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Investigating Insight Using Compound Remote Associate Problems

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Abstract

Many new problems and paradigms have been developed to answer questions pertaining to insight problem solving. One problem type that may be useful to the study of insight is the Compound Remote Associate (CRA) problem, developed by Bowden & Jung-Beeman (2003). However, it is uncertain to what extent CRA problems are insight problems. We performed a protocol analysis of people solving CRA problems and found that CRA do exhibit some characteristics of insight. However, certain considerations should be taken into account. Particularly, problems solved when the solution is the first thing considered are often judged to be insight by participants, but these problems do not exhibit any characteristics of insight aside from the 'Aha' experience.

Keywords: Insight; Problem Solving; Restructuring; Impasse

Introduction

Problem solving enables us to discover solutions to problems. Sometimes, however, we reach an impasse, or road block, in the problem solving process. We may realize there is some flaw in our efforts, and the solution may seem unattainable, but the source of our error remains hidden. We may contemplate for a long period of time until, all of the sudden, the answer seems obvious. This phenomenon has been termed insight, and is loosely defined as achieving a solution without knowing where the solution came from.

Some phenomenological features are unique to insight. Insight solutions often appear from nowhere and solvers experience an affective response of suddenness and surprise (Aha! experience), sometimes resulting after an impasse; insight solutions are obtained through processes known as restructuring, whereby an incorrect representation of the problem is changed, leading to the access of an insightful, correct representation of the problem (e.g., Bowden, Jung-Beeman, Fleck, & Kounios, 2005; Ohlsson, 1992; Schooler, Fallshore, & Fiore, 1995). The key components of insight are often described as impasse, restructuring, and 'Aha!'.

Problems Used for Insight Research

Many types of problems have been used to study insight. Classic insight problems have been used extensively, and sometimes the reason is solely based on the fact that they have previously been used to study insight (Weisberg, 1995). With the emergence of advanced neuroimaging techniques (e.g., functional Magnetic Resonance Imaging [fMRI], Electroencephalography [EEG], etc.), and the great amount of time it takes to solve (if at all) complex, classic insight problems, new problems and paradigms have been used to investigate insight (Bowden et al., 2005). One specific problem type that has been used is the compound remote associate (CRA) problem (Bowden & Jung-Beeman, 2007). CRA problems involve finding the one word that can form a compound word or phrase with each of three different words. For example, if three words—tree, sauce, and big—are presented, the solution is apple. CRA problems are solved much quicker than classic insight problems. They can be solved by insight or by noninsight, search processes (i.e., generate-and-test or trial-and-error), and individual problems can be solved with insight regardless of learning effects over multiple trials (Bowden & Jung-Beeman, 2007). Given these differences between classic insight problems and CRA problems, the question is to what extent CRA problems are insight problems.

Are CRA problems Insight Problems?

Though differences have been found between insight-CRA problems and noninsight-CRA problems (Bowden & Jung-Beeman, 2007; Bowden et al., 2005; Jung-Beeman et al., 2004; Kounios et al. 2006), we need more empirical evidence that CRA problems can be used to study insight. Specifically, evidence is needed to show that CRA problems exhibit properties characteristic of insight, and that there are differences between solving a CRA problem with insight and solving one without insight beyond the Aha experience.

Bowden and Jung-Beeman (2003; 2007) and Bowden et al. (2005) claim CRA problems exhibit phenomenological features and components of insight found in classic insight problems and, therefore, should be used to study insight. The processing is often unreportable, the problems misdirect (or fail to direct) retrieval processes, and people experience the Aha!. These are reasons to assume that CRA problems can be used to study insight. However, because CRA problems are hybrid problems, rated insight or noninsight by the solver on a forced choice scale, and are such short and simple problems, there is concern about their use to study insight. A critical component not listed above for CRA problems is the process of restructuring, and it is unclear to what extent CRA problems exhibit restructuring prior to insight solutions.

We designed a study using concurrent verbal protocols of CRA problem solving to determine if CRA problems solved with insight exhibit more characteristics of insight, than CRA problems solved without insight. The characteristics of insight examined are impasse, restructuring, and verbal overshadowing. We expect higher rates of impasse and more restructuring processes in insight solutions than noninsight solutions. Concurrent verbalization of cognitive processing has been shown to inhibit solving a problem with

insight (Schooler, Ohlsson, & Brooks, 1993) resulting in a lower solution rate such that fewer problems are solved with insight than when problems are not verbalized. However, other research (i.e., Fleck & Weisberg, 2004) suggests verbalization does not necessarily inhibit solutions by insight and differences in verbalization instructions may differentially influence problem solving processes. In fact, the present research used an adaptation of the coding scheme used by Fleck and Weisberg as well as similar verbalization instructions, therefore, it is plausible that insight solutions may not show this verbal overshadowing effect. The results of this study should further inform the use of CRA problems in the study of insight.

Method

Participants

Participants were 31 undergraduates enrolled in a psychology course at Mississippi State University who received course credit for their participation. All participants were native English speakers.

Design

The design was a 2 (Verbal-Task: verbalization, nonverbalization) x 3 (Solution-Type: insight, noninsight, other) within-subject design. Solution-Type was measured by the subjective ratings given by the participant, rather than manipulated.

Materials

The task, described as word association problems to participants, consisted of a set of 60 CRA problems taken from a larger set of 144 normed CRA items (Bowden & Jung-Beeman, 2003). Problems were chosen based on information from a baseline study at Mississippi State University using all 144 problems. Problems with the highest solution rates that had been solved with insight, on average, half of the time were included in the set. An additional six problems from the set of 144 problems were used for practice trials. The 60 problems were presented in random order and randomly assigned to Verbal-Task condition for each participant. The problems were displayed on a 17-in. computer monitor and answers were given by typing on a keyboard. The task procedure was implemented using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002). Concurrent verbal protocols were obtained via headset and recorded using E-Prime.

Procedure

Participants were run individually. After receiving informed consent, participants were instructed on the task and given descriptions of the differences for rating a problem with insight, noninsight, or other. These instructions were very similar adaptations taken from Jung-Beeman et al. (2004) and Kounios et al. (2006). The experimenter answered any questions the participants had about the tasks and the rating scale. Then the experimenter started the experiment on the computer, and the participants were instructed to read the directions presented for a second time via computer. After reading the general instructions, specific task instructions were given depending on the Verbal-Task condition for each participant. Participants were counterbalanced between Verbal-Task conditions so that half experienced the verbalization task first and the other half experienced the nonverbalization task first. For the verbalization condition, participants were instructed on how to verbalize their thoughts during problem-solving efforts based on the think-aloud instructions found in the appendix of Ericsson and Simon (1993). Participants who were asked to think aloud first were given instructions and training in how to verbalize their thoughts before the first task and told that they did not have to think aloud anymore right before the second task. If the first task was to solve problems without thinking aloud then participants were asked if they had any questions and allowed to continue. For these participants, think-aloud instructions were given after completing the nonverbalization task.

Participants were given three practice CRA problems before each Verbal-Task condition to make sure that they understood the difference in responses for rating a problem (insight, noninsight, and other), were verbalizing correctly, and understood the task requirements. The practice problems may have also helped to reduce some carryover effects from prior verbalization. Participants began the CRA task by pressing a button. The problem words were presented for a maximum of 30 seconds. Participants could give a solution at any time during the 30 second interval by typing their answer. If the given solution was incorrect they could continue work on the problem until time ran out. Upon correct solution within the time limit, participants were prompted to give a rating of whether they solved the problem via insight, noninsight, or other. The order of ratings was counterbalanced so that for half of the participants a rating of 1 was insight and a rating of 3 was noninsight and, for the other half, a rating of 1 was noninsight and a rating of 3 was insight. After a rating was given or solution time ran out, the next problem was presented. Thirty problems were presented and then the participant was asked to stop and notify the experimenter. The experimenter then gave the participant the appropriate instructions for the second Verbal-Task condition; after which, the participant continued to solve the next 30 problems while thinking aloud or keeping silent. Upon completion of the CRA task, participants were debriefed.

Results

Six subjects were dropped from all analyses (n = 25) due to outlier and zero data. One subject reported solutions by "other" much more often than any other subjects and five subjects reported solving problems only with insight, or only with noninsight, within at least one level of Verbal-Task.

Solution Rates and Times

Solution rates were calculated in each Verbal-Task condition for each Solution-Type as a percentage of problems solved (e.g. Insight percentage = number of insight solutions/number of total problems attempted). Response times were obtained for each solved problem to calculate the average time to solution for each Solution-Type and each Verbal-Task. Time started when the problem first appeared and ended when the final solution was entered. A verbal overshadowing effect is present if thinking aloud has a negative affect on response time and the number of problems solved (particularly with insight).

Overall, participants solved an average of 52.4% (*SD* = 11.10%) of problems. For solved problems, participants reported solution by insight 52.04% (*SD* = 15.27%) of the time, noninsight 37.14% (*SD* = 17.58%) of the time, and other 10.81% (*SD* = 11.16%) of the time. Average time to solution was 10.67 seconds (*SD* = 1.57). There were no effects of counterbalancing the orders of ratings or verbalization task conditions within subjects, so the data were collapsed across these levels of counterbalancing.

A 2 (Verbal-Task) X 3 (Solution-Type) within-subjects repeated measures analysis was performed to analyze the effects of Verbal-Task and Solution-Type (Insight, Noninsight, Other) on the percentage of problems solved (solution rates). More problems were solved in the Nonverbalization condition (M = 56.40%, *SD* = 11.37%) than in the Verbalization condition (M = 48.40%, *SD* = 14.52%), $F(1,24) = 8.64$, $p = .007$. Solution rates also differed for different Solution-Types, $F(2,48) = 30.69$, $p < .001$. Pairwise comparisons revealed that more problems were solved with Insight (M = .279, *SD* = .117) than Noninsight (M=.192, *SD* = .093), $t(24) = 2.58$, $p = .016$, and Noninsight than Other (M = .053, *SD* = .054), $t(24) = 5.353$, $p < .001$. Verbalization did not differentially affect the proportion of solutions across problem types as the Verbal-Task by Solution-Type interaction was not significant, $F(2,48) = .464$, $p = .631$ (Figure 1 shows a breakdown of the solution rates). Subsequent paired t-tests comparing the distributed proportions of correct insight, noninsight, and other solutions between levels of Verbal-Task also revealed no significant effects, all $t(24) < .70$, all $p > .50$, indicating that verbalization may affect the total number of problems solved but not the distribution of solution types.

For all following analyses only two levels of Solution-Type were used (Insight and Noninsight but not Other) because many subjects did not report "other" for any solved problems. A 2 (Verbal-Task) X 2 (Solution-Type) within-subjects repeated measure analysis was performed for solution response times. Response times were longer for Noninsight solutions (M = 12.9 seconds, *SD* = 3.29) than Insight solutions (M = 9.8 seconds, *SD* = 4.18), $F(1,24) = 5.74$, $p = .025$, and longer for Verbalization (M = 12.3 seconds, *SD* = 2.46) than Nonverbalization (M = 10.4 seconds, *SD* = 2.41), $F(1,24) = 10.21$, $p = .004$. As seen in the prior analysis, the interaction between Verbal-Task and Solution-Type was not significant, $F(1,24) = .553$, $p = .464$.

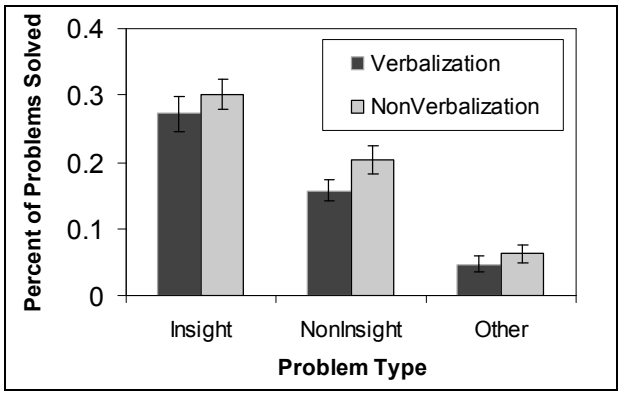

Figure 1: Solution rates of attempted problems. Mean percentage of attempted problems solved with insight, noninsight, or other while verbalizing and while not verbalizing. Error bars indicate one standard error.

Though it takes people longer to solve problems while thinking aloud, people will not likely solve any more problems if given more time. The results show that thinking aloud while attempting to solve CRA problems inhibits solution regardless of the solution method (insight, noninsight, or other) indicating an overarching verbal overshadowing effect. However, verbalization does not differentially affect insight and noninsight CRA solutions, which indicates that verbalization is not influencing the way in which the solution occurs but only if it occurs at all. Therefore, the verbal protocols may be used as data.

Verbal Protocol Analysis

The verbal protocols were coded for occurrences of impasses and restructuring elements. Impasse was calculated as the average number of impasses reached per correct solution and was coded into five different types. Restructuring was calculated as the average number of times restructuring occurred per correct solution and were coded into three different types. Because the amount of time a person spends on a problem affects the amount of impasses and restructuring that can possibly be obtained, each score for each problem was first divided by the amount of time it took to solve the problem before obtaining an average score for each participant. Details of each coding scheme are discussed below with each respective analysis.

When examining the verbal protocols we identified two distinct types of insight solutions. The first type of insight solution, termed "immediate-insight," occurs when the first candidate solution verbalized by the participant was the solution and this solution occurred within 15 s of the problem being presented. The second type of insight solution, termed "delayed-insight," are all other insight solutions not classified as "immediate-insight". A person may report the quickly solved problems as insight simply because they came to a solution so fast that it seemed sudden and surprising. However, it is unclear whether this should be called insight. Immediate insight solutions do not

Table 1: Within-subjects Repeated Measures Analysis for Each Level of Impasse (n=22).

	Means			
Analysis	Combined Insight	Immediate-insight	Delayed-insight	Noninsight
Rereading	0.0028 (0.0086)	0 (0)	0.0049 (0.0115)	0.0024 (0.0065)
Regenerating	0.0007 (0.0035)	0 (0)	0.0029 (0.0138)	0 (0)
Discontinuing	0.0006 (0.0020)	0 (0)	0.0028 (0.0099)	0.0038 (0.0131)
No New	0.0038 (0.0089)	0 (0) **	0.0089 (0.0173)	0.0058 (0.0083)
Frustration	0.0024 (0.0047)	0 (0) **	0.0135 (0.0297)	0.0071 (0.0157)
Total Impasse	0.0105 (0.0171)	0 (0) **	0.0332 (0.0375)*	0.0191 (0.0281)

Notes. Values represent mean number of occurrences per second. Standard deviations are in parentheses. Noninsight means remained the same for all analyses and are compared to each type of insight. Significant effects are represented by stars (*) in the "Insight" columns.
*$p < .10$. **$p < .05$.

exhibit any observable signs of impasse or restructuring in the verbal protocols and are the first solution candidate reported (clearly not insight as it is traditionally defined). Of solutions reported as insight, 77.73% (*SD* = 17.16%) were immediate-insight and 22.3% (*SD* = 17.16%) were delayed-insight. There were almost no immediate noninsight solutions. Therefore, in all subsequent analyses, noninsight solutions were not separated in order to simplify comparisons.

Three analyses for each coded variable were performed with only two levels of Solution-Type (Insight and Noninsight) and one level of Verbal-Task (verbalization). Three additional subjects were dropped from the analyses (*n*=22) because they did not report any delayed insight solutions. In an initial analysis we compared the combined delayed- and immediate- insight solutions ("combined insight") to noninsight solutions. A second analysis compared immediate-insight to noninsight solutions. A third analysis compared delayed-insight to noninsight solutions. The results of splitting insight into two categories reveal large differences between the effects seen in the combined insight versus noninsight analyses and the effects seen in the delayed-insight versus noninsight analyses.

Impasse Five types of Impasse were coded (Regenerating, Rereading, Discontinuing, No-New, and Frustration). Regenerating meant that a person generated the same solution candidate two or more times within a problem. Rereading meant that a person reread the problem words three or more times in succession without generating a solution candidate. Discontinuing meant that the person completely stopped solving the problem and in which no progress toward solution was being made. No-New meant that a person stopped generating new solution words for at least 15 seconds after onset of a problem or at least 10 seconds between candidates. Finally, Frustration meant that a person exhibited clear signs of emotional frustration and experienced real difficulty with the task or specific problem. The individual scores were summed to get a total impasse score. Two independent raters coded the data, and agreement between raters on the number of total impasses per solution was good (Pearson $r = .84$, Kendall's tau = .77).

Three within-subjects repeated measure analyses were performed on total impasse scores per Solution Type. In the first analysis, the amount of total impasse was no different for Noninsight (*M* = .191/second, *SD* = .028) than Combined Insight (*M* = .0105/second, *SD* = .017) problems, $F(1,21) = 1.687$, $p = .208$ (see Figure 2). In the second analysis, there was significantly less impasse for Immediate-insight solutions (*M* = 0, *SD* = 0) than Noninsight solutions, $F(1,21) = 10.11$, $p = .005$. When comparing Delayed-insight and Noninsight solutions, the amount of total impasse for Delayed-insight solutions (*M* = .033/second, *SD* = .038) is marginally greater than that of Noninsight solutions, $F(1,21) = 3.649$, $p = .070$ (see Figure 2). When immediate- and delayed- insight solutions are combined in the analysis there is a higher rate of impasse for noninsight solutions due to the effect of immediate-insight solutions, but when only delayed-insight solutions are included there is a lower rate of impasse for noninsight solutions (see Table 1).

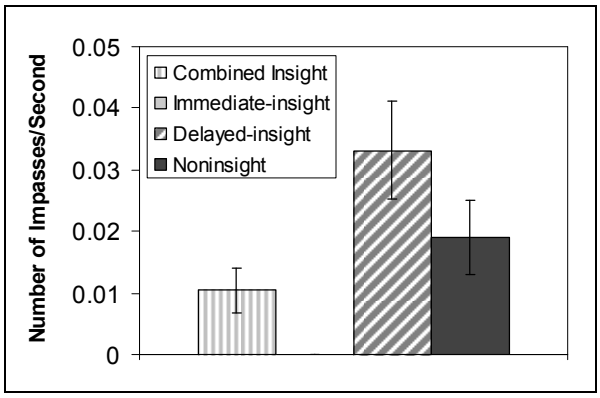

Figure 2: Mean rate of impasse for combined insight, immediate-insight, delayed-insight, and noninsight solutions. Immediate-insight does not show because it is zero. Error bars indicate one standard error.

Table 2: Within-subjects Repeated Measures Analysis for Each Level of Restructuring (n=22).

	Means			
Analysis	Combined Insight	Immediate-insight	Delayed-insight	Noninsight
Re-encoding	0.0174 (0.0199)	0 (0) **	0.0510 (0.0460)**	0.0296 (0.0332)
Elaboration	0.0039 (0.0096)	0 (0) *	0.0123 (0.0330)	0.0036 (0.0083)
Constraint Relaxation	0.0008 (0.0029)	0 (0)	0.0028 (0.0093)	0.0016 (0.0056)
Total Restructuring	0.0221 (0.0209)	0 (0) **	0.0660 (0.0497)**	0.0348 (0.0312)

Notes. Values represent mean number of occurrences per second. Standard deviations are in parentheses. Noninsight means remained the same for all analyses and are compared to each type of insight. Significant effects are represented by stars (*) in the "Insight" columns.
*$p < .10$. **$p < .05$.

Restructuring Restructuring was coded into three different types (Elaboration, Re-encoding, and Constraint Relaxation). Elaboration meant that a person switched to a different meaning of a problem word after trying and failing to find a solution with the first meaning of a word (i.e. star has multiple meanings: starlight or superstar). Re-encoding meant that a person switched to a different problem word to try and find a solution after failing with a previous word. Finally, Constraint Relaxation meant that a person revised the idea of the goal. The person switched the method for solving the problem or clearly stated that they needed to try something different to get a solution. Individual scores were summed to obtain a total restructuring score. Two independent raters coded the data, and agreement between raters on the number of total restructurings per problem was good (Pearson $r = .77$, Kendall's tau = .71).

Three within-subjects repeated measure analyses were performed on total restructuring scores per Solution Type. In the first analysis, the amount of total restructuring was no different for Noninsight solutions ($M = .0348$/second, $SD = .0312$) than Combined Insight solutions ($M = .0221$/second, $SD = .0209$), $F(1,21) = 2.251$, $p = .148$ (see Figure 3). In the second analysis, there is significantly less restructuring for Immediate-insight solutions ($M = 0$, $SD = 0$) than Noninsight solutions, $F(1,21) = 27.47$, $p < .0001$. Again, when comparing Delayed-insight and Noninsight solutions the amount of total restructuring is significantly greater for Delayed-insight solutions ($M = .066$/sec, $SD = .050$) than Noninsight solutions, $F(1,21) = 8.847$, $p = .007$ (see Figure 3). When immediate and delayed-insight solutions are combined in the analysis there is a higher rate of restructuring for noninsight solutions due to the effect of immediate-insight solutions, but when only delayed-insight solutions are included there is a lower rate of restructuring for noninsight solutions (see Table 2).

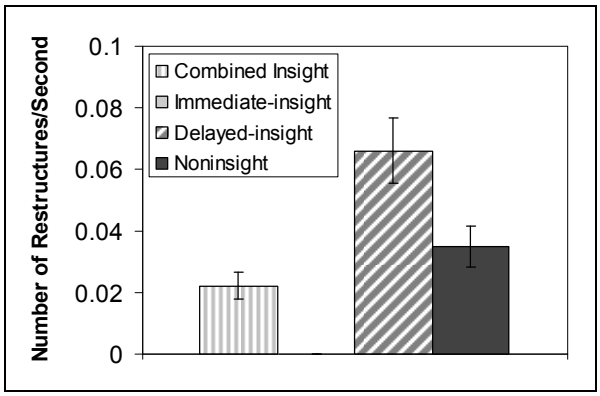

Figure 3: Mean rate of restructuring for combined insight, immediate-insight, delayed-insight, and noninsight solutions. Immediate-insight does not show because it is zero. Error bars indicate one standard error.

Discussion

The purpose of the experiment was to determine if CRA problems can reliably used as insight-like problems. If CRA problems are insight problems, then there should be higher restructuring scores and impasse scores for insight solutions compared to noninsight solutions. Also, according to Schooler et al. (2003), there should be a verbal overshadowing effect.

The results indicate at least some verbal overshadowing effect when solving CRA problems while thinking aloud. Verbalization hindered solution rates and response times for both insight and noninsight solutions. Short-term memory, working memory, and long-term memory retrieval are impacted by concurrent verbalization of processes that are not normally verbalized (Ericsson & Simon, 1993; Schooler et al., 1993). Verbalizing may hinder people from keeping track of where they are and where they are going (in working memory) as well as accessing seemingly distant concepts (in long-term memory). Therefore, both insight and noninsight CRA problem solving methods can be affected by concurrent verbalizations.

The analysis of verbal protocols provided a few unique findings. The results of the impasse and restructuring analyses comparing combined insight and noninsight solutions indicated that noninsight solutions had a slightly higher rate of impasse and restructuring. However, closer inspection of insight solutions revealed that many problems solved with insight were simply the first word that came to mind. The processes used here might not actually be that of insight. People may report insight simply because the answer was sudden. Or, there may have been insight, but that it occurred so quickly that participants were not able to verbalize much before solution. Using people's subjective 'Aha!' experience as a marker of insight might not be a

reliable indicator of insight by itself (or at least it indicates that different problem solving processes can lead to insight).

Further analyses revealed a significant difference in the methods used to solve the problems. The problems solved immediately with insight had no observable characteristics of insight (impasse and restructuring), while the delayed insight solutions had more of the characteristics of insight. When analyzed together insight solutions are derived faster and have significantly less rates of impasse and restructuring than noninsight solutions, but when immediate insight solutions are removed from the analysis the results differ. Delayed-insight solutions are derived in about the same time as noninsight solutions and have significantly more rates of impasse and restructuring than noninsight solutions. There may be two different methods for obtaining insight for CRA problems. Paraphrasing Newell (1973), people may perform a task using different methods and psychologists should take this into account when analyzing data. The effect of averaging over methods "conceals, rather than reveals" (p. 295) any true effect.

From the results, there is some concern that some prior results may have been clouded by averaging the data of the two distinct types of insight (immediate and delayed). For example, neuroimaging results using CRA problems have found more activity in the right anterior superior temporal gyrus, possibly indicating the sudden emergence of the correct solution, that may be facilitated by cognitive control activity prior to problem onset in the dorsal anterior cingulated cortex (Jung-Beeman et al., 2004; Kounios et al., 2006; Subramaniam et al., 2009). However, the results likely include many immediate-insight solutions in the data. There might be different, or additional, areas that are necessary for insight, which are not revealed in prior studies. The areas noted in these prior studies might actually be specific only to immediate-insight and not delayed-insight which often involve restructuring (a staple of the traditional insight definition).

The conclusion drawn is that separating the two types of insight solutions during analysis may reveal different results than prior studies. By pulling apart the two types of insight solutions the processes of insight can be further explored. For example, delayed-insight solutions reveal restructuring elements in the verbal protocols. Immediate-insight solutions do not show observable elements of restructuring. Therefore, the pattern of activation for immediate-insight solutions (and associated processes) may greatly differ from the pattern of activation for delayed-insight solutions. Comparing the solution types may reveal cortical areas necessary for restructuring while eliminating the activation of other common "insight areas." After all, the delayed type insight solutions seem to resemble real world insight more than the immediate type and fit better to the traditional definition of insight. In conclusion, CRA problems can, and should, be used to study insight. However, future work should differentiate immediate- and delayed- insight solutions.

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References

Bowden, E. M., & Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems. *Behavioral Research Methods, Instruments, and Computers, 35*, 634-639.

Bowden, E. M., & Jung-Beeman, M. (2007). Methods for investigating the neural components of insight. *Methods*, *42*(1), 87-99.

Bowden, E. M., Jung-Beeman, M., Fleck, J., & Kounios, J. (2005). New approaches to demystifying insight. *Trends in Cognitive Sciences*, *9*(7), 322-328.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data (rev. ed.)*. Cambridge, MA: The MIT Press.

Fleck, J. I., & Weisberg, R. W. (2004). The use of verbal protocols as data: An analysis of insight in the candle problem. *Memory & Cognition*, *32*(6), 990-1006.

Jung-Beeman, M., Bowden, E. M., Haberman, J., Frymiare, J. L., Arambel-Liu, S., Greenblatt, R., et al. (2004). Neural Activity When People Solve Verbal Problems with Insight. *PLoS Biology*, *2*(4), 500-510.

Kounios, J., Frymiare, J. L., Bowden, E. M., Fleck, J. I., Subramaniam, K., Parrish, T. B., et al. (2006). The Prepared Mind: Neural Activity Prior to Problem Presentation Predicts Subsequent Solution by Sudden Insight. *Psychological Science*, *17*(10), 882-890.

Newell, A. (1973). You can't play 20 questions with nature and win. In W. G. Chase (Ed.), *Visual Information Processing* (pp. 283-308).

Ohlsson, S. (1992). Information-processing explanations of insight and related phenomena. In M. T. Keane & K. J. Gilhooly (Eds.), Advances in the psychology of thinking (pp. 1-43). London: Harvester Wheatsheaf.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburgh: Psychology Software Tools Inc.

Schooler, J. W., Fallshore, M., & Fiore, S. M. (1995). Epilogue: Putting insight into perspective. *The nature of insight.*, 559-587.

Schooler, J. W., Ohlsson, S., & Brooks, K. (1993). Thoughts beyond words: When language overshadows insight. *Journal of Experimental Psychology: General*, *122*(2), 166-183.

Subramaniam, K., Kounios, J., Parrish, T. B., & Jung-Beeman, M. (2009). A brain mechanism for facilitation of insight by positive affect. *Journal of Cognitive Neuroscience*, *21*(3), 415-432.

Weisberg, R. W. (1995). Prolegomena to theories of insight in problem solving: A taxonomy of problems. *The nature of insight.*, 157-196.