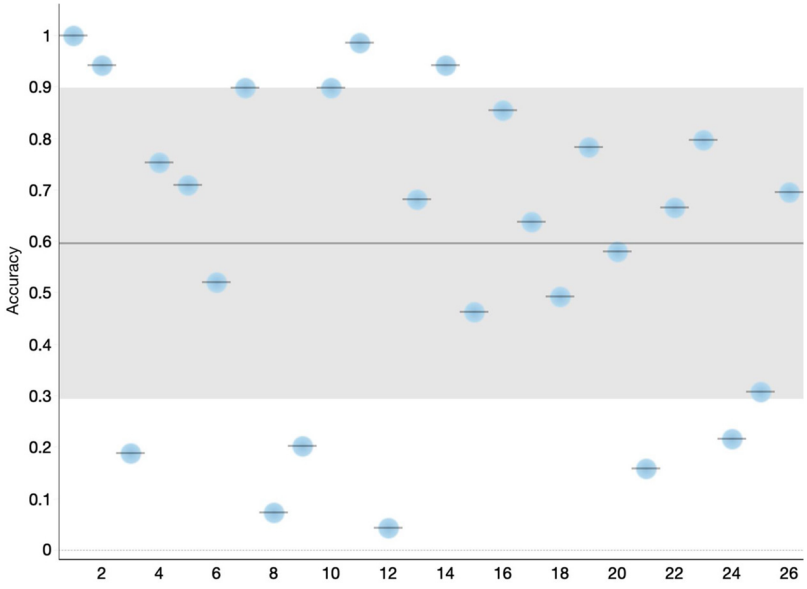

Fig. 2. Average solving rates for the anagrams individually and collectively. The central distribution (grey area) represents the standard deviation.

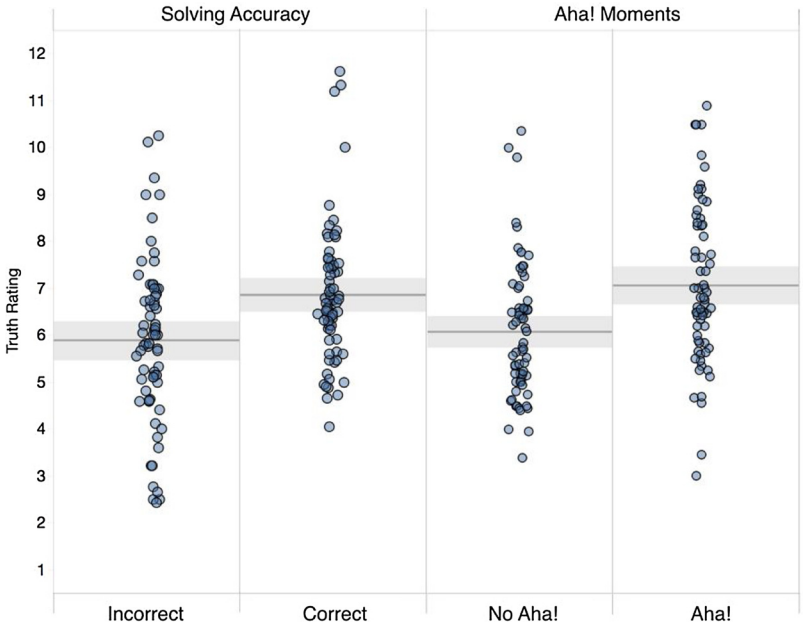

Fig. 3. Left: Truth judgments as a function of incorrectly and correctly solved anagrams. Right: Truth judgments as a function of the presence or absence of Aha! moments. Shaded areas represent 95 % confidence intervals.

comparably increased truth judgments for both true and false claims.

3.3. Truth judgments in the between-subjects conditions

We evaluated whether there was an overall difference in truth judgments in the three conditions: Anagram, No Anagram, and Delay. The ANOVA produced a marginal effect, $F(2,265) = 2.7, p < .069$, but none of the planned comparisons were significant. Therefore, the presence of the anagram—including both solved and unsolved trials—did not have an overall influence on truth judgments, and neither did presenting the key word after a delay. For an exploratory analysis of the between-subjects condition for easy compared to difficult anagrams, see: https://osf.io/wau7h/wiki/.

4. Discussion

There is a certain mystery about an idea that suddenly strikes the conscious mind, as if totally complete and true. The past century of research has progressed our understanding of the kinds of problem-solving processes that precede sudden solutions, and the best way to elicit insight experiences (Maier, 1931; Ohlsson, 1984; Schooler & Melcher, 1995; Sternberg & Davidson, 1995 Öllinger & Knoblich, 2009; Ohlsson, 2011; Laukkonen & Tangen, 2018). A less explored level of analysis is the role of insight in judgment and decision-making. Here we

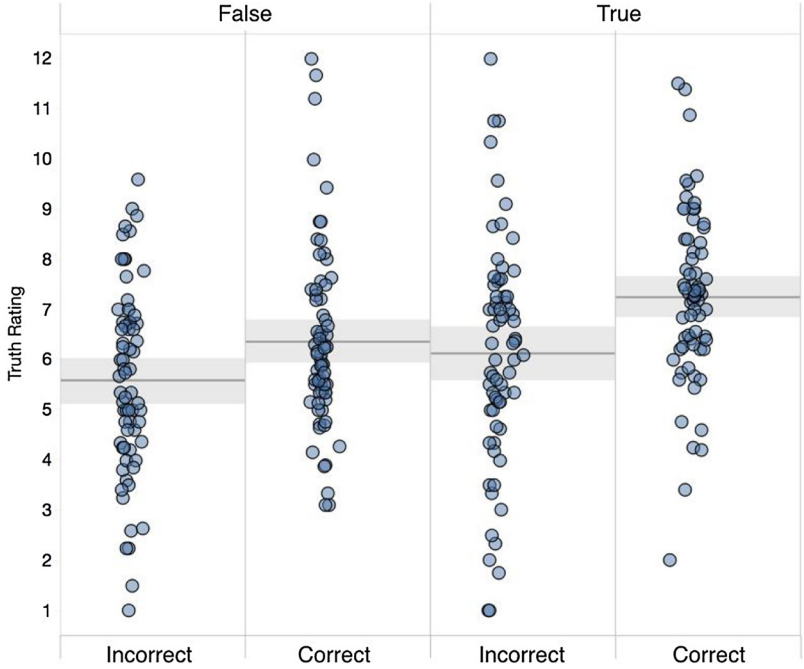

Fig. 4. Left: Truth judgments for false claims as a function of correctly and incorrectly solved anagrams. Right: Truth judgments for true claims as a function of correctly and incorrectly solved anagrams. Shaded areas represent 95 % confidence intervals.

tested the idea that humans interpret their feelings of Aha! heuristically as a signal regarding the quality of a new idea.

In the experiment, we artificially induced Aha! moments in order to influence truth judgments regarding 'facts' that were presented concomitantly. We reasoned that if people use their feelings of Aha! heuristically, then they should provide higher truth judgments overall when an Aha! experience occurs because they misattribute the feeling to the fact. Our results were in line with the predictions: successfully solving an anagram at the same time as reading a general knowledge claim resulted in higher truth ratings, even if the facts were false. We also found that the highest truth ratings were provided when solving the anagram elicited an Aha! moment, indicating that participants were being biased by their feelings of insight to believe that the claim was true (similar to the effect on memory judgments found in Dougal & Schooler, 2007). We suggest that these findings place the insight experience comfortably among other heuristics that people use to make quick decisions under uncertainty (Gigerenzer & Gaissmaier, 2011). Just as people turn to availability or representativeness (Kahneman & Tversky, 1972; Tversky & Kahneman, 1973), they too may turn to their Aha! experiences as a shortcut in place of a lengthy and effortful review of the evidence.

There are important links to previous research and theory that warrant further investigation and discussion (for a more theoretical overview of the Eureka Heuristic model of insight, see Laukkonen et al. (2018), and Chapters 4 and 5 of Laukkonen, 2019). Future work will need to disentangle which features of the Aha! phenomenology—if not the unique combination—are driving changes in perceived truth (e.g., positive affect, confidence, relief, fluency or surprise, Whittlesea & Williams, 2001; Topolinski & Reber, 2010; Webb et al., 2016). For example, it's possible that the Aha! experience elicited by the anagram leads to a sudden increase in processing fluency (Topolinski & Reber, 2010), which then increases the subjective 'truthiness' of the proposition. However, all participants were presented the solution to the anagram, and therefore fluent (i.e., smooth and easy) processing of the previously obscured word ought to be experienced regardless of solving success. Thus, it is unclear why a revealed solution would result in less ease of processing than a discovered solution, and why some discovered solutions are processed still more fluently than others. One possibility is that 'obviousness' and confidence dimensions of Aha! (Danek & Wiley, 2017) are important drivers of truthiness ratings above and beyond processing fluency.

It's also possible that existing theories regarding the 'origins of insight' and the processes involved in insight problem solving can accomodate the misattribution result (e.g., MacGregor, Ormerod, & Chronicle, 2001; Ormerod, MacGregor, & Chronicle, 2002; Ormerod & MacGregor, 2017). However, we still see that there is considerable value in viewing—for the first time to our knowledge—the Aha! as a feeling that may carry information (or bias) that guides subsequent decision-making in potentially profound ways. It is important to note that our findings relate to insight as the phenomenology of Aha!, as opposed to the classical definition of insight as a sudden and unexpected solution (Metcalfe & Wiebe, 1987; for an empirical demonstration of this distinction, see Laukkonen & Tangen, 2018).

The fact that insight experiences can be used to bias truth judgments opens many avenues for future research, and raises some disconcerting possibilities about the effect of Aha! on decision-making. In some instances, it is clearly disadvantageous to rely on phenomenology to decide whether an idea is true or not. For example, if one is suffering from a psychotic episode or mental illness (as in the case study of John Nash), or one has been exposed to false information, then feelings of insight may have no predictive power at all, and may instead promote false beliefs and perhaps in some cases perpetuate dangerous ideologies. Psychedelic compounds, which are receiving widespread attention (Pollan, 2018), may also have direct effects on the trustworthiness of insight phenomenology (Carhart-Harris & Friston, 2019). Investigating the circumstances and states of mind where false insights occur is a particularly exciting path for future research.

This experiment also highlights the concern of overgeneralizing feelings of insight. Presentations, news articles, advertising, and other media, may seek to exploit experiences of insight as a tool of persuasion, and may already unwittingly do so. More optimistically, it's possible that psycho-education regarding the nature and fallibility of our Aha! phenomenology could make us better decision-makers in complex situations. Therefore, while it is useful to know that feelings of insight carry useful information for making accurate truth judgments, it is perhaps even more important to recognize the situations under which they can be misleading.

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