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Examining Validity of Aha! Ratings as a Construct of Insight

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ABSTRACT

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Currently, there are two main views on insightful problem solving. Results of the studies supporting "business-as-usual" theory suggest that the processes involved in solving insight problems are the same as in analytical problem solving—slow, controlled, and effortful, while findings of the studies supporting the restructuring theory of insight suggest involvement of fast and automatic, one-trial-learning type of processes. The goal of the current study was to investigate the construct validity of the Aha! ratings, used in many studies as the measure of insight, by isolating its three components, effort, confidence, and suddenness, and examining their correlation with working memory span. Ninety-eight undergraduate students from a Southeastern university completed reading and operational span tasks, as well as the compound remote associates task. Self-reported ratings of Effort, Confidence, and Suddenness were collected individually for each compound remote associates set. Correlations between the three ratings were low to moderate; Cohen's kappa used to measure pair-wise agreement between the ratings was below .80 for each pair; Cronbach's alpha demonstrated low internal consistency. Of the three components, only Suddenness correlated with working memory capacity. Suddenness also correlated with the difficulty of the problem.

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INTRODUCTION

Insight, a sudden awareness of an underlying structure or pattern, or an unexpected comprehension of an answer to a question, not obvious before, is a cognitive process involved in learning and problem solving, usually defined by phenomenological sensations of surprise, pleasure, confidence, and ease (Topolinski & Reber, 2010). This process may be as simple and quick as "getting" a pun or as complex and resulting from a series of preceding efforts as Mendeleev's dream of the periodic table of elements (Kedrov, 1967).

The Gestalt View of Insightful Learning

The first investigations into the psychological phenomenon of insight were conducted by the Gestalt psychologists in the early 20th century (Sternberg & Davidson, 1995). The Gestalt psychologists argued that processes involved in *re-productive* thinking—an ability to use previously acquired knowledge and learned algorithms for solving familiar problems—were different from those eliciting *productive* thinking (Wertheimer, 1945). Instances of productive thinking are demonstrated when a new solution is born out of the internal, behavioral environment, with no external stimuli, often after an *impasse*—a sense of being "stuck", unable to perform any further steps while searching for a solution in the initial representation of the problem. One possible cause of impasse, *functional fixedness*— a mental predisposition to a familiar function of an object and an inability to apply it in a new way—was introduced by Duncker (1945). To demonstrate this notion, he developed an experiment in which participants, given a box of matches, several tacks, and a candle, were asked to fix a candle to the wall so that the wax wouldn't drip on the floor. The subjects demonstrated functional fixedness by their inability to consider the box containing matches as a candleholder.

To investigate the cognitive ability to produce novel solutions, Gestalt psychologists introduced a notion of *restructuring*, a mental process of abandoning faulty (incomplete or intentionally misleading) representation of a problem, which causes an impasse, and arriving at a new representation leading to a sudden solution (e.g. Duncker, 1945). During this process, prior knowledge and experience, never sharing a connection before, are being internally rearranged. This produces a novel problem representation, leading to a spontaneous solution. In contrast to the gradual, trial-and-error process of associative learning, this qualitatively different type of problem solving is a one-trial, insightful learning (Ash, Jee, & Wiley, 2012). For example, in Köhler's experiments (1925), his chimpanzees *suddenly*, and with no changes in the environment, arrived at the novel for them approach of reaching for food with an implement (joined bamboo sticks or stacked crates) after losing interest in unreachable bananas and abandoning unsuccessful attempts.

Modern Theories of Insight

Since the first explorations into the phenomenon of sudden learning, several theories attempting to explain its nature and mechanisms were proposed. Currently, a debate exists between two schools of thought. One holds the view of insight being a "business-as-usual" or "nothing special" process (Ball & Stevens, 2009; Chein & Weisberg, 2014; MacGregor, Ormerod, & Chronicle, 2001; Weisberg & Alba, 1982), not different from analytical thinking. The other views restructuring as a process of automatic redistribution of memory activation (Ash & Wiley, 2006; Durso, Rea, & Dayton, 1994; Knoblich, Ohlsson, Haider, & Rhenius, 1999; Metcalfe & Wiebe, 1987; Ohlsson, 1992). The alternative, dual-process, theory presumes involvement of both, Type 1 (fast and independent of working memory) and Type 2 (slow and heavily dependent on working memory) processes that are involved in insight (Evans, 2011;

Kahneman & Frederick, 2002; Lin, Hsu, Chen, & Wang, 2012). Before we explore these theories in more detail, it is worth mentioning that the Gestalt psychologists used the term *insight* sparingly, as a deep understanding of the problem internal structure. Thus, restructuring, from their point of view, is an underlying process, different from incremental learning, and capable of explaining one-trial-learning phenomenon. In many modern studies on insight, however, it is seen more as a synonym of the subjective Aha! experience that may or may not accompany sudden learning. This will be elaborated on in the *Aha! Ratings as the Source of the Conflicting Results* section.

Restructuring as an Automatic Process

Problem solving is not possible without memory since it involves allocating attentional resources and holding current goals in working memory (WM), while also activating relevant experiences in long-term memory (Baddeley, 2000). The main debate on mechanisms of insight revolves around involvement of different aspects of memory at different stages of problem-solving process. Building on the Gestalt theory of restructuring and seeing it as a process different from the analytical problem solving, some modern psychologists utilized current models of semantic networks and spreading activation in long-term memory to suggest that the mechanism of restructuring is an automatic process. For instance, Knoblich et al. (1999) found evidence for automatic processes related to the experience of impasse and mechanisms involved in overcoming it. Also, Metcalfe and Wiebe (1987) found that subjective ratings of perceived closeness to the solution on memory-retrieval trivia tasks were highly correlated with performance, while those on insight problems were not at all predictive of performance on the task, suggesting a sudden and automatic nature of insight. Moreover, a neuroimaging study by

Jung-Beeman et al. (2004) demonstrated that overcoming an impasse could involve switching between fine and coarse semantic coding regions of the brain.

Since solving an incomplete, unfamiliar or intentionally misleading problem involves searching through a faulty initial problem space, potentially leading to an impasse, it is a demanding process in terms of WM capacity. According to the model proposed by Baddeley and Hitch (1974), working memory is considered a more functional and dynamic component of memory than simply a temporary data storage. Working memory is a system which allows short-term manipulation of data by complex cognitive processes and comprises separate components for processing auditory stimuli and visuospatial information, as well as the central executive component—to combine and organize auditory and visual stimuli, distribute attentional resources between them, while using relative information from the long-term memory storage (Baddeley, 2003). To measure WM capacity, various WM span tasks were developed, where a demanding cognitive process, e.g., verification, comprehension, enumeration, is paired with a task of word recall (Conway, et al., 2005). Research findings suggest that individual differences in WM capacity are associated with individual differences in the attentional resources allocated by the central executive function of WM (Kane, Bleckley, Conway, & Engle, 2001).

To investigate the influence of individual differences in WM span on the performance on insight problems, Ash and Wiley (2006) conducted a study aimed at isolating the restructuring phase. One group of participants solved the classical version of spatial insight problems with many moves available in the initial faulty search space, while the other group solved different version of the same problems modified in such a way that the search space had only few possible moves. The latter version of the task allowed the search space to be quickly exhausted thus eliminating the search phase from the problem-solving process and preserving only the impasse resolving phase through restructuring. The researchers then examined how WM span correlated with the performance during isolated restructuring versus all the phases of the problem-solving process. They found that individual differences in ability to control attention predicted the performance on the insight problems that include both the initial search phase and the restructuring phase. However, WM span scores did not correlate with the performance on insight problems with the isolated restructuring phase, therefore suggesting an automatic nature of the process of restructuring.

“Business-as-Usual” View of Insight

The Gestalt theory contemplated covert mental processes whose mechanisms it did not have the framework to explain yet. As such, it was often misinterpreted as “something special” view, imbuing the process of restructuring with some “mysterious” notion of spontaneous insight (Dominowski, 1981; Weisberg & Alba, 1981a). Moreover, the second half of the 20th century was the time when the information-processing model of cognition was developed. This model compares mental processes to the processes operating in a computer and as such is rooted in memory, previous experience, and learning-based adaptation to the environment (Simon, 1978). Based on this model, some researchers viewed the notion of functional fixedness introduced by the Gestalt psychologists as a dismissal of the importance of previous experience in problem solving (Weisberg & Alba, 1981b).

These arguments gave rise to an opposing theory suggesting that insight does not differ from the “business-as-usual” mechanisms underlying analytical problem solving, and therefore is a “nothing special” process that largely depends on problem-specific knowledge (Weisberg & Alba, 1982; Weisberg, Dicamillo, & Phillips, 1978) and is controlled and effortful (Kaplan & Simon, 1990). Some of the proponents of this view employed the Compound Remote Associates task (CRA; Mednick, 1962) to find empirical support for it. In this task, subjects are asked to come up with a forth word that would create a new compound with the three words provided in each problem set. For example, for three given words, *man glue star*, the solution *super* produces a new compound with each, *superman, super glue, super star*. To support the "business-as-usual" view, Ball and Stevens (2009) argued that since articulatory suppression on CRA task hindered the performance, it provided evidence of insight being a non-automatic process. Also, in attempt to disprove the role of functional fixedness and restructuring in insight problems, Weisberg and Alba (1981a) demonstrated that participants did not attain a sudden solution after being given a hint to widen their search space on the nine-dot problem (Figure 1), thus removing fixation on the square, and that only providing a detailed description of the solution facilitated their performance.

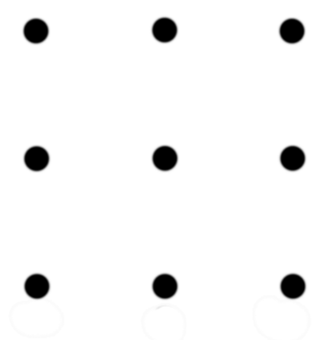

Figure 1. The nine-dot problem. The nine dots form a square. The solution consists of four straight lines that are interconnected and pass through all the dots. The lines should be drawn without lifting a pen from the paper.

Building on the fact that analytical problem solving depends on strategic processes (Gilhooly & Murphy, 2005) and, thus, requires WM resources, Chein, Weisberg, Streeter, and Kwok (2010) demonstrated that WM span predicted faster solving times on the nine-dot insight problem. Building on those findings, Chein and Weisberg (2014) presented participants with

WM span tasks and CRA problems, followed by participants' subjective insight ratings. Upon solving each CRA set, participants were asked to assess their method of arriving at a solution on a 4-point scale, running from highly strategic to highly insightful. These ratings were found to be correlated with the verbal WM capacity, suggesting that insight is an effortful and controlled process.

Dual-Process Theory

To contextualize the diverse proposals of implicit and explicit mechanisms involved in higher cognitive processes, including decision-making and problem solving, a dual-process theory was proposed (Kahneman & Frederick, 2002; Stanovich, 1999). It suggests that cognition engages two different systems involved in thinking, reasoning, social judgment, etc., with System 1 being fast, automatic or unconscious, and therefore independent of working memory, and System 2 being slow, effortful, conscious and thus heavily dependent on working memory. Arguing that while these "systems", as of yet, are still conceptual and not necessarily physiologically separate and/or shared with other species, Evans (2008; 2011) proposed to refer to the slow, capacity-limited, deliberate cognitive mechanisms as Type 2, while the automated, WM-independent, fast ones as Type 1.

Aha! Ratings as the Source of the Conflicting Results

The results of studies supporting "nothing special" or Type 2 view of insight and those supporting the notion of automated or Type 1 process of restructuring are in conflict. While the empirical evidence in favor of the former argues that the insight ratings highly correlate with WM capacity, the latter demonstrates that WM span correlates only with the performance on the pre-impasse stage of the insight tasks, but not with the restructuring phase.

To remedy this conflict, the current study proposes to re-examine current methodology utilized in defining and measuring the construct of insight. As with consciousness or awareness, insight is a ubiquitously familiar, yet difficult to define phenomenon. A recent review (Dietrich & Kanso, 2010) of 20 neuroimaging studies targeting neural correlates of the insight experience concluded that the results differ substantially from study to study, not only in terms of specific brain structures, but also in attributing Aha! experiences to a specific hemisphere. While acknowledging complexity of the insight problem-solving process and a possibility that it cannot be attributed to a handful of simple processes or specific neural correlates, the authors also point out that the lack of common methodology in defining insight in the reviewed studies may be a possible reason for empirical discrepancies. In many studies, insight is not clearly defined for participants, they are simply asked to rate how *insightful* their solution felt (Dietrich & Kanso, 2010). Moreover, multiple studies use the concept of insight interchangeably with phenomenological Aha! experiences (Chein & Weisberg, 2014; Jung-Beeman, et al., 2004; Posner, 1973; Worthy, 1975). For instance, in a study by Bowden and Jung-Beeman (2003), participants were instructed that the use of a strategy would qualify as a low-insight rating on a 1-5 rating scale, while the absence of awareness, "I just knew, I don't know how I knew", should be counted as a high-insight rating. A rating of 5 was explained to participants as the following: "When you saw the word you suddenly knew that it was the answer ('It popped into my head'; 'Of course!' 'That's so obvious'; 'It felt like I was already thinking that')." Other studies define insight as a complex experience, comprising such components as suddenness, obviousness, and confidence. For example, in Jung-Beeman et al.'s 2004 study insight was defined as follows:

> A feeling of insight is a kind of 'Aha!' characterized by suddenness and obviousness. You may not be sure how you came up with the answer, but are relatively confident that

> it is correct without having to mentally check it. It is as though the answer came into mind all at once—when you first thought of the word, you simply knew it was the answer. This feeling does not have to be overwhelming, but should resemble what was just described.

To illustrate further, in another study (Danek, Fraps, Müller, Grothe, & Öllinger, 2013) exploring insight through magic tricks, insight is defined very similar, as follows:

> We would like to know whether you experienced a feeling of insight when you solved a magic trick. A feeling of insight is a kind of 'Aha!' characterized by suddenness and obviousness. Like an enlightenment. You are relatively confident that your solution is correct without having to check it. In contrast, you experienced no Aha! if the solution occurs to you slowly and stepwise, and if you need to check it by watching the clip once more. As an example, imagine a light bulb that is switched on all at once in contrast to slowly dimming it up. We ask for your subjective rating whether it felt like an Aha! experience or not, there is no right or wrong answer. Just follow your intuition.

Thus, even when the multifaceted nature of insight is addressed, still, participants are instructed to assign only one number to it when rating the experience. Recently, some experiments were conducted which analyzed correlations between the components of Aha! ratings (Danek & Wiley, 2017; Webb, Little, & Cropper, 2016), however, no study has been conducted to assess the validity of Aha! ratings as a construct of insight.

An Aha! experience is assumed to include such components as surprise, pleasure, confidence, and ease (Topolinski & Reber, 2010), therefore, this construct could be a multidimensional entity encompassing strategy versus insight, suddenness, effort, and confidence components. Furthermore, it may be influenced by multiple confounding factors, such as false insights (Danek & Wiley, 2017) or a hindsight bias (Ash & Wiley, 2008).

The Current Study

To investigate the multiple components of the Aha! ratings used as the measure of the insight construct, we replicated Chein and Weisberg (2014) which utilized self-report insight ratings similar to Jung-Beeman et al.'s study described earlier. In contrast to the one-item measure they used, a measure which mixed feelings of suddenness, confidence, and effort in one rating, we broke down the Aha! ratings into three separate components, Suddenness, Confidence, and Effort. In the current study we administered verbal and operational WM span tasks, as well as the same version of the CRA task. To examine the validity of the Aha! ratings, Confidence, Effort, and Suddenness of each solution attempt on each of the CRA sets were measured separately through self-reported ratings. Following the data collection stage, the results were analyzed in terms of correlation between WM span and each component of the insight. The predictions were as follows. If insight is a three-factor structure that can be measured through confidence, suddenness, and effort ratings (specifically as high confidence, high suddenness and low effort), the three components should highly correlate with each other, have high internal consistency, and high level of pair-wise agreement as measured by Cohen's kappa, thus demonstrating construct validity. If each component also correlates with WM span, these would support the results of "business-as-usual" theory. If, however, components are not intercorrelated, as confidence and effort are not always indicative of insight (Danek & Wiley, 2017), this would suggest that the findings of studies supporting "business-as-usual" theory measure some other construct rather than insight.

Therefore, the aim of the current study is to explore validity of the Aha! construct associated with insight by means of recording the individual measures of suddenness, effort, and confidence independently, examining correlations of each of the components with the WM span, and extracting the component which drives the results of Type 2 or “nothing special” empirical studies.

METHOD

Participants

To replicate correlation between verbal working memory (WM) capacity and performance on compound remote associates (CRA) task found by Chein and Weisberg (2014; $r = 0.39$, $p < .01$), we performed power analysis (Cohen, Cohen, West, & Aiken, 2003) to define the sample size for the desirable power of $1 - \beta = .80$ and α set at .05. The sample size yielded by the analysis was $N = 84$. To account for possible data loss due to incompletion of tasks and/or lack of accuracy on tasks, 143 undergraduate students from Old Dominion University were recruited for course credit.

The demographics was as follows: 68.4% women; age ranged between 18 and 40 (M = 19.85, SD = 3.62); 76.5% had college algebra within the last five years; 93.9% were native English speakers (see Tables 1 and 2 for detailed demographics).

Participants signed the informed consent form before participation and were debriefed upon completion of all tasks. Exempt IRB application for this study was approved.

Table 1

Participant Demographics

	n (*M*)	% (*SD*)
Age	19.85	3.62
Sex		
Female	67	68.4
Male	31	31.6
Total	98	100.0
Algebra		
I've had a college level algebra class in the past 5 years.	75	76.5
I've had a college level algebra class in the past 10 years.	4	4.1
I've had a college level algebra class more than 10 years ago.	1	1.0
I've NEVER had a college level algebra class.	18	18.4
Total	98	100.0
English		
English has ALWAYS been my primary language.	92	93.9
English has been my primary language for MORE than 10 years.	2	2.0
English has been my primary language for LESS than 5 years.	1	1.0
English is NOT my primary language.	3	3.0
Total	98	100.0

Table 2

Participant Academic Major Count and Percentage

	n	%
Biochemistry	3	3.1
Biology	8	8.2
Chemistry	3	3.1
Civil Engineering	1	1.0
Communication	2	2.0
Computer Engineering	3	3.1
Computer Science	4	4.1
Criminal Justice	7	7.1
Dental Hygiene	1	1.0
English Education	1	1.0
Exercise Science	5	5.1
Health Services Administration	1	1.0
Human Services	2	2.0
Industrial Engineering	1	1.0
Marine Biology	1	1.0
Mechanical Engineering	4	4.1
Medical Laboratory Science	1	1.0
Nursing	13	13.3
Occupational and Technical Studies	2	2.0
Psychology	24	24.5
Recreation Therapy	2	2.0
Sociology	1	1.0
Speech-Language Pathology and Audiology	1	1.0
Sports Management	1	1.0
Therapeutic Recreation	2	2.0
Undecided	4	4.1
Total	98	100.0

Some of the data were excluded due to task incompletion; data of the participants whose accuracy on math or reading during OSPAN and RSPAN respectively dropped below 85% (Unsworth, Heitz, Schrock, & Engle, 2005; see Table 3 for the exclusion statistics) were also excluded. The drop rate on OSPAN (14.8%) and RSPAN (18.9%) were in line with the previous findings for the automated span tasks (Unsworth et al., 2005). The analyses were conducted on the remaining sample of 98 participants.

Table 3

Exclusion Criteria and Percentage of Data Excluded from the Analysis

Reason	n	%
Unfinished WM Tasks	3	2.1
Compromised WM Scores	4	2.8
Low OSPAN Accuracy	21	14.8
Low RSPAN Accuracy	27	18.9
Total Excluded	45	31.5
Total Collected	143	100.0

Materials

Compound Remote Associates Task. CRA task, a.k.a. Remote Associates Task (RAT; Mednick, 1962), is used to assess individual differences in associative processing, problems solving, creativity, and insight. As this was the main task utilized in Chein and Weisberg (2014), it was used in this study as well—to test the validity of Chein and Weisberg's construct of insight. Following a screen with three fixation points, participants were presented with a set of three words and a text box for typing their solution. They were asked to produce a fourth word that yields a new compound word (or phrase) with each of the three words in a set, in a 45-second time interval. For instance, the fourth word for the set *pine crab sauce* is the word *apple,* which produces new compounds *pineapple*, *crabapple*, and *apple sauce* (Appendix A). The reaction time and the entered word were recorded upon the “Enter” key strike. Once the solution was entered (either the correct or an incorrect one), subject were prompted to rate their solving process on three components, as follows: (a) on the Suddenness scale, from (1) *Not Sudden* to (4) *Very Sudden*—how unexpectedly the solution came; (b) on the Confidence scale, from (1) *Not Confident* to (4) *Very Confident*—how confident they are in the solution’s correctness; and (c) on the scale of Effort, from (1) *Not Effortful* to (4) *Very Effortful*—how hard they felt they had to work to come up with the fourth word (Appendix B). An average score on each component comprised a participant’s score for each dimension. In case of the correct response, participants were presented with the next set of words. Otherwise, they were given another trial with the incorrectly solved set, until the expiration of the 45-second interval. The task consists of 60 sets, which were presented in a random order.

Working Memory Span Tasks. Working memory capacity tasks are used to predict performance on higher and lower order cognitive tasks through dual-tasking (Conway et al., 2005). In problem solving and insight research these tasks are utilized to predict performance on analytical problem solving. WM span tasks present subjects with letters (or words) to memorize for later recall and also require processing of a secondary task, with semantic validation of sentences and simple arithmetic problems being most commonly used variations. Two WM capacity tasks, operation span task (OSPAN; Turner & Engle, 1989) and reading span task (RSPAN; Daneman & Carpenter, 1980), were utilized in the current study to account for individual differences on reading and arithmetic skills. The OSPAN and RSPAN scores were averaged to isolate the shared variance which represents the WM capacity score.

***OSPAN task*.** Subjects were presented with the letter sequences ranging from three to seven letters that they needed to recall at the end of each sequence. Each letter in a sequence is preceded by a simple arithmetic problem, e.g., "(8 + 2) ÷ 2", followed by a proposed solution, e.g., "5", to be evaluated as correct or incorrect (Appendix C). At the end of each sequence, participants are asked to select letters they can recall in a letter matrix presented on the screen.

***RSPAN task*.** Participants were presented with the letter sequences ranging from three to seven letters that they needed to recall at the end of each sequence. Each letter in a sequence is preceded by a sentence problem, e.g., "Every now and then I catch myself swimming blankly at the wall", to be evaluated for semantic correctness (Appendix D). At the end of each sequence, subjects are asked to select the recalled letters in a letter matrix presented on the screen.

Reliability and Validity of Tasks. CRA task was demonstrated to be a valid measure of creativity, as scores on the task correlate with scores on research creativity check list (r = .55, p < .005), as well as with Miller Analogy Test scores (r = .41, p < .025; Mednick, 1963). Spearman-Brown reliability coefficient for the task was found to be r = .92 and r = .91 for two independent samples (Mednick, 1963). In later reliability analysis, the task demonstrated high internal consistency (Cronbach's α = .82; Lee, Huggins, & Therriault, 2014). Scores on OSPAN and RSPAN tasks were demonstrated to correlate with scores on various higher and lower order cognitive tasks, including reading and listening comprehension, writing, reasoning, and complex-task learning, thus confirming their validity (see Conway et al., 2005, for detailed discussion). OSPAN task was demonstrated to be a stable measure in terms of internal consistency, with Cronbach α ranging from .89 to .93 in different samples (Turner & Engle, 1989). RSPAN task showed a similar consistency (Cronbach α = .80; Kane et al., 2004). Both tasks were also found to be stable across time, with test–retest correlations of .70 to .80 observed over minutes, weeks, and three months (Conway et al., 2005).

Procedure

Participants were seated in a quiet laboratory room, in front of a computer monitor, with a mouse and a keyboard. After the study introduction and completion of the consent form, they were asked to follow on-screen instructions and to complete the CRA task adapted from Chein and Weisberg (2014) and two WM span tasks—OSPAN and RSPAN. All three tasks are implemented as a software package using E-Prime 2.0 framework (Schneider, Eschman, & Zuccolotto, 2002). Stimuli were presented on the computer monitor and keyboard and mouse were used to record the participants' reactions. Upon finishing the sequence of three tasks, participants were debriefed and released.

RESULTS

On average, the participants (*N* = 98) correctly solved 24 problems (*M* = 23.30, *SD* = 6.15) out of 60 CRA sets (39%), which is in line with 42% success rate reported by Chein and Weisberg (2014).

Proportions of Solutions Measured by the 3-Item Scale

Many studies that utilize Aha! ratings use a binary scale for measuring insight (1 = *insight*, 0 = *non-insight*). As was discussed above, Chein and Weisberg defined insight as a solution accompanied by the feelings of *high* suddenness, *high* confidence, and *low* effort. Based on this operationalization, to assess the proportions of insightful and non-insightful solutions we dichotomized the 1-4 Likert scale scores on each component, as follows: (a) 1 and 2 on the Suddenness scale indicated low Suddenness (Suddenness = 0), while 3 and 4 indicated high Suddenness (Suddenness = 1); (b) 1 and 2 on the Confidence scale indicated low Confidence (Confidence = 0), while 3 and 4 indicated high Confidence (Confidence = 1); (c) the Effort scale is reversed, thus, 1 and 2 on the Effort scale indicated low Effort (Effort = 1), while 3 and 4 indicated high Effort (Effort = 0). Thus, only those problems that were solved with high Suddenness *and* high Confidence *and* low Effort were counted to be solved with insight. Non-insightful solutions were indicated by any other combinations of the components' levels, e.g., low Suddenness, high Effort, low Confidence (see Table 4 for the full list of combinations).

Our data indicated that 46% (*M* = 10.74, *SD* = 7.00) of the correct solutions were reported to be accompanied by insight. The remaining 54% (*M* = 12.55, *SD* = 5.61) of correctly solved problems were not accompanied by the feeling of insight. These proportions, 46% of insightful solution versus 54% of non-insightful solutions, are not in line with 64% and 36% solution rates for insightful and strategic solutions, respectively, reported by Chein and Weisberg on one-item Aha! rating scale. This suggests that the Aha! rating that mixes Suddenness, Effort, and Confidence in one-item scale and the 3-item measure with three separating rating scales for each component assess different constructs. This poses a question of which of the components drives the Chein and Weisberg results.

Table 4

Insight versus Strategy as Measured by the Three Components

	Suddenness	*Effort**	*Confidence*
Insight	*1*	*1*	*1*
Non-Insight	*1*	*1*	*0*
	1	*0*	*1*
	1	*0*	*0*
	0	*1*	*1*
	0	*1*	*0*
	0	*0*	*1*
	0	*0*	*0*

Note: *Effort is reversed, 1 = Low, 0 = High; Suddenness and Confidence, 1 = High, 0 = Low.

Proportions of Solutions Measured by Individual Components

Upon examination of each component individually (Table 5), the mean number of CRA problems solved with *high* Suddenness (*M* = 15.76, *SD* = 5.86) constituted 68% of the total number of correctly solved problems. The mean number of problems solved with *low* Suddenness (*M* = 7.54, *SD* = 4.34) represented 32% of the total number of correctly solved problems. Effort ratings demonstrated results similar to those of Suddenness, with *low* Effort reported on 65% of the total number of correctly solved problems (M = 15.16, SD = 7.58), on average, and *high* Effort reported for an average of 35% (M = 8.13, SD = 5.65). The mean of *high* Confidence reports was significantly higher than the other two components (see Table 6 for the paired samples *t*-tests), 79% of successfully solved problems (M = 18.41, SD = 6.73), and *low* level of Confidence accompanied the average of 21% (M = 4.89, SD = 3.90) of the correct solutions. These proportions suggest that the three components assess insight differently when reported individually, compared to the assessment of insight by the 3-item measure. This implies that the components assess different problems differently in terms of insight. Correlations computed for the components, as well as the assessment of internal consistency and item analysis confirm that.

Table 5

Statistics of Mean Aha! Ratings on Correctly Solved Problems

	Solved with Insight[a]		Solved without Insight[b]	
	M	*SD*	*M*	*SD*
Suddenness	15.76	5.86	7.54	4.34
Effort	15.16	7.58	8.13	5.65
Confidence	18.41	6.73	4.89	3.90

Note: [a]Insight: high Suddenness, high Confidence, low Effort.
[b]No Insight: low Suddenness, low Confidence, high Effort.

Table 6

Paired Samples t-Tests for Mean Number of Problems Solved with High Suddenness, High Confidence, and Low Effort

Pairs of Components	*M*	*SD*	*t*	*df*	*p*
Suddenness and Confidence	-2.65	4.06	-6.46	97	.000
Suddenness and Effort	.59	5.96	.98	97	.328
Confidence and Effort	3.24	5.73	5.61	97	.000

Note: $N = 98$.

Construct Validity of Aha! Ratings

Correlations. To assess the strength of association between dichotomized Suddenness, Effort, and Confidence in measuring insight, correlations between the components were computed. This analysis was done at the level of observation, in other words, for each problem solved by all subjects, $N = 2283$. Correlation between Suddenness and Effort was .28, between Suddenness and Confidence $r = .39$, between Effort and Confidence $r = .14$ (see Tables 7 and 8 for correlation coefficients). The components correlated with each other at $p < .01$, indicating some shared variance. However, the correlations were low to moderate which implies that three components assess insight differently.

Table 7

Correlation Matrix for Confidence, Suddenness, and Effort Measured on a 4-point Likert Scale

	Confidence	Suddenness	Effort[a]
Confidence	1	.49**	.23**
Suddenness		1	.36**
Effort			1

Note: [a] Effort is reversed, with low numbers indicating high level of Effort and high numbers indicating low level of Effort. N = 2283; **p < .01.

Table 8

Correlation Matrix for Dichotomous Confidence, Suddenness, and Effort

	Confidence	Suddenness	Effort[a]
Confidence	1	.39**	.14**
Suddenness		1	.28**
Effort			1

Note: [a]Effort is reversed, with 0 indicating high level of Effort and 1 indicating low level of Effort. N = 2283; **p < .01.

Internal Consistency and Item Analysis. To examine whether the three components demonstrate internal consistency as a measurement instrument with three dichotomous items, Cronbach's alpha was calculated; α =.53 indicated lower than the minimum suggested level of .70 for basic research and .80 for applied research (Nunnally & Bernstein, 2010). Cronbach's alpha was also calculated for the components measured on a 4-point Likert scale. The 4-point scale also demonstrated low internal consistency, α =.63.

One of the main item statistics assessed during the item analysis is the item mean, which is also referred to as the item difficulty for dichotomous items. The mean of .5 (for a dichotomous item) suggests that the item discriminates well between the participants who scored high (1 = insight) and those who scored low (0 = non-insight) on the item. Items with the mean of greater than .5 are considered over-endorsed as more than a half of participants scored 1 on the item, while the items with the mean of less than .5 are considered under-endorsed since the majority of the participants scored 0 on the item (Furr, 2017). The item analysis (Table 9) indicated that Confidence had a higher (.79) than the recommended mean of .5 for a dichotomous item, indicating over-endorsement of the item, which implies that Confidence does not discriminate well between high and low scorers (Furr, 2017).

Table 9

Item Analysis Statistics for Three-Component Measure of Insight at the Level of Observation

	M	*SD*	*N*
Suddenness	.68	.47	2283
Effort	.65	.48	2283
Confidence	.79	.41	2283

Note: Items are dichotomous, 1 for insight and 0 for non-insight.

Another important statistic of an item is its correlation with the total scale from which the item was removed. The corrected item-total correlation examines whether the item and the rest of the measurement assess the same construct. The minimum recommended corrected item-total correlation value for this purpose is .30 (Nunnally & Bernstein, 2010). Corrected item-total correlation for Effort (.26) was below minimum recommended .30 (Nunnally & Bernstein, 2010), indicating that Effort does not correlate with the scale well, suggesting that it may not measure the same construct as the rest of the scale. Corrected item-total correlation for Suddenness was .44 and for Confidence was .33.

Additionally, as a part of item analysis, Cronbach's α is assessed when the item in question removed from the scale. If α increases with the item removal it suggests that the inclusion of the item in the scale lowers its internal consistency (Furr, 2017). Indeed, if Effort is removed from the scale, Cronbach's α increases from .525 to .560 (Table 10), suggesting that Effort negatively influences the internal consistency of the measure.

Table 10

Item-Total Statistics for Three-Component Measure of Insight

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	R^2	Cronbach's α if Item Deleted
Suddenness	1.44	.45	.44	.21	.25
Effort	1.47	.54	.26	.08	.56
Confidence	1.33	.57	.33	.16	.44

Note: N = 2283.

Agreement Between the Components of Aha! Rating. To examine the agreement between the components in assessment of each solution for insight, Cohen's kappa was calculated for each pair of the components (Suddenness and Effort, Suddenness and Confidence, Effort and Confidence). This was done at the level of observation, $N = 2283$. Our data demonstrated the following values of Cohen's kappa (see Table 11): (a) agreement between Suddenness and Effort, $\kappa = .278$, $SE = .021$, 95% CI: [.24, .32]; (b) agreement between Suddenness and Confidence, $\kappa = .377$, $SE = .021$, 95% CI: [.34, .42]; and (c) between Effort and Confidence, $\kappa = .133$, $SE = .021$, 95% CI: [.09, .17] (see Fleiss, Cohen, & Everitt, 1969, for computing kappa confidence intervals). None of kappas were close to the minimum recommended level of agreement of .80 (McHugh, 2012).

Table 11

Cohen's Kappa Measuring Agreement on Presence of Insight on CRA Problems Between Suddenness, Effort, and Confidence

	κ	*SE*	Lower Bound	Upper Bound
Suddenness and Effort	.28	.021	.24	.32
Suddenness and Confidence	.38	.021	.34	.42
Effort and Confidence	.13	.021	.09	.17

Note: $N = 2283$.

Additionally, we examined an agreement between the components in the assessment of insight within subject—how much the components agreed on sorting 60 problems into insight/non-insight categories within each subject, and also within problem—agreement within the same problem on assessing the ratings of insight in 98 participants. To accomplish that, we computed distributional statistics of kappa values within subject and within problem. The mean kappa values were below .80, the distributions had a wide range, with lower bounds being negative in some cases (Table 12).

Table 12

An Agreement between Each Pair of Aha! Rating Components at the Level of Observation as Measured by Cohen's Kappa, within Problem and within Subject

	M	*SD*	Min	Max	Range
Within Problem					
Suddenness and Effort	.25	.17	-.12	.79	.91
Suddenness and Confidence	.34	.18	-.01	.77	.78
Effort and Confidence	.09	.18	-.36	.50	.86
Within Subject					
Suddenness and Effort	.25	.39	-.87	.95	1.82
Suddenness and Confidence	.34	.33	-.57	1.00	1.57
Effort and Confidence	.10	.35	-.87	.95	1.82

Note: $N = 2283$.

To give an example of kappa distribution within problem, Table 13 demonstrates the result of the calculations of the agreement between Suddenness and Effort within each of the 60 problems. The distribution of kappa values had a range of .91, with the mean of .25, minimum of -.12, maximum of .79, and the standard deviation of .17. These results suggest that the components do not demonstrate agreement, not only when sorting solutions into insight/non-insight categories within the same problem, but also within the same subject. This implies that participants might be rating their solutions on qualitatively different scales depending on which component of the Aha! rating they chose to focus on to make their insight/non-insight judgment.

Table 13

An Agreement between Effort and Confidence on Presence of Insight during Solving for Each Problem in CRA Task as Measured by Cohen's Kappa

			Confidence Interval	
CRA Problem #	*κ*	*SE*	Lower Bound	Upper Bound
1	0.18	0.12	-0.05	0.41
2	0.30	0.12	0.05	0.54
3	0.13	0.13	-0.12	0.38
4	-0.02	0.08	-0.18	0.14
5	0.20	0.12	-0.03	0.44
6	0.30	0.13	0.05	0.55
7	0.20	0.12	-0.04	0.44
8	0.17	0.13	-0.08	0.42
9	0.40	0.11	0.18	0.63
10	0.11	0.12	-0.13	0.34
11	0.22	0.11	0.00	0.45
12	0.33	0.16	0.02	0.64
13	0.11	0.16	-0.21	0.43
14	0.06	0.15	-0.24	0.36
15	0.51	0.13	0.25	0.77
16	0.15	0.15	-0.14	0.44
17	0.40	0.14	0.12	0.68
18	0.05	0.16	-0.27	0.37
19	0.27	0.12	0.03	0.51
20	0.05	0.16	-0.25	0.36
21	0.15	0.16	-0.16	0.46
22	0.23	0.14	-0.05	0.51
23	0.30	0.15	0.01	0.59
24	0.41	0.15	0.12	0.70
25	0.22	0.16	-0.08	0.53
26	-0.12	0.17	-0.45	0.21
27	0.45	0.13	0.19	0.71
28	0.24	0.17	-0.10	0.58
29	0.28	0.19	-0.08	0.65
30	0.44	0.14	0.16	0.72
31	0.27	0.17	-0.05	0.60
32	0.19	0.14	-0.07	0.46
33	0.32	0.20	-0.08	0.72
34	0.16	0.17	-0.17	0.50
35	0.11	0.21	-0.29	0.51
36	0.23	0.16	-0.09	0.54
37	0.36	0.16	0.05	0.66
38	0.21	0.18	-0.15	0.58
39	0.18	0.22	-0.25	0.60
40	0.48	0.18	0.12	0.84
41	0.14	0.23	-0.32	0.60
42	0.17	0.17	-0.16	0.50
43	0.21	0.24	-0.26	0.68
44	0.37	0.25	-0.12	0.85
45	0.05	0.27	-0.48	0.58
46	0.27	0.17	-0.06	0.60
47	0.54	0.18	0.19	0.89
48	-0.07	0.22	-0.50	0.37
49	0.09	0.26	-0.42	0.61
50	0.31	0.31	-0.31	0.92
51	0.33	0.22	-0.10	0.77
52	0.17	0.32	-0.45	0.78
53	0.26	0.26	-0.25	0.76
54	0.50	0.18	0.14	0.86
55	0.35	0.30	-0.24	0.94
56	0.10	0.33	-0.55	0.75
57	0.33	0.22	-0.09	0.76
58	0.36	0.20	-0.02	0.75
59	0.69	0.16	0.37	1.01
60	0.79	0.14	0.52	1.06
Total	0.28	0.02	0.24	0.32

Note: N = 2283.

Solving Time and Insight

The mean solving time in milliseconds for problems solved correctly with insight (high Suddenness, low Effort, high Confidence; *M* = 8993.15, *SD* = 2617.74) was significantly lower, *t*(87) = -.16.07, *p* < .001, than the mean solving time for problems solved correctly without insight (*M* = 17495.37, *SD* = 4789.75; see Figure 2). These results are in line with the findings of Chein and Weisberg (2014). However, they contradict the results of the previous studies which found that insightful solutions, operationalized as solving after impasse, take significantly longer than strategic solutions (Ash, Jee, & Wiley, 2012). This might suggest that either the search space of CRA task is not big enough, or faulty problem representation is not as common—compared to classical insight problems, and/or that the operationalization of insight as solving after impasse and Aha! ratings measure different constructs.

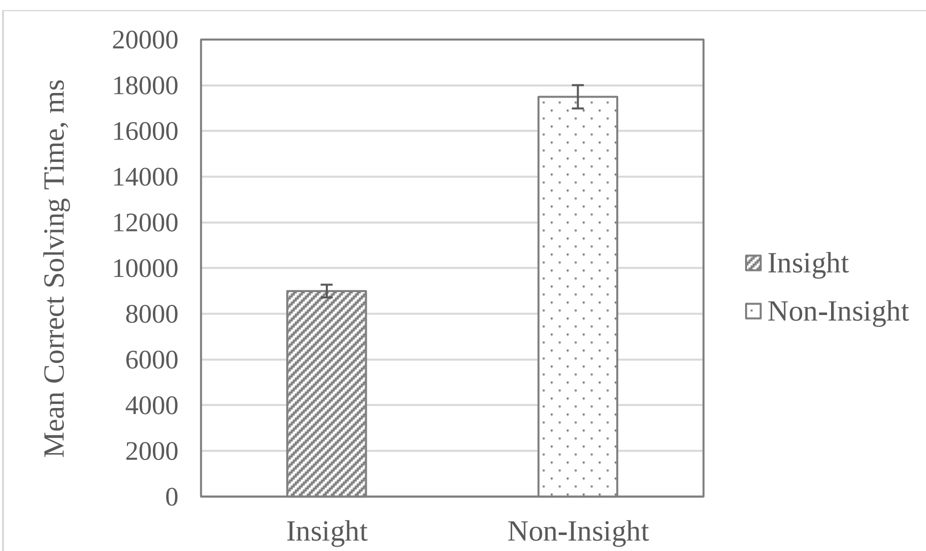

Figure 2. Mean correct solving time as a function of insight. Error bars represent standard error.

Working Memory Span and Insight

WM Span Scores. OSPAN scores (*M* = 38.72, *SD* = 15.27) and RSPAN scores (*M* = 33.84, *SD* = 15.81) were nearly normally distributed (see Figures 3 and 4), with the mean and standard deviation values (Table 14) in line with previous findings on automated WM tasks (Unsworth et al., 2005). To assess how much the scores on two measures of WM span overlapped, we correlated RSPAN and OSPAN scores. They correlated at $r = .597$ ($p < .01$), sharing 35% of variance.

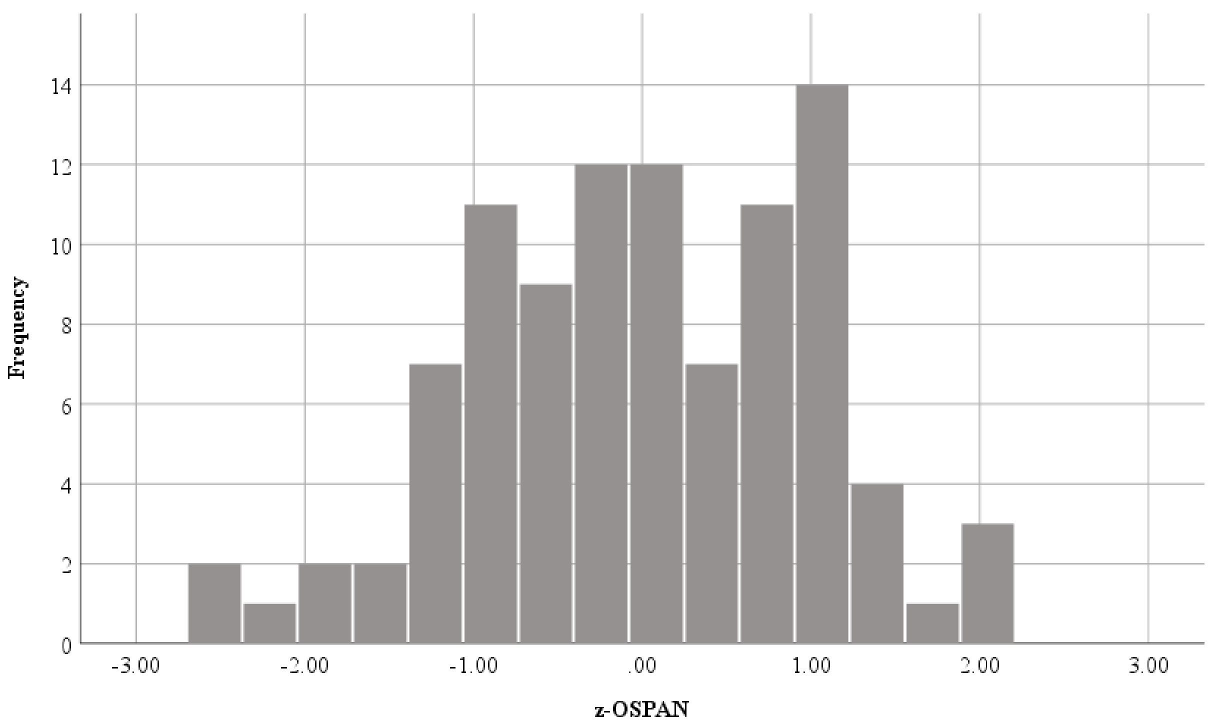

Figure 3. Distribution of OSPAN scores, $N = 98$.

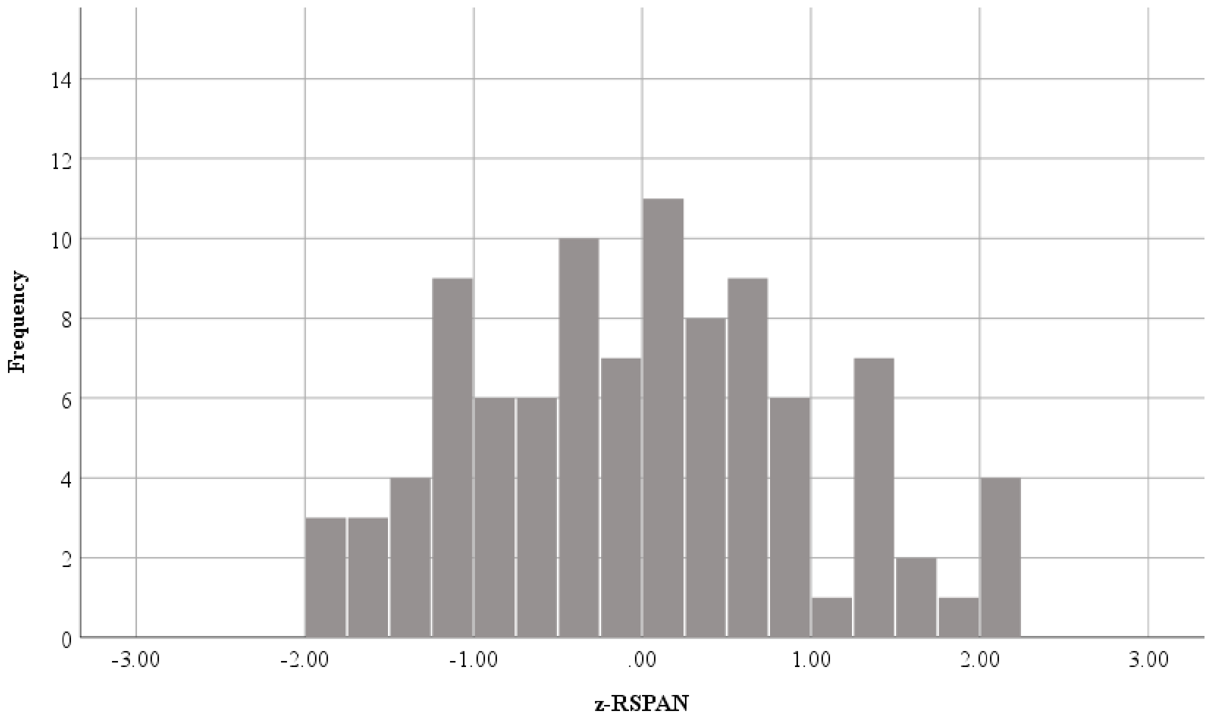

Figure 4. Distribution of RSPAN scores, *N* = 98.

Table 14

Working Memory Span Tasks Statistics

Measure	N	Range (Min, Max)	M	SD	Skew	Kurtosis
OSPAN	98	71 (0, 71)	38.72	15.27	-.27	-.28
RSPAN	97	65 (3, 68)	33.84	15.81	.24	-.48

WM Span and the Number of Correctly Solved CRA Problems. Chein and Weisberg (2014) found a moderate correlation between OSPAN scores and the number of problems solved correctly with insight ($r = .39$, $p < .01$). They also created a composite WM span score which was computed as the mean of OSPAN and spatial symmetry span (SSPAN) scores. The composite WM scores in their study also correlated with the number of problems solved correctly with insight ($r = .35$, $p < .05$). They interpreted these results as evidence that insight is a controlled process, dependent on WM resources.

In the current study, the composite WM span score was computed as the mean of OSPAN and RSPAN z-scores. This was done in order to isolate shared variance of individual differences in working memory and to exclude variance attributed to differences in reading and arithmetic. The distribution of the composite WM scores was nearly normally distributed (Figure 5). We found that correlation between the composite WM span score and the number of correctly solved problems was not significant, neither when solved with insight nor without insight.

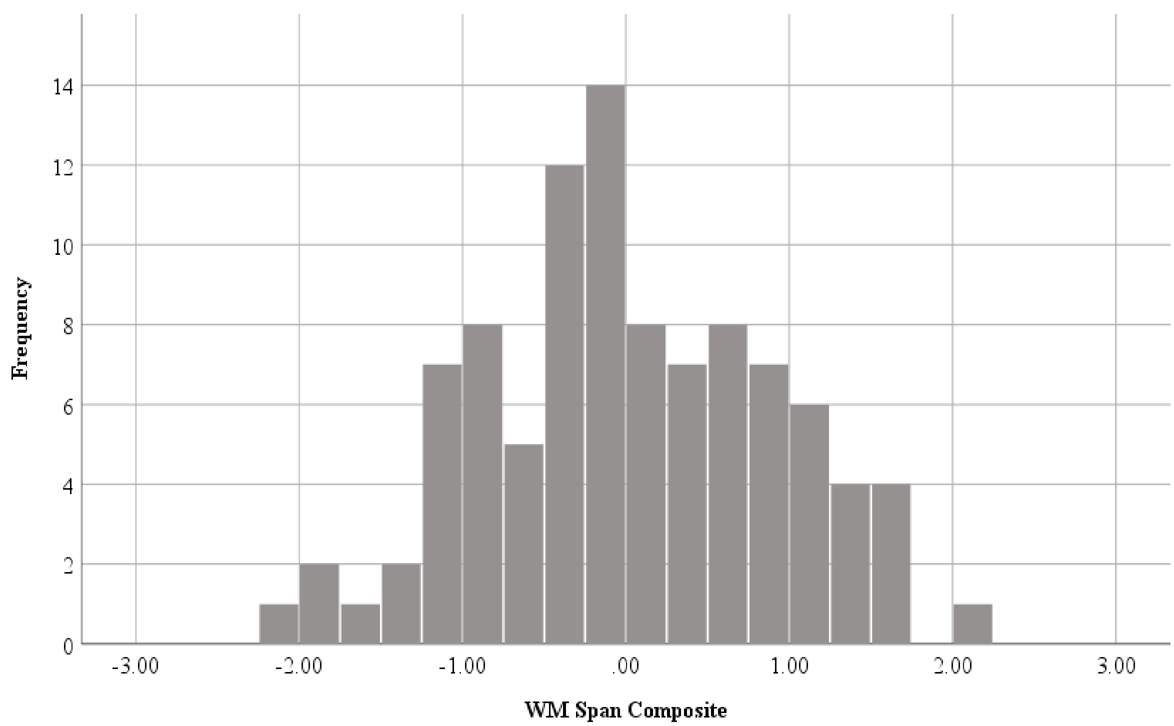

Figure 5. Distribution of composite WM scores, $N = 98$.

Analyzed individually, OSPAN and RSPAN scores did not correlate with the number of correctly solved problems, neither through insight nor through strategic problem solving (see Table 15 for correlation coefficients). However, OSPAN scores positively correlated with the number of correctly solved problems that were accompanied by high Suddenness ($r = .21$, $p < .05$). This correlation is slightly less, but still in line with the correlation between OSPAN scores and the number of problems solved with insight found by Chein and Weisberg ($r = .39$, $p < .01$; 2014). This suggests that the association between insight and WM span found in their study is driven by the Suddenness component alone.

WM Span and Solving Time. Composite WM span score also did not correlate with the correct solving time, neither with insight nor without insight. This might suggest that the search space of CRA task is not big enough to create enough cognitive load for the working memory while searching for the solution (see Webb, Little, & Cropper, 2016, for performance of CRA task as an insight task).

Table 15

Correlation Matrix for the Number of Correctly Solved Problems, Aha! Rating Components, Solving Time, and WM Span Scores

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Number of Problems Solved Correctly with Insight																				
1 Suddenness (High)	1	.63**	.80**	.79**	-.30**	-.05	-.21*	-.17	-.27**	-.09	-.06	.11	.35**	.18	.12	.24*	.21*	.13	.18	.74**
2 Effort (Low)		1	.69**	.86**	0.11	-.60**	-.11	-.33**	-.21*	0	-.09	.09	.25*	.36**	.13	.32**	.15	.14	.15	.68**
3 Confidence (High)			1	.78**	.08	-.03	-.43**	-.07	-.29**	-.16	.07	-.01	.34**	.30**	.29**	.31**	.18	.08	.13	.82**
4 Full Insight				1	-.16	-.46**	-.33**	-.54**	-.30**	-.23*	-.10	.09	.34**	.41**	.24*	.40**	.14	.10	.13	.64**
Number of Problems Solved Correctly without Insight																				
5 Suddenness (Low)					1	.31**	.52**	.65**	-.10	.03	-.05	-.29**	-.14	-.09	.03	-.09	.01	-.06	-.03	.42**
6 Effort (High)						1	.33**	.76**	-.07	-.06	.03	-.23*	-.09	-.39**	-.03	-.26*	.02	-.10	-.04	.18
7 Confidence (High)							1	.59**	-.01	.16	-.24*	-.14	-.21*	-.35**	-.28**	-.28**	.02	-.01	.01	.16
8 Full Strategy								1	.02	.22*	.05	-.25*	-.18	-.43**	-.16	-.33**	.05	-.04	.01	.32**
Correct Solving Time with Insight																				
9 Suddenness (High)									1	.53**	.60**	.66**	-.04	.21	.24*	.23*	-.05	-.15	-.10	-.35**
10 Effort (Low)										1	.47**	.69**	.19	.02	.18	.19	.16	.04	.14	-.07
11 Confidence (High)											1	.55**	.42**	.46**	.33**	.55**	.13	.01	.07	-.08
12 Full Insight												1	.08	0.12	.16	.21	.05	-.05	.01	-.10
Correct Solving Time without Insight																				
13 Suddenness (Low)													1	.55**	.58**	.80**	.14	.10	.12	.24*
14 Effort (High)														1	.58**	.81**	.17	.15	.17	.11
15 Confidence (Low)															1	.75**	.13	.14	.16	.15
16 Full Strategy																1	.11	.08	.10	.16
Working Memory																				
17 OSPAN																	1	.60**	.89**	.21*
18 RSPAN																		1	.89**	.08
19 WM Span																			1	.15
20 Total Number of Correctly Solved Problems																				1

$N = 98$; $^{*}p < .05$; $^{**}p < .01$

Suddenness and Problem Difficulty

Since only Suddenness correlated with WM span and also the solutions rated with high Suddenness happened significantly faster than the strategic ones (see Solving Time and Insight section above), we also investigated the relationship between Suddenness and problem difficulty to explore whether the easiest problems were solved more suddenly. This was done at the problem level, $N = 60$. Problem difficulty was operationalized as the number of participants who solved the problem correctly, with the lower numbers representing more difficult problems and higher numbers representing easier problems. The average Suddenness rating and problem difficulty correlated at $r = .56$ ($p < .01$), sharing 31% of variance (see Table 16). This suggests that the problems solved with higher Suddenness are easier to solve. Difficulty also negatively correlated with solving time, $r = -.72$, $p < .01$, suggesting that easier problems are also solved faster.

Table 16

Correlation Matrix for Problem Difficulty, Mean Solving Time, Mean Suddenness, Mean Effort, and Mean Confidence

	Difficulty	Solving Time	Suddenness	Effort[a]	Confidence
Difficulty	1	-.72**	.56**	-.47**	.26*

Note: [a] Effort is reversed, with low numbers indicating high level of Effort and high numbers indicating low level of Effort. $N = 60$; $^{**}p < .01$; $^{*}p < .05$.

DISCUSSION

Construct Validity of Aha! Ratings as a Measure of Insight

The aim of the current study was to investigate the construct validity of Aha! ratings as a measure of insight. Our analysis yielded low Cronbach's α suggesting that three items of an Aha! rating (Suddenness, Effort, and Confidence) do not demonstrate internal consistency. Moreover, since uni-dimensionality is a subset of consistency (Yu, 2001), high Cronbach's α does not indicate uni-dimensionality of the scale. However, low internal consistency implies that the measure is *not* unidimensional (modus tollens; Copi, 2015). Thus, an Aha! rating that includes suddenness, effort, and confidence is not uni-dimensional and therefore does not measure a unitary construct.

Furthermore, item analysis conducted on the measure revealed that (a) Confidence demonstrated poor discrimination between the levels of construct (insight versus non-insight), thus, it does not differentiate well between insightful and strategic solutions; (b) Effort showed low correlation with the rest of the measure, suggesting that it assesses a different construct than the scale. Also, pairwise agreement between the components measured by Cohen's κ was below minimum required level. This implies that different components sorted the same solution into different categories (insight versus non-insight). This also suggests that using a one-item Aha! rating that involve all three components, participants might be rating their solutions on qualitatively different scales—depending on which component of the Aha! rating they chose to focus on to make an overall judgment. Therefore, the Aha! ratings comprised of Suddenness, Effort, and Confidence do not demonstrate construct validity as a measure of insight.

Insightful versus Sudden Solutions

Our study replicated the significant positive correlation between WM span and the number of problems solved correctly with insight found by Chein and Weisberg (2014). However, the significant correlation was observed only for the Suddenness component of the measure, but not for other components individually and not for the problems solved with *full* insight (high Suddenness, low Effort, high Confidence). This suggests that the correlation coefficient found by Chein and Weisberg's study, using a scale that mixed metacognitive assessment of suddenness, effort, and confidence in one item, is driven by the feeling of suddenness alone. This result is also supported by Chuderski and Jastrzębski (2018) who collected self-reports of insight experience with only one item, Suddenness, and found significant positive correlation with WM span as well. The fact that insight is operationalized as simply a sudden solution poses a question of whether Aha! ratings actually measure the phenomenon of insight. Ash, Cushen, and Wiley (2009) reviewed multiple empirical and theoretical works that define insight as a process which includes (a) initial faulty representation, (b) impasse—feeling of being stuck and unable to reach a solution once the faulty problem representation space is exhausted, and (c) sudden realization of a solution. Thus, suddenness is only one of the multiple stages of the insightful problem solving and by itself it can produce false insights (Danek & Wiley, 2017).

The current study found that strategic solutions take longer time to solve, compared to insightful ones, which is in line with "business-as-usual" results (e.g., Chein and Weisberg, 2014; Jung-Beeman et al. 2004). In addition, while also using the CRA task, Sandkühler and Bhattacharya (2008) found that the solutions accompanied by the feeling of suddenness were obtained significantly faster than those that did not feel as sudden. Building on the argument in the previous paragraph, if solutions are rated on suddenness only, the solving process does not always involve insight (exhausting faulty search space, reaching an impasse, and overcoming the constraints). Thus, solutions that are strategic (involve only the search through the problem space phase) or solutions that accompanied by a feeling of suddenness (but do not involve faulty representation space and an impasse) should take less time than the insightful solutions. In fact, it was shown empirically that when insight is operationalized as a solution after impasse, insightful solutions take significantly longer than strategic ones (Ash, Jee, & Wiley, 2012; Lee, 2015). It was also demonstrated that when insight is assessed through Aha! ratings and as solving after impasse in the same study, the Aha! ratings and coding for impasse demonstrate opposite trends when it comes to solving time (Lee, 2015). Moreover, if participants experience impasse, it is possible that the solution does not feel as effortless, since exhausting the faulty solution space, feeling stuck, and only then arriving at a solution might not be assessed as an effortless process metacognitively.

Finally, we also found that easier problems are more likely to be rated with high Suddenness and solved faster than the more difficult ones. This suggests that in addition to assessing speed and suddenness of the solution, Aha! ratings also measure easiness of the problem, but not the presence of insight during the problem solving process.

Limitations

Additionally, the fact that strategic solutions take longer to arrive at compared to insightful ones might be due to the facts that (a) either the search space of the CRA task is not big enough or (b) faulty problem representation in CRA is not as common—compared to classical insight problems. One of the goals of the current study was to replicate the design of Chein and Weisberg (2014) study and the correlation between the measure of insight and WM span found by the authors. The intention was to make sure the conditions in the two studies were the same and the only difference was the three-item scale (Suddenness, Effort, and Confidence) in the current study, compared to the one-item scale that mixes all three in Chein and Weisberg. Thus, the use of the CRA task was a given. However, it was also a limitation of the study. Beside the argument that the task does not offer an adequate and explicit search space, it is also common in the literature to use CRA task as a task of *convergent* rather than *divergent* thinking, the latter being a creative process and the former—an analytic one (e.g., Dewhurst, Thorley, Hammond, & Ormerod, 2011; Jones & Estes, 2015; Lee & Therriault, 2013; Ma & Hommel, 2018). Moreover, in contrast to the CRA task, classical insight problems explicitly demonstrate solving times and patterns of the insightful problem-solving processes (Lee, 2015; see also Webb et al. 2016 for a review).

Conclusion

Based on all these, we suggest that the operationalization of insight needs to be revised if the future research is to move forward with investigations into this cognitive process. It seems there are at least two ways of achieving that, either (a) Aha! ratings should exclude confidence and effort and include some other components that would account for the incorrect initial representation and impasse phases, or (b) insight should be measured by the means of assessing impasse, e.g., Think Aloud protocols (e.g., Ash, Lee, & Shurkova, 2018; Lee, 2015) and/or through physiological measures, e.g., duration of eye-fixations (e.g., Huang, 2017; Knoblich, Ohlsson, & Raney, 2001). The operationalization of insight which includes methods that assess impasse would also assist neuroimaging techniques when studying insight as currently there is also no agreement on neither coarse nor fine-grained neural substrates of insightful problem solving (see Dietrich & Kanso, 2010, for a review). Lastly, we argue that the CRA task is not suitable for empirical investigations into the insight phenomenon, while classical insight problems allow to model insightful problem-solving process more accurately.

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APPENDIX A

COMPOUND REMOTE ASSOCIATES TASK SET

Word 1	Word 2	Word 3	Solution	Word 1	Word 2	Word 3	Solution
tail	water	flood	gate	mouse	bear	sand	trap
peach	arm	tar	pit	cross	rain	tie	bow
fork	dark	man	pitch	dress	dial	flower	sun
wet	law	business	suit	fur	rack	tail	coat
piece	mind	dating	game	opera	hand	dish	soap
way	board	sleep	walk	wagon	break	radio	station
grass	king	meat	crab	health	taker	less	care
shock	shave	taste	after	carpet	alert	ink	red
guy	rain	down	fall	hound	pressure	shot	blood
teeth	arrest	start	false	animal	back	rat	pack
iron	shovel	engine	steam	office	mail	hat	box
pine	crab	sauce	apple	hammer	gear	hunter	head
mail	board	lung	black	pie	luck	belly	pot
pea	shell	chest	nut	man	glue	star	super
fight	control	machine	gun	tank	hill	secret	top
aid	rubber	wagon	band	type	ghost	screen	writer
night	wrist	stop	watch	wheel	hand	shopping	cart
rocking	wheel	high	chair	fox	man	peep	hole
cane	daddy	plum	sugar	baby	spring	cap	shower
cracker	fly	fighter	fire	age	mile	sand	stone
show	life	row	boat	off	military	first	base
duck	fold	dollar	bill	note	chain	master	key
worm	shelf	end	book	fly	clip	wall	paper
loser	throat	spot	sore	tooth	potato	heart	sweet
print	berry	bird	blue	lift	card	mask	face
basket	eight	snow	ball	mill	tooth	dust	saw
preserve	ranger	tropical	forest	cat	number	phone	call
pike	coat	signal	turn	test	runner	map	road
date	alley	fold	blind	bottom	curve	hop	bell
sage	paint	hair	brush	right	cat	carbon	copy

APPENDIX B

POST-SOLUTION RATINGS

Sometimes when we solve a problem, we feel unsure that our answer is the correct solution (*Not Confident*). Other times, we feel absolutely certain that the answer we have come up with is correct (*Very Confident*).

How confident are you in your solution? *Not Confident* (1) to *Very Confident* (4)

Sometimes when we solve a problem, we feel like we consistently make progress towards the solution; that we take incremental steps that lead to the final solution and the solution didn't just come "out of the blue" (*Not Sudden*). Other times, we can work on a problem and not feel as though we are making any progress towards a solution, but the solution will just “pop into our head” (*Very Sudden*).

How sudden did the solution come to you? *Not Sudden* (1) to *Very Sudden* (4)

Sometimes when we solve a problem, the answer comes to us easily, without having to use a lot of mental effort (*Not Effortful*). Other times, we have to think very hard and it feels like it takes a lot of mental work to come up with a solution (*Very Effortful*).

How much effort was required to find the solution? *Not Effortful* (1) to *Very Effortful* (4)

APPENDIX C

OPERATION SPAN STIMULI

IS	(10 ÷ 2)	– 3 = 2	?	F
IS	(10 ÷ 10)	– 1 = 2	?	K
IS	(7 ÷ 1)	+ 2 = 7	?	L
IS	(3 ÷ 1)	– 2 = 3	?	X
IS	(2 x 1)	– 1 = 1	?	R
IS	(10 ÷ 1)	+ 3 = 13	?	B
IS	(9 x 2)	+ 1 = 18	?	Q
IS	(9 ÷ 1)	– 7 = 4	?	M
IS	(8 x 4)	– 2 = 32	?	H
IS	(9 x 3)	– 3 = 24	?	X
IS	(4 ÷ 1)	+ 1 = 4	?	L
IS	(10 ÷ 1)	– 1 = 9	?	F
IS	(8 x 4)	+ 2 = 34	?	B
IS	(6 x 3)	+ 2 = 17	?	Q
IS	(6 ÷ 3)	+ 2 = 5	?	K
IS	(6 x 2)	– 3 = 10	?	J
IS	(8 ÷ 2)	+ 4 = 2	?	R
IS	(8 ÷ 2)	– 1 = 3	?	B
IS	(9 ÷ 1)	– 5 = 4	?	W
IS	(6 ÷ 2)	– 2 = 2	?	X
IS	(7 x 2)	– 1 = 14	?	J

IS	(6 x 2)	– 2 = 10	?	K
IS	(2 x 2)	+ 1 = 4	?	F
IS	(7 x 1)	+ 6 = 13	?	Q
IS	(3 ÷ 1)	+ 3 = 6	?	B
IS	(10 ÷ 1)	+ 1 = 10	?	M
IS	(4 x 4)	+ 1 = 17	?	L
IS	(3 x 3)	– 1 = 8	?	R
IS	(3 x 1)	+ 2 = 2	?	H
IS	(4 ÷ 2)	+ 1 = 6	?	X
IS	(5 ÷ 5)	+ 1 = 2	?	F
IS	(2 x 3)	+ 1 = 4	?	R
IS	(9 ÷ 3)	– 2 = 1	?	B
IS	(10 ÷ 2)	– 4 = 3	?	M
IS	(5 ÷ 1)	+ 4 = 9	?	K
IS	(10 x 2)	+ 3 = 23	?	J
IS	(7 ÷ 1)	+ 6 = 12	?	F
IS	(3 x 2)	+ 1 = 6	?	L
IS	(6 x 4)	+ 1 = 25	?	X
IS	(9 ÷ 3)	– 1 = 2	?	B
IS	(8 ÷ 1)	– 6 = 4	?	R
IS	(9 x 1)	+ 9 = 1	?	M

APPENDIX D

READING SPAN STIMULI

No matter how much we talk to him, he is never going to change.	?	F
The prosecutor's dish was lost because it was not based on fact.	?	K
Every now and then I catch myself swimming blankly at the wall.	?	L
We were fifty lawns out at sea before we lost sight of land.	?	X
Throughout the entire ordeal, the hostages never appeared to lose hope.	?	R
Paul is afraid of heights and refuses to fly on a plane.	?	B
The young pencil kept his eyes closed until he was told to look.	?	Q
Most people who laugh are concerned about controlling their weight.	?	M
When Lori shops she always looks for the lowest flood.	?	H
When I get up in the morning, the first thing I do is feed my dog.	?	X
After yelling at the game, I knew I would have a tall voice.	?	L
Mary was asked to stop at the new mall to pick up several items.	?	F
When it is cold, my mother always makes me wear a cap on my head.	?	B
All parents hope their list will grow up to be intelligent.	?	Q
When John and Amy moved to Canada, their wish had a huge garage sale.	?	K
In the fall, my gift and I love to work together in the yard.	?	J
At church yesterday morning, Jim's daughter made a terrible plum.	?	R
Unaware of the hunter, the deer wandered into his shotgun range.	?	B
Since it was the last game, it was hard to cope with the loss.	?	W
Because she gets to knife early, Amy usually gets a good parking spot.	?	X
The only furniture Steve had in his first bowl was his waterbed.	?	J
Last year, Mike was given detention for running in the hall.	?	K
The huge clouds covered the morning slide and the rain began to fall.	?	F
After one date I knew that Linda's sister simply was not my type.	?	Q
Jason broke his arm when he fell from the tree onto the ground.	?	B
Most people agree that Monday is the worst stick of the week.	?	M
On warm sunny afternoons, I like to take a walk in the park.	?	L
With intense determination he overcame all obstacles and won the race.	?	R

A person should never be discriminated against based on his race.	?	H
My mother has always told me that it is not polite to shine.	?	X
The lemonade players decided to play two out of three sets.	?	R
Raising children requires a lot of dust and the ability to be firm.	?	B
The gathering crowd turned to look when they heard the gun shot.	?	M
As soon as I get done taking this envy I am going to go home.	?	K
Sue opened her purse and found she did not have any money.	?	J
Jill wanted a garden in her backyard, but the soil was mostly clay.	?	F
Stacey stopped dating the light when she found out he had a wife.	?	L
I told the class that they would get a surprise if they were orange.	?	X
Jim was so tired of studying, he could not read another page.	?	B
Although Joe is sarcastic at times, he can also be very sweet.	?	R
Carol will ask her sneaker how much the flight to Mexico will cost.	?	M
The sugar could not believe he was being offered such a great deal.	?	W

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PUBLICATIONS

Judah, M. R., Shurkova, E., Y., Hager, N. M., White, E. J., Taylor, D. L., Grant, D. M. (2018). The relationship between social anxiety and heartbeat evoked potential amplitude. *Biological Psychology, 139*, 1-7.

Shurkova, E., Ishak, R., Olariu, S., & Salleh, S. (2008). Emergent behavior in massively-deployed sensor networks. *Mobile Information Systems, 4*(4), 313-331.

SELECTED PRESENTATIONS

Shurkova, E. Y., & Ash, I. K. (2019, May). *Construct validity of Aha! ratings as a measure of insight.* Poster to be presented at the 31st APS Annual Convention, Washington, DC.

Ash, I. K., Lee, K. D., & Shurkova, E. Y. (2018, November). *The relationship of working memory span, cognitive reflection test, and compound remote associates performance*. Poster presented at the 59th Psychonomic Society Annual Meeting, New Orleans, LA.

Shurkova, E., Martin, B., Judah, M. R., Saulnier K. G., & Allan, N. P. (2017, April). *Straight-forward attentional control scale*. Poster presented at the annual convention of the Virginia Association for Psychological Science, Norfolk, VA.