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RESEARCH

The lack of Aha! experience can be dependent on the problem difficulty

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Abstract

Previous research on how problem-difficulty affects solution-types of insight-problems has yielded contradictory findings. Thus, we aimed to examine the impact of problem-difficulty on solution-types in both inter- and intra-problem-difficulty contexts. For this, we employed the original 8-coin, and 9-dot problems and four hinted-versions of those that were manipulated by using hints-to-remove-sources-of-difficulty to alter their difficulty level. Those manipulations were executed based on the assumptions of constraint-relaxation and chunk-decomposition as posited by representational change theory. The study involved a total of 165 participants who were tested in five groups (33 per se), with each group receiving an original or hinted problem. Following their correct solutions, problem-solvers classified their solution-types (insight or non-insight solutions) by whether they had an Aha!-experience during the solution. Across all groups, 56.1% of correctly solved insight problems were solved with Aha!-experience, based on participants' self-reports, implying that correct solutions should not be equated with insight. Subsequently, the solution-type rates were compared for both original problems (inter-problem-difficulty) and hinted versions of those at each difficulty level (intra-problem-difficulty). Inter-problem-difficulty comparisons demonstrated that the easier 8-coin problem was more likely to be solved with insight than the harder 9-dot problem. In contrast, intra-problem-difficulty comparisons revealed that harder problems were more likely to be solved with insight. These findings suggest that problem-difficulty should be considered in future studies of insight. Finally, separate analyses on the predictive values of the cognitive-affective-dimensions on solution-types revealed that, after adjusting for problem-difficulty, problem-solvers with higher suddenness scores in both problems exhibited a significantly higher probability of generating insight solutions.

Introduction

Remember the very moment a solution occurred to you all of a sudden while you were attempting to solve a problem? This moment was first named "insight" by Gestalt psychologists during the early 1900s (Duncker, 1926, 1945; Köhler, 1925, 1959; Maier, 1940; Wertheimer, 1945/2020). Since then, it has been the subject of numerous studies in the field of problem-solving, particularly over the last fifty years. In this line of work, insight is broadly defined as a unique mental process in which the solution comes to mind with a sudden realization known as the moment of "Aha!" or "eureka" (i.e., Bowden & Jung-Beeman, 2003; Danek et al., 2018; Duncker, 1945; Kounios & Beeman, 2009; Metcalfe & Wiebe, 1987; Wertheimer, 1945/2020). In contrast to the earlier definitions of insight problems, recent studies have demonstrated that the problems can be solved through either an insightful or an incremental (non-insight, step-by-step) process (i.e., Bowden, 1997; Bowden & Beeman, 1998; Danek et al., 2013; Kounios et al., 2008; Salvi et al., 2016), and this has led researchers to direct their attention to the factors likely to affect the solution types produced by problem solvers. There remains a need, therefore, to conduct further studies to examine the factors associated with different solution types.

The theoretical explanations of the fundamental mechanisms involved in solving insight problems assign considerable importance and complementarity to the concepts of "impasse" and "restructuring". The term "impasse" denotes a

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critical juncture in the process of solving a problem, wherein the problem solver thinks that all conceivable options have been thoroughly explored and exhausted. The term "restructuring" implies necessary reactions to overcome the impasse (Ohlsson, 1992). More specifically, representational change theory (RCT) explains why problem solvers reach an impasse and how they should react to overcome it. According to this theory, prior experiences can influence the initial mental representation of insight problems and cause confinement to an overly restricted problem space, leading to an impasse. RCT proposes two methods to overcome the impasse: constraint relaxation (CR) and chunk decomposition (CD). The former involves modifying the initial problem representation by relaxing constraints, while the latter involves segregating chunked items (Knoblich et al., 1999, 2001; Ohlsson, 1992, 2011). Eventually, the likelihood of successful restructuring, as per RCT, is determined by the level of difficulty in relaxing the constraints on the problems and decomposing chunked items in the problems. Empirical testing using several visuospatial insight problems such as matchstick problems (Knoblich et al., 1999), the 8-coin problem (Öllinger et al., 2013), and the car park game (Jones, 2003) provided support for the aforementioned assumptions of RCT. However, those studies have not focused on the type of solution, specifically whether it was accompanied by an Aha! experience or not.

However, regarding the new approaches to investigating insight, scrutinizing and evaluating the types of solutions to the insight problem appears to yield more information into the insight problem solving process. The starting point of this research topic, namely solution types, can be traced back to the cognitive processes associated with problem-solving, which gave rise to two distinct perspectives: the special-process and business-as-usual. Both rely primarily on a comparative analysis of the cognitive processes involved in solving problems that require insight versus those that do not (non-insight or analytical problems). From the business-as-usual perspective, insight problem solving is not fundamentally different from non-insight problem solving. This is because the process of restructuring in insight problem solving occurs gradually (incremental) through mechanisms that share similarities with those involved in non-insight problem solving (i.e., Chein et al., 2010; Cinan et al., 2013; Durso et al., 1994; Fleck & Weisberg, 2004, 2013; Gilhooly & Murphy, 2005; MacGregor et al., 2001). Conversely, the special-process perspective posits that the act of solving insight problems is distinguished by a unique process that differs from the processes involved in solving non-insight problems. Various potential indicators were examined using phenomenological, behavioral, biobehavioral, and neuroscientific methodologies to define reliable and precise criteria for assessing insight and whether it is a distinct and unique mental process. Among them, the Aha! moment, feeling of knowing, suddenness, and neural activation in the right hemisphere appear to be prominent candidates for such an indicator (i.e., Beeman & Bowden, 2000; Bowden & Beeman, 1998; Davidson, 1995; Jung-Beeman et al., 2004; Kounios & Beeman, 2014; Kounios et al., 2008; Metcalfe & Wiebe, 1987; Topolinski & Reber, 2010).

Bowden (1997) introduced a novel method for evaluating insight in terms of the types of solutions to insight problems. This method involved quantifying self-reported subjective experiences related to insight problem-solving, in which problem solvers rated their Aha! experiences. This method has been used in numerous neuroimaging studies (i.e., Beeman & Bowden, 2000; Bowden & Beeman, 1998; Bowden & Jung-Beeman, 2003; Jung-Beeman et al., 2004; Kounios et al., 2008), which have contributed to our understanding of insight problem-solving regarding the neural basis of the phenomenological aspect of insight. For instance, Jung-Beeman and colleagues (2003) utilized compound remote associate test (CRAs), and they observed increased activation in the right hemisphere when the problem was reported to be solved with insight as opposed to without insight, implying the distinctive characteristics of insight solutions. Moreover, their findings revealed that 41% of the participants who solved the CRAs did not have an Aha! experience while attempting to solve the CRAs. This demonstrated that solutions to insight problems may not always be accompanied by an Aha! experience. Thus, recently, the debate on the distinction of problem types (insight problems vs. non-insight problems) has shifted towards a distinction of solution types (insight solutions vs. non-insight/incremental solutions) of insight problems, which also constitutes the mainstay of the present study.

Subsequent research on this phenomenological aspect of insight problem-solving employed the subjective binary Aha! experience responses (i.e., Danek et al., 2016; Jung-Beeman et al., 2004; Salvi et al., 2016) or Aha! ratings (i.e., Ellis et al., 2011; Threadgold et al., 2018) of participants as a means of evaluating insight to search for the solution processes of those problems. The results of various studies using CRAs (Salvi et al., 2016; Webb et al., 2016) and different insight problems, for example, magic tricks (Danek et al., 2013; Danek et al., 2014; Danek & Wiley, 2017; Hedne et al., 2016), rebus puzzles (Salvi et al., 2016; Threadgold et al., 2018), classic insight problems (Danek et al., 2016; Webb et al., 2016), anagrams (Salvi et al., 2016), and line drawings (Salvi et al., 2016) were in line with the fact that correctly solved insight problems can be solved either with or without an Aha! experience. These studies provide evidence that the correct solution to insight problems does not indicate that these problems are being solved with insight, and additional measures of insight are essential. Moreover, studies have shown that the subjective Aha! experience is not exclusive to correct solutions, as it can also be present in conjunction with incorrect solutions. Nevertheless, they were found to differ in some characteristics. According to the findings of Danek and Wiley (2017), the subjective Aha! experience accompanying correct solutions (also referred to as "true insights") is distinguished by faster occurrence, more intense Aha! ratings, and greater levels of pleasure, suddenness, and certainty in comparison to those that accompany incorrect solutions (also referred to as "false insights"). Recently, the solution process of the correct and incorrect solution of magic tricks was monitored by Danek et al. (2018) through a repeated rating task paradigm. The findings provided empirical support for the links between suddenness and the subjective Aha! experience in terms of true and false insights, showing that the stronger Aha! experiences coincide with sudden changes in ratings toward a correct solution rather than gradual changes toward a correct solution or changes toward incorrect solutions.

Those studies mentioned above focus mainly on discerning the differentiating factors linked to true and false insight by contrasting types of solutions in correctly and incorrectly solved insight problems. The factors that impact the emergence of true insights, however, are not well understood. There have been few reports of solution type rates for correctly solved insight problems or investigations of the potential factors that may impact those rates. These studies show that the rates of insight solutions and non-insight solutions are slightly different from each other in correct solutions to various insight problems. As demonstrated by Kounios et al. (2008), the insight solution rate for correctly solved anagrams was 56.1%. Similarly, Danek et al. (2013) reported 50% insight solutions for magic tricks and 52.9% of those for classical insight problems (Danek et al., 2016). Laukkonen et al. (2021) found that rate to be 55% for verbal insight problems. In contrast, the study conducted by Fedor et al. (2015) revealed a comparatively elevated insight solution rate of 74% for five-square problems. On the other hand, three distinct studies have reported the insight solution rates of CRAs to be 56% (Jung-Beeman et al., 2004), 50.8% (Subramaniam et al., 2009), and 72% (Laukkonen et al., 2021). Those rates demonstrate that, with a few exceptions, insight and non-insight solutions are roughly equivalent across studies using different insight-based problems. Given that the problems used in these studies are likely to have varying degrees of difficulty, this observation brings about the idea that the types of solutions for successfully solved insight problems may be independent of problem difficulty. There needs to be a thorough investigation into whether or not this is the case. In due course, two questions arise: How is the subjective Aha! experience related to the solution of insight problems? Which specific characteristic of the problem impacts the likelihood of a problem-solver experiencing an Aha! moment while solving it? In order to obtain answers to these questions, the present research will focus on the solution types of correctly solved classical visuospatial insight problems. The subjective Aha! experience will be utilized as an indicator of insight solutions. Additionally, the level of difficulty of the problem will be considered as a potential specific characteristic that may influence the types of solutions generated.

In fact, contradictory results have been found in the few studies that have attempted to explain the variations in solution types of correctly solved insight problems in terms of their objective difficulty. One study conducted by Danek et al. (2016) compared the binary subjective Aha! experiences of three classical insight problems with varying degrees of difficulty. The number of constraints that needed to be relaxed for a solution determined the relative difficulty of each problem. The problems were ranked accordingly, from most to least difficult: 9-dot, 8-coin, and matchstick problems. The percentage of people who had an Aha! experience while solving the 9-dot problem was much lower than that of the 8-coin and matchstick problems. It was also lower for the 8-coin problem than it was for the matchstick problem. All indicating that the difficulty of problems was inversely proportional to the subjective Aha! experience. In another study, Danek and Wiley (2017) classified magic tricks as single-step or multi-step problems based on the number of steps required to solve them. The researchers then compared the subjective Aha experience as well as self-reported cognitive (suddenness and certainty) and affective (pleasure, surprise, relief, and drive) dimensions of the correct solutions to these problems of varying difficulty. The findings revealed that single-step solutions were perceived to be more sudden than multi-step solutions. However, no significant variations were observed in subjective Aha! ratings, solution times, or other subdimensions between single-step and multi-step solutions. Similarly, Kizilirmak et al. (2018) found no difference in the rates of subjective Aha! experiences among the correct solutions to the CRAs that were classified based on their difficulty level, which was determined by the solution rate and reaction time for each item.

To sum up, the findings of Danek et al. (2016) suggest that difficulty has an impact on the types of solutions that are generated for correctly solved visuospatial insight problems, as it was found that easier problems tend to be more conducive to the emergence of insight solutions. On the other hand, the findings of Danek and Wiley (2017) and Kizilirmak et al. (2018), studying the solution types of magic tricks and verbal-insight problems, respectively, indicate that problem difficulty has no impact on the types of correct solutions that were generated for either. These contradictory outcomes can be attributed to two primary factors. Firstly, the utilization of different types of problems, namely visuospatial and verbal, across studies. Secondly, the determination of problem difficulty from diverse perspectives, as each study concentrated on diverse origins of problem complexity. Researchers have known since the earliest studies on the insight that some problems, particularly the 9-dot problem, exhibit relatively low solution rates compared to others. This indicates that insight problems have varying levels of difficulty and that the utilization of such problems across studies may potentially yield divergent outcomes. Thus, it appears important to account for the possible confounding effect of problem difficulty on the results.

There is a reliable approach for altering the difficulty level of an insight problem that enables the problem to be tailored to varying levels of difficulty through the facilitation of restructuring. This allows us to examine the potential variations in the subjective experiences associated with the solution, contingent upon the difficulty level of the problem. This approach involves using hints within the field of insight, which are commonly employed to identify key obstacles or sources of difficulty that prevent individuals from solving insight problems. The findings of earlier studies indicate that providing hints to remove sources of difficulty enhances the likelihood of successful structuring of the initial mental representation of the problem, which facilitates the correct solution and contributes to the increase of solution rates (i.e., Danek et al., 2014; Jones, 2003; Kershaw, 2004; Kershaw & Ohlsson, 2004; Knoblich et al., 1999; MacGregor et al., 2001; Öllinger et al., 2013, 2014; Ormerod et al., 2006; Weisberg & Alba, 1981). Research on the impact of hints on solution types for different insight problems indicates that the provision of hints leads to incremental solutions, which implies a reduced likelihood of experiencing an Aha! moment in the presence of hints (i.e., Ammalainen & Moroshkina, 2021; Cushen & Wiley, 2012; Davidson, 1995; Durso et al., 1994; Strickland et al., 2022). For instance, in a recent study conducted by Ammalainen and Moroshkina (2021), anagrams presented with true-reportable and true-unreportable hints were found to be solved at higher rates than those presented without hints. The rate of solving anagrams presented with false-reportable and false-unreportable hints did not differ from that of those presented without hints. The results also demonstrated that the solutions to the anagrams presented without hints received higher Aha! ratings than those presented with either false or true hints (both reportable and unreportable). The solutions to anagrams presented with true-reportable hints received the lowest Aha! ratings. This indicates that as the problem gets easier, insight problems are more likely to be solved incrementally, and thus one would expect insight to occur in more difficult insight problems. However, this is not in line with the earlier studies, which found that problem difficulty had no effect (Danek & Wiley, 2017; Kizilirmak et al., 2018) or had an effect but in the opposite direction (Danek et al., 2016) on the solution types of correctly solved insight problems.

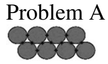
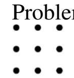
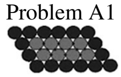
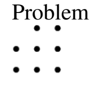
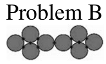
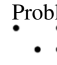
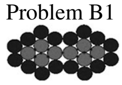
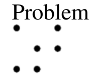
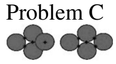
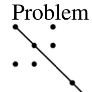
The present study

The present research centered on the solution types of correctly solved visuospatial insight problems with varying difficulty levels. Solution types for those problems were obtained dichotomously: correct solutions with a subjective Aha! experience were classified as insight solutions, and correct solutions without a subjective Aha! experience were classified as non-insight solutions. This classification was applied to ensure comparability of the present findings with those of Danek and colleagues' (2016) study. We aimed to evaluate the effect of problem difficulty on solution types in both inter-problem and intra-problem contexts. For this, we employed 8-coin and 9-dot problems to investigate the effect of inter-problem difficulty on the solution types of those problems, considering that the original 8-coin problem was easier than the original 9-dot problem (i.e., Danek et al., 2016). Using two congeneric insight problems with visuospatial features allowed us to examine the effect of inter-problem difficulty on the solution types of those problems. As previously noted, prior research has indicated that providing hints to remove the source of difficulty in a problem can be used to alter the difficulty level of the problem by inducing restructuring. This enables us to observe and contrast the rates of solution types within the problem that emerge contingent on its difficulty level, which was altered with hints. In this regard, to investigate the effect of the intra-problem difficulty on its solution type, we used versions of each 8-coin and 9-dot problem designed with hints at removing particular sources of difficulty from the original problem, conforming to the CR and CD assumptions of RCT.

In the view of RCT, constraints on the problem and/or tight chunks in the problem prevent finding the solution in insight problems, which suggests that either of those, alone or together, may constitute the source of the difficulty of the problem. This also implies that removing those sources of difficulty by relaxing the constraints of the problem and decomposing it into its components would facilitate finding the correct solution. Thus, in this study, we used those hints, alone and in combination, to remove the sources of problem difficulties in order to alter the intra-problem difficulty. As mentioned above, this allowed us to look into how the level of difficulty within a problem affected the solution types of those problems. To exemplify, the 8-coin problem consists of eight red coins, and among those, four of them are positioned in close proximity to each other in the upper section, while the remaining four coins are slightly shifted to the right and placed adjacent to each other in the lower section. The goal is to make each coin touch the other three coins, which requires replacing those coins on top of three others in the same way (Ormerod et al., 2002). In line with the RCT, Öllinger et al. (2013) stated that the difficulty in the 8-coin problem stems from the erroneous belief held by problem solvers that the coins can only be moved in the two-dimensional problem space (boundary constraint) and also that coins in contact with many others cannot be separated (i.e., tightly chunked items). Researchers relaxed the boundary constraint of the 8-coin problem by partially placing one of the coins on another coin so that the problem solvers could realize that the coins could be moved in three-dimensional (3-D) space. In addition, they manipulated the chunk tightness by reducing the total number of coins that are in contact in the problem configuration. We adopted the idea about manipulations on the 8-coin problem from Öllinger and colleagues and extended it for this study. We predicted that relaxing the constraints of the problem, separating it into its components, and giving hints at increasing levels would enhance the possibility of representational change and solution. Accordingly, in addition to the original 8-coin and 9-dot problems, we incorporated problems that were manipulated solely with CR, solely with CD, with both CR and CD, and with CR-CD and AH (additional hint). Thus, we employed the varying intra-problem difficulty levels of the problems across the study groups. The original and four hinted versions of the 8-coin problem and the 9-dot problem designed for this study were given in Table 1, and manipulations applied to each problem were described in the Method-Manipulations: Hints to Remove the Source of Difficulty section.

As per prior research, the procedure of providing explicit instructions and introducing novel information while engaged in problem-solving tasks may change the task requirements of the problems, leading to the generation of more incremental solutions (Chronicle et al., 2001; Cushen

Table 1 Characteristics of 8-coin and 9-dot problems designed by hints to remove difficulty source of each for the present study

Study groups	Hint type	8-coin problem	3D space	TNC	NSG	9-dot problem	MDOS	ND	NDT
Control group	None (original problems)	Problem A 	–	13	1	Problem X 	–	9	2
CR group	Constraint relaxation	Problem A1 	+	13	1	Problem X1 	+	9	3
CD group	Chunk decomposition	Problem B 	–	11	1	Problem Y 	–	7	0
CR & CD group	Constraint relaxation Chunk decomposition	Problem B1 	+	11	1	Problem Y1 	+	7	1–2
CR & CD & AH group	Constraint relaxation Chunk decomposition Additional hint	Problem C 	+	9	2	Problem Z 	+	7	1–2

For 8-coin problem additional hint was grouping, whereas it was given as the first line starting from out of the right down corner dot for 9-dot problem

CR Constraint relaxation; *CD* Chunk decomposition; *AH* Additional hint; *TNC* Total Number of Contacts of coins; *NSG* Number of separate groups of coins; *MDOS* Moving dot outside of square; *ND* Number of dots; *NDT* Number of non-dot turns of the lines required for solution

& Wiley, 2012; Ormerod et al., 2002). The reason we chose to utilize visuospatial insight problem in this study was to minimize the potential impact of explicit hints on solution types. The 8-coin and 9-dot problems were considered appropriate for providing implicit, non-verbal hints and were accordingly modified solely with such hints. Nonetheless, despite the absence of explicit verbal hints, we assumed that implicit nonverbal hints could also change the problem's environment and task demands by altering the contextual information among the problem elements. Accordingly, the allocation of value to environmental information by problem solvers was regarded as a confounding factor. To minimize the influence of variations in the participants' utilization of contextual information during problem-solving process on the results, we employed the Cognitive Bias Task (CBT) to measure their response selection styles (target-different, target-similar, and target-indifferent). We then assigned them to the study groups in a balanced way, taking into account their response selection styles (see the Method section for details about CBT). By doing this, no statistically significant variations were detected among the participants belonging to different study groups in terms of their utilization of environmental information in the provided context.

In sum, the present research aims to determine whether and how the difficulty of the problem influences the presence of insight in correctly solved visuospatial insight problems by ruling out confounding factors. To examine this potential influence, the present study obtained measures of solution types of correctly solved insight problems under both inter-problem and intra-problem conditions for testing the following hypothesis: If the difficulty of the problem has no effect on its solution types, then correctly solved easy and hard (in both inter- and intra-problem difficulty contexts) insight problems should have similar solution types. If, however, the difficulty of the problem affects its solution types, then correctly solved easy and hard (in both inter- and intra-problem difficulty contexts) insight problems should have different solution types. The present study has a complementary claim regarding the direction of this effect, as follows: As hints induce incremental solutions to easier problems, the subjective Aha! experience should accompany the solution of harder insight problems. In addition, there is a growing body of research looking into other subjective phenomena that may be present with the solution of insight-based problems, besides the Aha! experience. Recently, it has become more prevalent in studies of insight to include individual ratings on the cognitive and affective dimensions of problem-solving to explore this (i.e., Savinova & Korovkin, 2022; Spiridonov et al., 2021; Stuyck et al., 2021; Webb et al., 2016, 2019). However, the previous studies have yielded converging and diverging results among those dimensions, indicating the need for further investigation to clarify their potential contribution to insight problem-solving. Nonetheless, with the exception of the research conducted by Danek and Wiley (2017), the objective problem difficulty was not considered in those studies. Furthermore, the cognitive and affective aspects of correctly solved visuospatial insight problems have yet to be investigated. Therefore, along with problem difficulty, the present research aims to explore how the cognitive (suddenness and certainty) and affective (pleasure, surprise, relief, and drive) dimensions of the problem-solving process are related to the solution types of correctly solved visuospatial insight problems. As previously reported by Danek and Wiley, true insight solutions (correct solutions accompanied by a subjective Aha! experience, named insight solutions in this study) to magic tricks are predicted by suddenness, pleasure, and certainty. We, therefore, hypothesized that besides problem difficulty, suddenness, pleasure, and certainty would be significant predictors of insight solutions in both insight problems.

Methods

Participants

The age range for participants in this study was 20–31 years old. Participants were required to be at least 20 years old due to a study indicating that electrical brain activity reaches maturity in the early twenties (Mathes et al., 2016). To eliminate the confounding effects of age and aging on cognition, the upper age limit for participation was set at 31 (Bruine de Bruin et al., 2020; Löckenhoff, 2018). A psychiatric or neurological diagnosis was regarded as a potential confounding factor. In addition to this, high levels of paranoid ideation, depression, psychoticism, and obsessive–compulsive traits were considered potential confounding factors based on previous studies demonstrating their effects on the leading biases in decision-making (Dudley et al., 2016; Fear & Healy, 1997; Freeman et al., 2008; Sastre-Buades et al., 2021). Thus, the inclusion criteria for this study were: a) being between the ages of 20 and 31; and b) scoring below the midpoint on the SCL-90-R subscales for paranoid ideation, depression, psychosis, and obsessive–compulsive disorder. Exclusion criteria included: a) any past or present psychiatric or neurological disorder; b) familiarity with the 8-coin or 9-dot problems; and c) current substance abuse. A priori power analysis was conducted using Gpower 3.1.9.7. Results indicated the required sample size to achieve 80% power for detecting a medium effect of 0.3, at a significance criterion of $\alpha = .05$, was 133 for chi-square test. The statistical power achieved for the sample size of 165 subjects was determined to be 0.89 through post hoc power analysis, which was considered sufficient for detecting a medium effect of 0.3 at a significance criterion of .05.

Data were collected from 207 voluntarily participating individuals. 42 participants were excluded from the study because of their familiarity with the insight problems or technical or procedural issues. Final data were recruited from 165 participants (mean age: 24.52, SD = 2.68; 115 females). Of those, 35.2% were undergraduates (n = 58), 44.8% were graduate students (n = 74), and 20% were university graduates (n = 33). To eliminate the effects of differences in problem solvers' utilization of contextual information on their restructuring processes, one hundred sixty-five volunteers were assigned to one of five study groups (control or experiment) according to their response selection styles (measured via CBT; see procedure section). Each study group comprised 33 individuals (23 females per group).

Materials

Symptom check list-90-revised (SCL-90-R)

The Turkish version of the SCL-90-R was used to evaluate the subjective experiences of individuals with psychological symptoms and distress levels (Dağ, 1991; Deragotis & Cleary, 1977; Koğar, 2019). Each subscale was measured on a 5-point scale ranging from 0 (not at all) to 4 (extremely). Among the volunteers, only those with scores below the subscale's median were included in the study. Thus, the subscale score ranges in this study were as follows: paranoid ideation (0–12), depression subscale (0–26), psychosis subscale (0–20), and obsessive–compulsive subscale (0–20).

Cognitive bias task (CBT)

CBT was developed by Goldberg et al. (1994) to identify the response selection styles (biases) of individuals towards a target considered to be a cognitive context. CBT is a non-veridical (agent-centered) decision-making task in which participants can express subjective preferences as target-different, target-similar, and target-indifferent (mixed) response selection styles. CBT consists of sixty trials, each of which contains a stimulus consisting of three cards (one target card on top and two choice cards vertically aligned below). Each card is defined by five binary characteristics: shape, color, size, contour, and number. The similarity index is calculated by comparing the target card and the two choice cards for each trial; it ranges from 0 (different) to 5 (identical). Target-choice similarity index pairs are equally represented and counterbalanced throughout the trial sequence, which was the same for all participants.

For this study, the CBT was prepared with Psychopy3 (Peirce et al., 2019) computer software. Participants were instructed to look at the target card and select one of the choice cards they liked best by pressing the up arrow key for the superior choice card or the down arrow key for the inferior choice card. They were told that there was no right or wrong answer. A cumulative total score was calculated by summing the similarity indices of the participants' choices for each trial throughout the task. Higher scores regarding extreme target-different and target-similar responses are considered context-dependent decisions resulting from stimulus-driven response selection, in which the target card guides choice behavior based on similarities or differences in the five dimensions between the target card and the choice cards. Lower scores regarding target-indifferent responses (switching between target-different and target-similar responses) are considered context-independent decisions, indicating that the target card is not used as a context in order to respond, and thus response selection was internally driven and stimulus-independent.

8-coin problem

The original 8-coin problem, designed by Ormerod and colleagues (2002), and four different versions of this problem were used in this study (see Table 1). Problem B used in this study was adopted from the study of Öllinger et al. (2013). All problems were prepared via the Unity3D game engine (Unity Technologies, n.d.), and the coins were approximately 18 mm in diameter and three mm high. Problem solvers are required to replace two coins so that each of the coins touches the other three coins in three minutes.

9-dot problem

The original 9-dot problem designed by Maier (1930), and four different versions of this problem were used (see Table 1) in this study. The Unity3D game engine (Unity Technologies, n.d.) was used to create all of the problems. The diameter of each dot is 5 mm, and the distance between the dots is 1 cm. Problem solvers are required to draw four consecutive straight lines by crossing each dot in three minutes. Due to the fact that the first line is given as an additional hint in Problem Z, problem solvers are required to start from any end of the given line and draw three consecutive straight lines by crossing each dot for this problem in 3 min.

Manipulations: hints to remove the source of difficulty

Öllinger and colleagues (2013) described the difficulties in solving the 8-coin problem based on the CR and CD assumptions of RCT and stated that problem-solvers think that coins can only be moved in two-dimensional (2D) space (boundary constraint) and coins in contact with one another cannot be separated when solving the 8-coin problem. The same causes of difficulty were acknowledged in this study for the 8-coin problem. The difficulties of the 9-dot problem were described as follows: self-imposed "lines stay inside the square" thought as a boundary constraint, and a higher number of dots that lines must cross as tighter chunks. Table 1 displays the problems given to the study groups in the present research.

The control group received the original 8-coin and 9-dot problems, and the four experiment groups received their versions manipulated by hints to remove the source of difficulty for this study. The CR group received Problem A1 and Problem X1 with hints to remove boundary constraints, while the CD group received Problem B and Problem Y with hints to remove the tight chunks constraint. The CR-CD group received Problem B1 and Problem Y1 with hints to remove both the boundary constraints and tight chunks. The CR-CD-AH group received Problem C and Problem Z, both of which were designed with an additional hint besides those for removing the boundary constraints and tight chunks. Thus, Problem C also hinted at removing the grouping constraint, and Problem Z hinted at removing an additional square boundary constraint by providing the first line. Due to these manipulations, the number of non-dot turns required to solve the 9-Dot problems designed for this study varied between 0 and 3.

For the 8-coin problem, the boundary constraint—the idea that coins can only be moved in 2D space—has been relaxed by giving 3D hints in two ways. The first way, adapted from Öllinger et al. (2013), involved replacing coins on top of others. Accordingly, Problem C was designed by replacing a coin on top of two others. However, Öllinger et al.'s 3D hint method not only relaxes constraints but also groups the coins and decomposes the chunked items. With this method, coins in Problem C were split into two groups, and the number of contacts between coins was also reduced. Therefore, in the second way, we aimed to relax the 2D constraints of the problem by keeping the chunked items constant without changing the number of separate groups of coins. Accordingly, Problems A1 and B1 were designed by placing 24 blue-colored coins under and around the eight red-colored coins in order to stabilize the number of contacts between the coins while providing hints for 3D. The boundary constraint of the "9-dot" problem was relaxed by moving one dot out of the imaginary square (Problem X1, Problem Y1, and Problem Z). The tight chunks, which is the number of contacts between coins in 8-coin problems (Problems B, B1, and C) and the number of dots in 9-dot problems (Problem Y, Y1, and Z), was decomposed by reducing the number of those in each problem.

Subjective aha! experience measures

The participants who solved the given problem were first asked to answer the familiarity question: "Have you seen this problem before?" Yes, or no. Then they were asked to categorize their solution experiences into insight and non-insight solutions. The instructions for the judgments on solution type were adopted from Danek et al. (2014) as follows: "We would like to know whether you experienced a feeling of insight when you solved the problem. A feeling of insight is a kind of 'Aha!' moment characterized by suddenness and obviousness, like an enlightenment. You are relatively confident that your solution is correct without having to check it. In contrast, if the solution occurred to you slowly and stepwise, you experienced no Aha! As an example, imagine a light bulb that is switched on all at once in contrast to gradually dimming it up. Your answer will not be considered true or false. We just want to know what you were going through." Accordingly, participants chose one of the following answers: Yes, I experienced an Aha! moment. No, I haven't experienced an Aha! moment.

Rating scale for the cognitive and affective dimensions of problem-solving experience

Participants rated their subjective solution experiences on a linear scale from 1 to 10 with respect to cognitive (suddenness and certainty) and affective (pleasure, surprise, relief, and drive) dimensions, with the following statements adopted from Danek and Wiley (2017):

Suddenness: "This solution came to me…" In step:1; All at once: 10.

Certainty: "How certain are you that your solution is correct?" Uncertainty: 1; Certainty: 10.

Pleasure: "At the moment of solution, my feelings were…" Unpleasant: 1; Pleasant: 10.

Surprise: "The moment of solution was…" Not surprising: 1; Surprising: 10.

Relief: "At the moment of solution, I felt…" Tense: 1; Relieved: 10.

Drive: "I would like to see similar problems." No: 1; Yes: 10.

Procedure

The study protocol was approved by the Research Ethics Committee of Istanbul University Social and Human Sciences. Individuals were invited to the study through social media accounts and social networks. Participants were tested in two stages. In the first stage, individuals were asked to fill out the Informed Consent Form, Demographic Information and Eligibility Form, as well as the Paranoid Ideation, Depression, Psychoticism, and Obsessive–Compulsive Subscales of the SCL-90-R via Google Forms in order to determine whether they met the participation criteria. Those who met the participation criteria for this study were invited to the second stage. In the second stage, participants accessed the experimenter's computer remotely. Participants were tested individually on CBT and then assigned to one of the five study groups. For this, first, the CBT score of each participant was categorized according to their target-different (below 25%), target-indifferent (between 25 and 75%), and target-similar (above 75%) choice behaviors. Afterward, the participants were evenly distributed to one of the five study groups (see Table 1) according to their response selection types. The CBT scores of the study groups did not differ in this way ($F_{(4,160)} = 0.167$, $p = .955$). After being assigned to a study group, each participant initially worked on one of the 8-coin problems and then on one of the 9-dot problems, depending on which group they were assigned to.

Since there is no consensus on the time limit to give participants to solve insight problems in the literature, participants were given three minutes to solve each problem, based on the findings of Weisberg and Alba (1981), who showed that the average time required to solve the 9-dot problem, widely regarded as the most challenging visuospatial insight problem, was three minutes. The reason for setting an average time limit for the solution process instead of giving participants unlimited time to solve the problem was to minimize the potential effects of prolonged problem-solving efforts on the intensity of participants' subjective experiences. When the participant's proposed solution was incorrect, they were informed and directed to continue solving. There were no additional written or verbal hints during the experiment. If the participant solved the problem, they were asked to respond to the subjective problem-solving experience questions and rate the scale for the cognitive and affective dimensions of the problem-solving experience.

Design

The between-subject design with five independent groups (1. control, 2. CR, 3. CD, 4. CR and CD, and 5. CR and CD and AH) receiving the original or one of four hinted versions of two insight problems was used. The between-subject factor was intra-problem difficulty; the within-subject factors were inter-problem difficulty and the cognitive and affective dimensions of problem-solving experience. The dependent measure was the solution type of the correctly solved insight problems.

Data analyses

First, participants who correctly solved the problem classified their solution types as insight solutions (with Aha! experience) or non-insight solutions (without Aha! experience). The solution-type rates for both original problems (inter-problem difficulty) and hinted versions of those at each difficulty level (intra-problem difficulty) were compared. Nevertheless, the findings showed no linear relationship between the rate of solution and the level of hint provided. For instance, the 9-dot problem designed with a CR hint (Problem Y) was solved by the majority of problem solvers, as opposed to other versions of the same problem designed with more hints. A conceivable rationale for this could be the questionable nature of the CR and CD manipulations asserted in line with the RCT, or the existence of other neglected factors that impede the efficacy of hints for problem solvers. As a consequence of considering that not every participant could benefit from the hints provided in different types and degrees, additional analyses were deemed necessary. For this, the difficulty of each problem was determined ex post facto based on the overall rate of correct solutions for each problem rather than the type and level of the hints provided. Accordingly, the 8-coin and 9-dot problems were categorized into two difficulty levels, easy and hard, based on their total solution rates, as follows: Problems with solution rates greater than the total correct solution rate for each problem (33.3% for the 8-coin; 28.5% for the 9-dot) were categorized as easy (low-level difficulty), while those with solution rates less than the total correct solution rate for each problem were categorized as hard (high-level difficulty). Problem A, Problem A1, and Problem B were categorized as hard 8-coin problems, whereas Problem B1 and Problem C were categorized as easy problems. On the other hand, among the 9-dot problems, Problem X, Problem Y1, and Problem Z were categorized as hard, while Problem Y was categorized as easy. Since Problem X1 was unsolved, it was discarded from the analysis.

The 2X2 chi-square test of independence was used to examine the effect of inter-problem and intra-problem difficulty on the solution types of correctly solved 8-coin and 9-dot problems. The predictive values of intra-problem difficulty, cognitive (suddenness and certainty), and affective (pleasure, surprise, relief, and drive) dimensions of problem-solving experience on the solution types of the correctly solved insight problems were computed via hierarchical binary logistic regression analysis (HBLR) with the forward likelihood ratio (FLR) method separately for 8-coin and 9-dot problems. The overall model fit was evaluated by the likelihood ratio chi-square test and the Hosmer and Lemeshow test. The predictor variables' contributions to the variability of the dependent variable (solution types) were assessed with the Nagelkerke R^2 indicator.

Results

Descriptive statistics, inter- and intra-problem comparisons

In total, 165 participants worked on one of the original or hinted versions of the 8-coin problem and one of the original or hinted versions of the 9-dot problem (330 trials = 165 participants x two problems). Of those, 55 (33.3%) participants solved the given 8-coin problem, while 47 (28.5%) participants solved the given 9-dot problem. The overall solution rate for the insight problems was 30.9% (102 out of 330 trials). Figure 1 depicts the problem-solving performance of the study groups in solving the original and hinted versions of the 8-coin and 9-dot problems. The clustered bar chart plots the percentages of problems unsolved, solved with insight, and solved without insight for each study group for each insight problem.

The frequencies and solution rates of the study groups for each problem are given in Table 2. The solution rates of the study groups were compared with a chi-square test separately for 8-coin and 9-dot problems. The results showed no difference in the solution rates of the 8-coin problems between the study groups, $\chi^2_{(4,165)} = 8.45$, $p = .076$, Cramer's V = .23. There was a statistically significant difference between the study groups in the solution rates of the 9-dot problems, $\chi^2_{(4,165)} = 87.65$, $p = .000$, Cramer's V = .73. Further analysis of the effectiveness of hints on the solution rate of the insight problems is not relevant for the purposes of this study and will therefore be presented elsewhere.

Participants who correctly solved the given 8-coin and/or 9-dot problems categorized their solution types as insight (with Aha!) or non-insight (without Aha!) solutions. 56.1% of all correctly solved original or hinted versions of the two problems were classified as insight solutions. Table 2 also displays the frequencies and rates of solution types of the study groups in solving the given 8-coin and 9-dot problems separately. Across all study groups, 27 (49.1%) of participants who solved the given 8-coin problem reported having insight solutions, while 28 (59.6%) of participants who solved the given 9-dot problem reported having insight solutions. The solution types of the study groups were compared with a chi-square test separately for 8-coin and 9-dot problems. The test results showed no difference in the solution types of the original and hinted versions of the 8-coin problems between the study groups, $\chi 2(4,55) = 2.70$, $p = .608$, Cramer's V = .22. There was a statistically significant difference between the study groups in the solution types of

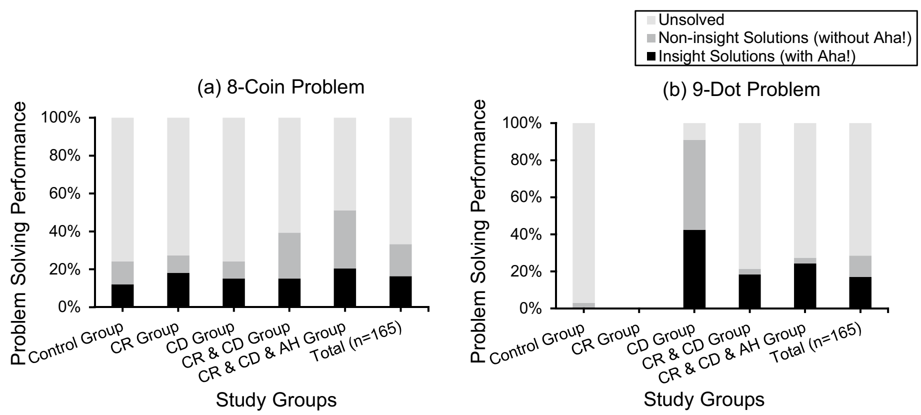


Fig. 1 Problem-solving performance of the study groups **a** Problem solving performance of study groups in solving 8-coin problems **b** Problem solving performance of study groups in solving 9-dot problems

Table 2 Frequencies and rates of solution and solution types of insight problems in the study groups

Insight problems	Solution types	Study groups										Total correct solutions		X^2 (SD)
		Control group		CR group		CD group		CR & CD group		CR & CD & AH group				
		Problem A		Problem A1		Problem B		Problem B1		Problem C				
		n	%	n	%	n	%	n	%	n	%	n	%	
8-coin problems	Non-insight solutions	4	50	3	33.3	3	37.5	8	61.5	10	58.8	28	50.9	2.70 (4)
	Insight solutions	4	50	6	66.7	5	62.5	5	38.5	7	41.2	27	49.1	
	Solvers/total	8/33	24.2	9/33	27.3	8/33	24.2	13/33	39.4	17/33	51.5	55/165	33.3	8.45 (4)
		Problem X		Problem X1		Problem Y		Problem Y1		Problem Z		Total		
9-dot Problems	Non-insight solutions	1	0	0	0	16	53.3	1	14.3	1	11.1	19	40.4	8.75 (3)*
	Insight Solutions	0	0	0	0	14	46.7	6	85.7	8	88.9	28	59.6	
	Solvers/Total	1/33	3	0/33	0	30/33	90.9	7/33	21.2	9/33	27.3	47/165	28.5	87.65 (4)**

CR Constraint relaxation; *CD* Chunk decomposition; *AH* Additional Hint

*$p < .05$, **$p < .001$

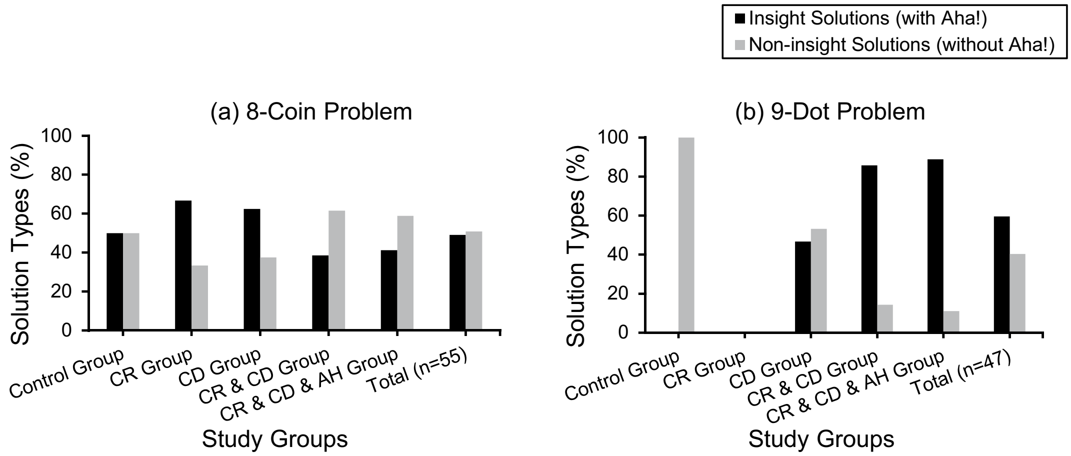


Fig. 2 **a** Solution type ratios of correctly solved 8-coin problems. **b** Solution type ratios of correctly solved 9-dot problems in study groups. Note. Please notice that in Panel b, the entirety (100%) of the non-insight solutions of the control group is based on a single correct solution

the original and hinted versions of the 9-dot problems, $\chi 2(3,47) = 8.75$, $p = .033$, Cramer's V = .43. Figure 2 plots the rate of solution types for the original and hinted versions of the 8-coin and 9-dot problems separately that were correctly solved in each study group. In addition, it shows the overall solution type rates of the total correct solutions for each given 8-coin and 9-dot problems. The bar chart depicts the ratio of percentages of two types of solutions: insight solutions and non-insight solutions.

For the comparisons of the solution types of the 8-coin and 9-dot problem at the intra-problem difficulty level, the original and hinted versions of both problems were classified into two (easy or hard) categories due to their total solution rates. The frequencies and percentages of solution types for easy and hard 8-coin problems and easy and hard 9-dot problems are shown in Table 3. The chi-square test results revealed that the solution types of easy and hard 8-coin problems did not differ statistically significantly, $\chi^2_{(1,55)} = 2.18$, $p = .140$, Cramer's V = .20. A statistically significant difference was found in the solution types of easy and hard 9-dot problems, $\chi^2_{(1,47)} = 5.74$, $p = .017$, Cramer's V = .35. Figure 3 plots the percentages of solution types for easy and hard 8-coin problems and easy and hard 9-dot problems separately at the intra-problem difficulty level. The line graph illustrates the solution type trends in solving easy and hard 8-coin and 9-dot problems. For the participants who solved easy problems, non-insight solutions were higher than insight solutions. On the other hand, for the participants who solved hard problems, insight solutions were higher than non-insight solutions.

Hierarchical binary logistic regression results

HBLR analyses were conducted in order to determine the predictive values of cognitive-affective dimensions on the solution type of the correctly solved 8-coin problems and 9-dot problems separately by controlling the intra-problem difficulty. The dependent variable for each problem was

Table 3 Frequencies and chi-square results for solution types in correct solutions of easy and hard insight problems

Insight problems	Difficulty level	Solution types				X^2 (SD)
		Insight solutions (with Aha!)		Non-insight solutions (without Aha!)		
		n	%	n	%	
8-coin problems (Total n = 55)	Easy	12	40	18	60	2.18 (1)
	Hard	15	60	10	40	
9-dot problems (Total n = 47)	Easy	14	46.67	16	53.33	5.74* (1)
	Hard	14	82.35	3	17.65	

Difficulty level classification for 8-coin problems, easy problems: Problem B1 and Problem C. Hard problems: Problem A, Problem A1 and Problem B. Difficulty level classification for 9-dot problems, easy problems: Problem Y. Hard problems: Problem X, Problem Y1 and Problem Z

*$p < .05$

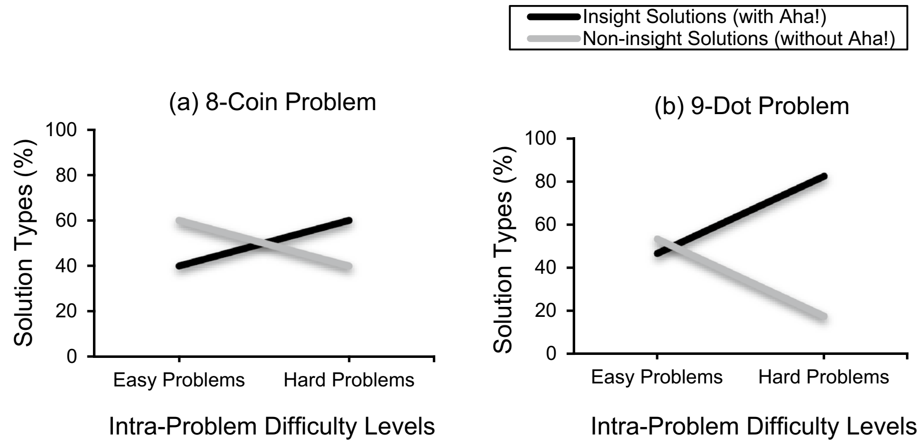


Fig. 3 Multiple line percent of intra-problem difficulty level by solution types for **a** 8-coin problems and **b** 9-dot Problems

solution types: insight solutions = 1 and non-insight solutions = 0. Intra-problem difficulty as a categorical independent (control) variable: easy = 0 and hard = 1. Cognitive (suddenness and certainty) and affective (pleasure, surprise, relief, and drive) dimensions as continuous independent variables: scale from 1 to 10. In the HBLR analysis for both the correctly solved 8-coin and 9-dot problems, the intra-problem difficulty was added to the first block with the enter method and controlled, and then cognitive-affective dimension scores were added to the second block with the FLR method to determine cognitive-affective predictors of solution types of the correctly solved problems.

The results of the HBLR analysis run for 8-coin problems and 9-dot problems separately are presented in Table 4. The upper panel of Table 4 shows the results of the HBLR analysis for the 8-coin problems. When intra-problem difficulty was added to the beginning block, the block 1 model did not make a significant improvement over the null model, − 2 LL = 74.03, $\chi^2_{(1)} = 2.20$, $p = .138$. Block 1 model individually explained 5.2% (Nagelkerke R^2) of the total variance and correctly classified 60% of the cases. After suddenness was added to the model in block 2, explained variance increased by 21.6%; thus, the final block 2 model explained 26.8% of the total variance in the solution type of 8-coin problems and correctly classified 72.7% of the cases. The Hosmer and Lemeshow test was insignificant ($\chi^2_{(6)} = 3.05$, $p = .802$). All suggest a good-fitting model, which is significantly different from the null model. In the block 2 model, intra-problem difficulty and suddenness made a significant contribution to the prediction of the solution type of the 8-coin problems. The odds of the hard problems being solved with insight were 3.817 times greater than those of the easy problems (OR = 3.817, CI = 1.049–13.883). The odds of a participant with a higher suddenness score experiencing insight were 1.358 times greater than those of a participant with a lower suddenness score (OR = 1.358, CI = 1.103–1.672). Certainty, pleasure, surprise, relief, and drive did not significantly influence the solution type of the 8-coin problems.

The lower panel of Table 4 shows the results of the HBLR analysis for the 9-dot problems, which was run to reveal the predictive values of cognitive-affective scores on the solution types of the 9-dot problems by controlling the intra-problem

Table 4 Hierarchical binary logistic regression results for predicting solution type of 8-coin and 9-dot problems

Insight problems	Independent variable	B	SE B	Wald X^2	df	*p*	OR	95% CI	
								LL	UL
8-coin problem	Block 1 – step 1								
	Difficulty levels	0.811	0.553	2.152	1	.142	2.25	0.761	6.648
	Block 2 – step 1								
	Difficulty levels	1.339	0.659	4.133	1	.042	3.817	1.049	13.883
	Suddenness	0.306	0.106	8.322	1	.004	1.358	1.103	1. 672
9-dot problem	Block 1 – step 1								
	Difficulty levels	1.674	0.734	5.202	1	.023	5.33	1.265	22.477
	Block 2 – step 1								
	Difficulty levels	2.462	0.903	7.436	1	.006	11.726	1.998	68.807
	Suddenness	0.313	0.135	5.401	1	.020	1.368	1.050	1.782

Difficulty levels: easy problems = 0, hard problems = 1

CI confidence interval; *LL* lower limit; *UL* upper limit difficulty level. Block 1 model made a significant improvement to the null model when intra-problem difficulty was added to the model, -2 LL = 57.30, $\chi2_{(1)} = 6.12$, $p = .013$. Block 1 model individually explained 16.5% (Nagelkerke R2) of the total variance and correctly classified 63.8% of cases. After suddenness was added to the model in block 2, explained variance increased by 15.7%; thus, the final block 2 model explained 32.2% of the total variance in the solution type of 9-dot problems and correctly classified 74.5% of the cases. The final block 2 model made a significant improvement in fit relative to the block 1 model, -2LL = 50.63, $\chi2_{(2)} = 12.80$, $p = .002$. The Hosmer and Lemeshow test was insignificant, $\chi2_{(7)} = 6.39$, $p = .495$ All indicate a good-fitting model that differs significantly from the null model. In the final block 2 model, intra-problem difficulty and suddenness made a significant contribution to the prediction of the solution type of 9-dot problems. The odds of the participants solving hard problems (OR = 11.726, CI = 1.998–68.807) via insight were 11.726 times greater than those of the easy problems. The odds of a participant solving problems with a higher suddenness score (OR = 1.368, CI = 1.050–1.782) via insight were 1.368 times greater than those of a participant with a lower suddenness score. Certainty, pleasure, surprise, relief, and drive did not significantly contribute to solution type of 9-dot problems.

Discussion

In the present study, we investigated the effect of inter- and intra-problem difficulty on the solution types of the correct solutions of the original and four hinted versions of the two classical visuospatial insight problems. Comparisons of solution type rates between the two original insight problems were used to determine the effect of inter-problem difficulty on the solution types of correctly solved insight problems. The effect of intra-problem difficulty on the solution types of correctly solved insight problems was evaluated by comparing solution type rates across study groups. In addition, the effect of intra-problem difficulty on the solution types of correctly solved insight problems was further explored by comparing the rates of the solution types of the problems classified as easy and hard within each insight problem.

Inter-problem comparisons

The correct solution rates were found to differ between the two problems, as predicted. The correct solution rates for the original 8-coin problem and the original 9-dot problem are compatible with those found by Danek et al. (2016), indicating that the original 9-dot problem is more difficult than the original 8-coin problem. Furthermore, since the total correct solution rate of all 8-coin problems remained higher than the total correct solution rate of all 9-dot problems, we can conclude that the difficulty of the 9-dot problem persisted despite the manipulations by hints to remove the sources of difficulty. Eventually, in this study, 56.1% of correctly solved insight problems across all study groups were solved with insight, showing that insight problems can be solved either with or without insight. This is consistent with the findings of previous studies employing trail-wise solution-type judgments (categorical Aha! experiences), which reported an insight solution rate of around 50% for correctly solved matchstick and verbal insight problems, regardless of whether feedback is provided or not (i.e., Danek et al., 2013, 2016; Jung-Beeman et al., 2004; Kizilirmak et al., 2018; Kounios et al., 2008; Laukkonen et al., 2021; Salvi et al., 2016; Subramaniam et al., 2009). Notably, none of these studies have taken into account the difficulty of the problem except for the studies of Danek et al. (2016) and Kizilirmak et al. (2018). The present results confirm that correct solutions to insight problems do not necessarily indicate that insight has occurred; thus, converging subjective and/or behavioral measures are required to capture insight.

Upon comparing the present findings with the insight solution rates of correctly solved visuospatial insight problems previously reported, it is evident that the present total insight solution rate for the two original problems (44.4%) is lower than those reported for the original 8-coin and original 9-dot problems (52%; Danek et al., 2016) and the five-square problem (74%; Fedor et al., 2015). One possible explanation for this difference is that the time allotted to participants to solve problems differed across those studies. Danek et al. and Fedor et al. allowed participants to work on the problem for seven minutes and 15 min, respectively, whereas in this study participants had only three minutes. The utilization of the average time limit in this study can be criticized for having led to a decrease in the correct solution rate and the accompanying Aha! experience rate hypothetically compared to those we would have observed if the given solution time was unlimited. However, when suddenness is considered a major possible indicator of insight-based solutions, setting an average time limit may be necessary for prolonged problem-solving efforts not to obscure the subjective judgments of the participants regarding the experiences that accompany the correct solutions. Notwithstanding, as time duration was not the primary focus of the present study, we are unable to provide any conclusive evidence regarding the impacts of solution time on either problem-solving performance or the accompanying subjective experiences, which restricts the generalization of the present findings. Future studies should take time limit (i.e., average time limit condition vs. unlimited condition) into account as an independent variable and explore if there are any changes in solution rate as well as Aha! experience and other subjective (cognitive and emotional) dimensions accompanying insight problem-solving.

Despite the fact that the present findings show lower insight solution rates than those reported by Danek et al. (2016) for the correct solutions of the same problems, the existence and direction of the difference between insight solution rates for both problems are consistent. The present findings reveal that half of the correct solutions to the original 8-coin problem and none of those for the original 9-dot problem are classified as insight solutions, whereas Danek et al. reported the corresponding rates as 66.7% and 20%, respectively. It can be inferred from the findings of both the present and Danek et al.'s study that the original 8-coin problem, which is comparatively easier, has a higher probability of being solved through insight as compared to the harder 9-dot problem. Danek et al. posited that solutions necessitating fewer steps for overcoming only a few constraints felt more sudden, akin to an "Aha!" moment, compared to solutions requiring multiple steps to overcome numerous constraints. This argument, however, acknowledges the potential for misinterpretation by problem solvers who may rely on suddenness rather than insight when answering questions about their subjective experiences that accompany solutions. Nevertheless, to reach such conclusions, we further considered the factor of intra-problem difficulty, as we thought it was inadequate to solely evaluate the solution types of the problems based on inter-problem difficulty.

Intra-problem comparisons

The observation of statistically significant changes in correct solution rates resulting from the use of hints indicates successful restructuring, as does our success in altering the difficulty level of the problem, which allows us to investigate the changes in solution types, if any. Comparisons of solution rates obtained from study groups for each insight problem revealed notable differences between the solution rates of the original and hinted versions of the 9-dot problems, suggesting that hints altered the difficulty level of the 9-dot problem. Nevertheless, the solution rates of the original and hinted 8-coin problems did not differ, suggesting that hints did not alter the difficulty level of the 8-coin problem. The present study further sought to ascertain whether the intra-problem difficulty of insight problems has an impact on the solution types. To achieve this, we classified both problems based on their respective solution rates as easy and hard, and accordingly, we contrasted the solution types of easy and hard problems for each problem (see Fig. 3). The present results indicate that the intra-difficulty level of the 8-coin problem had no effect on the solution types. On the other hand, the solution types of the easy and hard 9-dot problems were found to be distinct. The utilization of hints in the 9-dot problem revealed that the solution types of correctly solved 9-dot problems are contingent upon their difficulty, with insight solutions being more prevalent in more challenging 9-dot problems. Although there was no statistically significant disparity between the solution types of the easy and hard categories of the 8-coin problem as opposed to those of the 9-dot problem, the solution types of the easy and hard categories of both problems exhibited a comparable pattern. In both problems, the correct solutions for easy insight problems typically lack insight, whereas those for hard insight problems typically involve insight.

That is to say, the present findings demonstrated that the proportion of participants who reported solving the problem with insight was fairly similar among those who solved easy and hard problems. In such a way that in this study, 12 easy and 15 hard 8-coin problems and 14 easy and 14 hard 9-dot problems were solved with insight. In contrast, there was a discrepancy in the quantity of non-insight solutions between problems categorized as easy and those classified as difficult. A total of 18 easy and 10 hard 8-coin problems, as well as 16 easy and three hard 9-dot problems, were solved without insight. The observation that insight solutions are equally evident in both easy and hard problems leads to the conclusion that they are not affected by the level of difficulty of an insight problem. However, the level of difficulty of a problem may have an impact on solution types, whereby easier problems are less likely to elicit an Aha! experience and are thus more prone to being solved without insight. Consequently, it can be inferred that insight solutions are more probable to accompany correctly solved hard problems but less probable to accompany correctly solved easy problems. This is in line with prior research that has shown the provision of hints leads to more incremental solutions, implying that easy problems are more amenable to incremental problem-solving than insight problem-solving (i.e., Ammalainen & Moroshkina, 2021; Cushen & Wiley, 2012; Davidson, 1995; Durso et al., 1994; Strickland et al., 2022).

The fact that there is only one prior study on this subject limits the discourse of the present results. Despite the expanding body of literature on the types of solutions to insight problems, this study represents the second attempt, following Danek et al. (2016), to explore subjective factors that accompany correct solutions to classical insight problems, especially the 9-dot problem. The present results show a contradiction to those of Danek et al. by providing additional clarification regarding the influence of intra-problem difficulty on the types of solutions generated for classical insight problems. The scarcity of studies using classical insight problems can be attributed to their relatively low solution rates. As previously noted, it was observed that even after the elimination of sources of difficulty through the provision of hints, the overall rate of solution for the 9-dot problem remained lower than that of the 8-coin problem.

Collecting data with the 9-dot problem is quite challenging compared to other classic insight problems, which leads researchers to opt for less complex problems in search of insight and related factors. Another possible reason for the avoidance of classical insight problems by researchers may be due to their theoretical framework, the accuracy effect, which requires the gathering of both correct and incorrect responses to investigate the distinctions between true and false insights. In the context of classical insight problems, since problem solvers can distinguish whether they have successfully solved the problem or not, they are not expected to produce incorrect solutions that they perceive as correct, as in magic tricks and CRAs. Since these problems are not suitable for producing incorrect solutions that are believed to be correct, their use in research may not be preferred. On the other hand, they are suitable for conveying non-verbal hints, making them an optimal tool for studies using a difficulty-centered methodology.

To sum up, expanding upon Danek et al.'s (2016) research, in this study we employed hints as a method for altering the difficulty level of the problem itself, with the aim of investigating the impact of intra-problem difficulty on its solution types. The present findings have two implications: first, we may not be able to find the factors that determine the presence of insight by looking at the insight solutions alone without taking both inter- and intra-problem difficulty into account. Second, apart from directing attention towards the presence of insight and related factors, it may be necessary to broaden our perspective and conduct further investigations on the causes of the lack of insight.

Cognitive and affective dimensions of insight problem solving

The findings of the regression analysis conducted on the prediction of solution types for correctly solved insight problems revealed that the probability of insight solutions was significantly greater for 9-dot problems but not for 8-coin problems, when the problem was more difficult. After adjusting for problem difficulty, we observed that problem solvers with higher suddenness scores in both problems exhibited a significantly higher probability of generating insight solutions. This indicates that suddenness is a common, unique, and significant predictor of correctly solved insight problems accompanied by insight. Drawing from the definition of the Aha! experience, which is described as being characterized by suddenness in the prompts presented to the participants at the beginning of the study, it can be thought that this result is predictable. Concurring with prior claims (i.e., Danek & Wiley, 2017; Moroshkina et al., 2022), we too posit that it is possible for problem solvers to confuse short-term durations of solutions with suddenly occurring Aha! moments. In that sense, technically, problem-solvers may refer to their experiences as Aha! when the solution is achieved through a limited number of steps and a brief duration of time. Eventually, defining an Aha! experience as sudden occurrence can cause substitution and lead participants to misjudge quick solutions as Aha! experiences. Given the circumstances, it is reasonable to hypothesize that suddenness would be a better indicator of correct solutions to the 8-coin problem, which requires two moves, as opposed to the 9-dot problem, which requires four moves to achieve a correct solution. The present results, however, revealed that suddenness predicts insight solutions to both problems when controlling for the difficulty level of the problems. We are unable to make further interpretations due to the fact that we did not collect solution time data or detect the changes in suddenness throughout the problem-solving process. Future research should employ both objective and subjective measures of suddenness in order to distinguish suddenness from Aha! moments.

Upon comparing our findings to those of Danek et al. (2017), who utilized the same prompt and evaluated the predictive efficacy of the same cognitive and affective dimensions on correctly solved magic tricks, only suddenness is a significant predictor of insight solutions across both studies. In contrast to the effects observed in magic tricks, the factors of certainty, pleasure, or relief did not exhibit a discernible impact on the generation of insight solutions for the 8-coin and 9-dot problems. This observation suggests that the subjective experiences associated with accurate problem-solving may vary based on the particular type of insight problem. Further investigation is necessary to determine the influence of such dimensions on solution types across various types of insight problems. Research in the future should gather both subjective and objective data of each of these dimensions, along with problem difficulty, to enhance the precision of understanding the essence of insight.

Limitations

The present study involved altering the level of difficulty of the problems by providing hints that aimed at eliminating the factors that impeded the problem-solving process, specifically the perceptual constraints. This alteration in question may have caused the elimination of the perceptual characteristics of the problems that were deemed crucial for the occurrence of the Aha! experience. Thus, eliminating the sources of difficulties may have simultaneously resulted in the elimination of the source of insight. Hence, the lack of insight cannot be solely attributed to the problem difficulty or simplicity. This makes it problematic for us to argue that easy problems are more likely to be solved without the Aha! experience. Thereby, subsequent investigations that employ hints to remove difficulty should incorporate both non-insight and insight problems with varying levels of difficulty for a more clear understanding.

Another limitation of the present study is the absence of concurrently gathered subjective and objective data on the variables. We evaluated the objective difficulty of the problems independently of their subjective difficulty as perceived by the problem solvers. However, we should have collected subjective problem difficulty data and compared it with objective problem difficulty. On the other hand, we gathered data on the subjective cognitive and affective aspects of problem-solving experiences among problem solvers, but we did not acquire objective data on those dimensions. The solution times for each problem should have been recorded for comparative analysis with the subjective suddenness rate. Evaluating one variable with both subjective and objective measures would enlarge our perspective and provide a better understanding of what we're after. Thus, future research should use both subjective and objective measures of each of these dimensions, along with the difficulty of the problem, to enhance our grasp of the essence of insight.

Conclusion

This study represents a novel investigation into the impact of inter- and intra-problem difficulty on insight solutions in the context of accurately solved visuospatial insight problems. Consistent with prior research, the current findings support the evidence showing that insight problems can be solved with or without insight. This implies that it would be inappropriate to assume that a correct solution to an insight problem is indicative of the occurrence of insight. Thus, an additional assessment is necessary to ascertain the subjective aspect of the problem-solving process, specifically whether a problem has been solved through insight or not. The results also provided new evidence by showing that easy problems are more likely to be solved without insight, while hard problems are more likely to elicit insight-based solutions. In this respect, the present results provide information concerning how intra- and inter-problem difficulty is involved in generating insight solutions and suggest that problem difficulty should be considered in studies searching for insight and related phenomena. Additionally, upon controlling the difficulty level, it was discovered that suddenness provided the shared predictor for insight solutions to both problems. We think that the present findings can be interpreted in conjunction with the findings of future research utilizing comparable data on different kinds of insight problems with varying levels of difficulty. Utilizing hints to remove the source of difficulty seems to be a reliable approach for observing changes in problem-solving performance as well as accompanying experiences or related factors thereof.

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Data availability The datasets generated during and/or analyzed during the current study are available in the OSF repository, https://osf.io/2dc8g/?view_only=bbc6136b3df4479aa09cdcb891932523

Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethical approval The Research Ethics Committee of Istanbul University Social and Human Sciences approved the study protocol (E-35980450-663.05-74878).

Informed consent All participants provided informed consent in both sessions.

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