Problem Solving and Memory:

Investigating the Solvability and Memorability of Remote Associates Problems

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Abstract

Normative data on Remote Associate Test (RAT) problems is lacking for problems solved via semantic association rather than through the formation of compound words. The present study fills this void by collecting normative data on a variety of RAT problem types in terms of solvability, response time, and correlations between solvability and lexical characteristics. Analyses revealed variability in problem solvability, with association problems being solved significantly more than mixed types, and compound problems solved by the least number of subjects. Furthermore, this project used subsequent memory tests to examine the effect that solving a problem has on one's ability to remember the content later. During free recall testing, subjects remembered significantly more words from problems they had successfully solved than problems they had failed to solve. The implications of our results for understanding factors that influence problem solving and subsequent memory for problems are discussed.

Keywords: problem solving, memory, remote associates, normative data

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People are constantly confronted with problems in daily life. During the course of a single morning, one might have to locate lost car keys, figure out why the garage door will not open, and determine the fastest route around construction, all before facing new problems at work. Problems vary in difficulty and importance, in how well they are defined and how they are presented, but they are an unavoidable part of life. A problem can be defined as a question for which the answer is not readily obvious (Lovett, 2002), or a goal that is not immediately attainable (Hambrick & Engle, 2003). Greeno (1978) has suggested three basic groupings to classify types of problems. The first type includes problems of inducing structure, in which people must determine relations or patterns between items. Another type is problems of arrangement, where people must arrange given components in a specific fashion to solve the problem. Finally, there are problems of transformation, which require people to execute a certain sequence of transformations to achieve the end goal. These categories illustrate the diversity of problem types people encounter and solve.

Problem Solving

Despite the frequency in which people encounter problems in need of solving, problem solving itself is considered a complex function which remains relatively poorly understood. Problem solving is a higher-order cognitive process that requires executive control and integration of more basic skills (Goldstein & Levin, 1987) and is an extraordinarily broad domain, which has been defined in numerous ways. However, simply stated, it can be considered as the analysis and transformation of information toward a specific goal (Lovett, 2002).

Just as problems themselves vary greatly in type, there are also countless approaches to studying problem solving. In the early 20th century, Gestalt psychologists began studying problem solving by focusing on the solver's cognition and perception of the problem (Lovett, 2002). When given a goal-oriented problem, there are two ways in which one might respond. If the solver readily produces the behavior required to solve the problem, it is considered reproductive thinking, based on past experience or knowledge (Dominowski & Dallob, 1995). Productive thinking, on the other hand, occurs when previous experience proves insufficient to solve the problem, and a new strategy is required. The latter category is often argued to involve insight—sudden comprehension of the solution—and was a major focus of Gestaltists (Dominowski & Dallob, 1995). In the 1950's, psychologists including Newell, Shaw, and Simon (1958) revived problem solving research, examining it using computer programs and a metaphor of the mind as an information-processing system. In the 1980's, the role of learning processes in problem solving became a major research focus, with emphasis on comparisons between experts and novices (Lovett, 2002).

Research has unearthed many issues that affect problem solving ability, including motivation, creativity, emotion, environment, time of day, intellectual ability, fixation, comprehension, language parsing, expertise, and memory, to name a few (e.g., Dominowski & Dallob, 1995; Kostovsky, 2003; Lovett, 2002; Wieth & Zacks, 2011). The present study focuses specifically on the relation between problem solving and memory. Some psychologists theorize that problem solving is simply a type of remembering, claiming that memory retrieval is the main function underlying successful problem solving (e.g., Weisberg & Alba, 1981). In contrast, emphasizing the distinction between memory and problem solving lies at the heart of many theories, including the idea of insight (Dominowski & Dallob, 1995). Metcalfe (1986) noted that people can predict quite accurately whether or not they will eventually remember an item. She devised an experiment to compare this feature of memory with problem solving, hypothesizing that if problem solving was indeed the same as remembering, then people would, after a short exposure to a problem, be able to predict their future problem-solving success. However, the data were not consistent with this hypothesis, as subjects were unable to predict problem solvability.

Working Memory

While it is necessary to recognize problem solving and memory as separate domains of cognition, it is also important to note that the two are related and influence each other in many ways. Memory is often separated into two stores or systems in psychology—long-term and short-term. Information is either retrieved from a still active short-term memory, or a more-or-less inactive long-term memory (Dominowski & Dallob, 1995). Baddeley and Hitch (1974) replaced the concept of "short-term memory" with "working memory" to better represent memory's role in active consciousness (Schwartz, 2011). Working memory has emerged as a major research area in cognitive psychology, and while knowledge on the topic is growing, we still know relatively little about the true role of working memory in problem solving (Hambrick & Engle, 2003).

However, research has shown that working memory does play a role in many basic abilities germane to problem solving, such as comprehension of word order or high-imagery sentences (Baddeley, Elridge, & Lewis, 1981; Glass, Eddy, & Schwanenflugel, 1980). Comprehension is necessary for problem solving ability in that one must completely understand the instructions and what is being asked, and also that problems often require solvers to comprehend the larger meaning of a set of events or words. Furthermore, working memory capacity, which is responsible for bringing representations into focus and maintaining accessibility to these representations, is crucial for sustaining focused attention to a problem, suppressing unnecessary memory items, and avoiding problem-solving obstacles like functional fixedness (Hambrick & Engle, 2003; Hasher & Zacks, 1988; Horn & Masunaga, 2000).

Long Term Memory

Investigations into long term memory (LTM) have also proliferated within psychological research in recent decades. Long-term memory (LTM) is an unlimited capacity store capable of holding information over long periods (Weiten, 2007). Information moves from working memory to LTM through a process involving rehearsal, semantic association, and depth of processing (Schulman, 1975). While verbal working memory is based mostly on phonological encoding, LTM involves deeper semantic encoding, based on word meanings, rather than just perceptual codes (Weiten, 2007).

For this reason, many theories of verbal LTM organization are rooted in semantics. Bousfield (1953) found that people automatically organize items into storage categories based on meaning, a concept known as clustering. More complex knowledge may be further classified via multilevel conceptual hierarchies. Likewise, schemas—clusters of knowledge on a particular object based on previous experience—also influence organization of memory (Koriat, Goldsmith, & Panksy, 2000). A great deal of knowledge cannot be neatly organized into schemas or hierarchies. To explain LTM organization of this knowledge, Collins and Loftus (1975) proposed semantic networks made up of nodes representing words or concepts, with pathways of varying lengths linking associated ideas.

Common methods of assessing and measuring LTM include free recall and recognition. In a free recall task, the person must generate the target word from memory based only on instructions or global cues. On the other hand, verbal recognition tasks present the subject with words, and the subject must identify the target memory (Schwartz, 2011). Both of these measures involve retrieval of information from the LTM. Collins and Loftus' semantic association network model describes retrieval as involving spreading activation (Collins & Loftus, 1975). This means that when one word is activated in a person's memory, their thoughts naturally go to related words. Activation starts at the initial word, then spreads to other words (nodes) along the network's pathways, meaning that closer, more semantically similar words are more likely to be activated than more distant words (Collins & Loftus, 1975).

It is interesting to question why some ideas can be easily retrieved from LTM, while others cannot, and to examine factors affecting this retrieval. For example, information which goes against an established schema may be more difficult to remember than information consistent with the schema (Koriat, Goldsmith, & Panksy, 2000). Another important factor is incubation, a problem solving phase which provides time for conscious or subconscious recombination of information leading to progress toward retrieval of a solution (Seifert et al., 1995). Seifert and colleagues (1995) also emphasized the importance of impasses in problem solving and answer retrieval. Impasses occur when a person cannot find a solution, and therefore stops working before arriving at an answer. Seifert et al. (1995) suggested that problems resulting in impasses would leave failure indices in LTM, special memory traces which might guide later incubation or retrieval.

Craik and Lockhart (1972) proposed a different idea as to why some items are remembered better than others. Their idea was based on a memory framework referred to as "depth of processing". This conceptual framework goes beyond the multistore model of sensory memory, short term memory, and long term memory as distinct entities which information must pass through sequentially. In the depth of processing continuum, retention is a function of depth, and greater "depth" involves greater semantic or cognitive analysis. Stimuli which are very meaningful, familiar, and compatible with existing cognitive structures will be processed to a deeper level and will be better retained than less meaningful concepts. Craik and Lockhart (1972) explained that recognized stimuli may undergo "elaboration encoding" in which a recognized word triggers associated concepts, leading to further processing and enrichment. This analysis creates a memory trace, which becomes stronger and more persistent as analysis deepens. These ideas may explain why certain stimuli are better encoded and retrieved during problem solving and memory tasks.

Problem Solving and Memory

Both depth of processing and verbal LTM are involved in the process of problem solving, making explorations of verbal problem solving and memory essential endeavors to further our understanding. A useful task for investigating problem solving is the Remote Associates Test (RAT) developed by Mednick (1962). Traditionally used to study creativity and insight in problem solving, the RAT has only recently appeared in studies involving memory (e.g. Storm, 2011; Topolinski & Strack, 2008). RAT problems each consist of a triad of cue words that are related to a common associate solution word (CA), either through semantic association, synonymy, or formation of a compound word. These problems are referred to as "remote associates" because the three cue words do not need to be directly related to each other, but rather are linked by their association with the common fourth word. In fact, the strongest associates to each cue word—the words that first come to mind—are often completely unrelated to the other cue words, adding to the difficulty of RAT problem solving (Storm, 2011).

RAT problems can be solved in a short period of time, are simpler than many other classic tests of insight, have concise single-word answers, and are physically compact for easy presentation (Bowden & Jung-Beeman, 2003b). They provide a good measure of insight problem solving ability, and are also easily adapted to recall and recognition memory tests.

Topolinski and Strack (2008) used the RAT to examine the influence of mindset and intention on intuitive judgment. Although their experiment's main focus was intuition, it also produced interesting results involving both problem solving and memory. They found that when participants were uninformed of the underlying semantic structure of the triads and were instructed to simply read the words, the CA was automatically activated in a later lexical decision task. However, when participants were instructed to memorize the triads, the CA was actually inhibited, meaning that this memorization impeded activation of the CA on the lexical task. While the majority of the effects mentioned thus far demonstrate memory's influence on problem solving, Topolinski and Strack's findings also showed an influence of problem solving on memory. In their experimental setup, a portion of triads shown to participants were "coherent", consisting of words that could be remotely associated, while others were "incoherent", meaning that no common associate actually existed. During a subsequent recall task, words from coherent triads were better remembered than words from incoherent (unsolvable) triads. The authors suggested that this effect might be caused by an underlying activation of the CA in coherent trials, which could facilitate retrieval of its associates.

Another recent study that has revealed information concerning problem solving's influence on memory is Dougal and Schooler's (2007) exploration of the discovery misattribution hypothesis. This hypothesis suggests that the experience of successfully solving an insight problem can be confused with recognition memory (Dougal and Schooler, 2007). For the first part of Dougal and Schooler's study, subjects were shown 60 words and instructed to memorize them. Following the memorization, subjects were given anagrams to solve, and also asked to identify the word as old (from the memorized list) or new. The results showed that successfully solved anagrams were more likely to be judged as "old" than unsolved anagrams, whether or not they had actually been on the memorized list. An additional finding showed that solving anagrams instead of simply viewing words when judging recognition increased the proportion of words judged as "old". While Dougal and Schooler showed that problem solving can create false memories, Howe et al. (2010) found that false memories can prime problem solving. Participants in this study were verbally presented with Deese/Roediger-McDermott lists, where words in each list were all associates of an unpresented critical lure. Half of these critical lures were also answers to compound RAT problems. After the DRM, subjects underwent a test of free recall, and then completed 8 RAT problems (4 of which had solutions in common with the critical lures). It was discovered that when the critical lure had been falsely recalled, RAT problems were solved faster and more often. In cases where the lure had not been falsely recalled, RAT solution rates and times were no different than the cases that had not been primed. These results imply that false memories are capable of facilitating and priming problem solving.

Storm, Angello, and Bjork (2011) exposed participants to 60 word pairs, each consisting of one RAT cue word and one semantically associated word (e.g. playing-fun, credit-union). This cue-response training was followed by completion of the RAT problem solving task, and finally, a surprise recall test in which they were shown a cue word and instructed to recall the associated response. Half of the words, "baseline pairs", had not been seen during the RAT, while the remaining half, "fixation pairs," had. The results showed that RAT performance led to the forgetting of the original associated pairs. The problem-solving-induced forgetting occurred even when the participant had failed to solve the related problem, and when impossible RAT problems were administered (Storm et al., 2011).

The Zeigarnik Effect

Past research on the memorability of solved versus unsolved problems has yielded mixed results due to variations in methodology and stimuli (Patalano & Seifert, 1994). A classic experiment by Zeigarnik (as cited in Patalano & Siefert, 1994) demonstrated that problems were more memorable when participants were interrupted by the experimenter and thus unable to solve them—a concept which has since become known as the "Zeigarnik effect." The Zeigarnik effect implies that interruptions during problem completion might lead to heightened memory access for these problems. This improved retrieval ability would be beneficial, considering the usefulness of being able to quickly return to and reattempt unsolved problems (Patalano & Seifert, 1994).

Attempts to replicate the Zeigarnik effect in various experiments have had limited success. These mixed findings may be an outcome of differences in experimental setup, including problem solving time allotment, problem type, or processes used (Patalano & Seifert, 1994). However, Yaniv and Meyer (1987) found a similar effect in their investigation of the "tip of the tongue" experience, which occurs when a certain word cannot be recalled, despite a sensation of almost remembering. Subjects were shown definitions of familiar yet infrequently used words, and asked to provide the word. In a later test, faster lexical decisions were made for the unsuccessfully retrieved "tip-of-the tongue" words, suggesting elevated activation or availability of the unsolved problems. Patalano and Seifert (1994) examined instances in which subjects themselves reached an impasse in problem solving, instead of being interrupted. They found that when most problems in a set were solved, unsolved problems were better recalled. As they manipulated problem difficulty and set-size, they found that unsolved-problem memorability was significantly contingent on the ratio of solved to unsolved problems, while solved-problem memorability was not.

The Generation Effect

In contrast to the Zeigarnik effect, other studies have suggested an effect in which solved problems become fixed in the mind and are therefore more easily recalled (Bertsch, Pesta, Wiscott, & McDaniel, 2007; Patalano & Seifert 1994). This "generation effect" refers to the finding in which subjects who generate information or answers are better able to remember it than subjects who simply read the information (Bertsch, et al., 2007). Pachauri (1935) performed manipulations of Zeigarnik's original experiment and discovered that in certain circumstances, subjects actually recalled completed tasks better than interrupted ones. He suggested that completed problems become a whole entity, fixed in the mind, allowing for easier recall (Pachauri, 1935). A number of other studies have demonstrated that well-understood, unambiguous situations, such as solved problems, are often easier to recall than incompletely understood problems (Bransford & Johnson, 1972; Dooling & Lachman, 1971; Patalano & Seifert, 1994). Topolinski and Strack's finding (2008) that words from coherent triads were better recalled than words from incoherent (unsolvable) triads could also be used in support of this phenomenon. Additionally, Bartlett (1932) found that subjects were more likely to remember story details that conformed to a memory schema. These findings suggest that a solved problem organized around a single, complete problem solving schema would be more memorable than an unsolved problem, not adhering to one set schema (Patalano & Seifert, 1994).

Aims

The present study extends previous work on RAT problem solving and memory by creating a set of solvability norms for previously un-normed problems, and examining the impact of problem solving on memory by testing if items from solved or unsolved problems are more easily remembered. Like the Topolinski and Strack (2008) and Storm et al. (2011) studies, the present study uses RAT problems and subsequent tests of memory. In 2003, Bowden and Jung-Beeman developed and normed a set of 144 compound RAT problems. However, the present study examines a wider variety of problem types, and the cue triads in the present study were associated with a common fourth word either by formation of compound words, semantic association, or a mixture of both. Prior to using these problems in investigations of memorability, it is important to understand the properties of the problems, the ease with which they can be solved, and individual difference variables that may affect how capable people are of solving them.

The first aim of this study was therefore to collect normative data on a 70-problem set. We anticipated that there would be variability in how easily problems were solved, indexed both by the time taken to solve a problem, and the number of people who were able to provide the correct solution. We also predicted that there would be differences in problem solvability due to differences in cue word and solution word characteristics, including association type, concreteness, familiarity, imageability, meaningfulness, and part of speech. Normative data on these problems will provide solvability trends and data useful for selecting problems based on difficulty or response time for future studies.

The secondary aim of the present study was to examine subsequent memory for solved problems. We hypothesize that there will be differences in memorability of RAT problems based on their solvability. We expect that RAT problems which are successfully solved will be better remembered on subsequent free recall and recognition tests than those left unsolved. This could imply that solved problems involve more elaborate processing and spreading activation due to comprehension and answer generation, allowing for easier retrieval. Plus, solving provides an additional association cue in memory that may enhance subsequent memorability. Alternatively, we might find that a Zeigarnik-like effect exists, where unsolved problems are better remembered than solved problems.

Method

Participants

Seventy-six young adults between the ages of 18 and 21 participated in the study. Sixteen participants were excluded from analysis due to possible interfering health conditions or failure to meet study criteria. Specifically, subjects were excluded if they had psychological or psychiatric conditions that might affect attention or memory, or if they were taking medications known to affect cognition. All participants were right-handed native English speakers. After exclusions, sixty subjects were included in the analysis (26 male, *mean age* =18.7, *SD* =.89).

All participants were part of the University of Michigan's introductory psychology subject pool. Subjects gave informed consent to participate in the study, and received course credit for their participation. This study was approved by the University of Michigan Institutional Review Board.

Materials

Remote Associates Test: The Remote Associates Test (RAT) was programmed using ePrime 2.0 (Psychology Software Tools, Pittsburgh, PA). Seventy word problems were taken from Craig (personal communication), McFarlin and Blascovich (1984), Smith and Blankenship

(1991), and Thompson (1993). Each problem consisted of three cue words, which were related to one another through a fourth, solution word. This solution word was related to each of the cue words either through semantic association (ex: *fire* and *burn)*, formation of a compound word or phrase (ex: *fire* and *hydrant)*, or contained cues that were related to the solution through a mixture of both compound words and semantic association. Problems of each of these three types were selected from the papers mentioned, and care was taken to include each cue and solution word only once in the problem set. The resulting RAT problem set consisted of 17 association problems, 14 compound problems, and 39 mixed problems. A list of these problems and their solutions can be found in Table 1.

Recognition task stimuli: Forty-eight words were randomly selected from the 210 cue words that had been presented during the RAT (old words) and 48 words were randomly selected from a list of 92 words that had not been seen on the RAT (new words). New words were taken from other RAT problems that were not included in this study (Craig, personal communication; McFarlin & Blascovich, 1984; Smith & Blankenship, 1991; Thompson, 1993) so as to keep characteristics of old and new words relatively similar. All subjects were shown the same set of words, but in randomized order.

Procedure

RAT: Subjects were given instructions via computer before completing the actual task. This consisted of a description of problem format, information on ways in which the fourth word could be associated with the cues, and an example problem. All participants were presented with the same set of 70 RAT problems, and problems were randomized to prevent any confounding primacy or recency effects during later memory tests. Problems were presented on the screen one at a time. The three cue words for each problem were presented in a column, with the order of words in each problem also randomized. Additionally, there were no repeated cue or solution words in the 70-problem set. Each problem was shown for seven seconds, followed by presentation of a text box in which the participant could enter their solution. There was no time limit for entering a solution once prompted with the text box, however once the text box appeared, the subject could no longer view the cue words for the problem. If the participant thought of the solution before the seven-second timeframe ended, they were instructed to press the space bar as soon as they solved the problem and enter their solution when the text box appeared. Response times were recorded for these cases. Furthermore, if the participant failed to come up with a solution word, they were allowed to leave the solution text box empty and skip to the next problem.

Memory Tests: Directly following the RAT, memory tests were given to determine the relationship between problem solving and memorability. Participants were not told about the memory tests before the RAT, and were not instructed to attempt memorization of words during problem solving.

Participants first completed the free recall test, in which they were simply instructed to report as many words from the problem solving task as possible from memory. Additionally, they were told to enter only as many words as they could remember, and not to guess. Participants entered words into a computer program one at a time, with no importance placed on word order and no time limit on the task.

Following the free recall test, the recognition test was administered. Old and new words were randomized and shown one at a time on the computer screen. Each word was displayed for 1200 milliseconds, and participants were instructed to decide whether or not the word was one they had seen on the RAT. Participants used the two mouse buttons to signify if the word was new or old.

Neuropsychological Tests: After completing the RAT problems and memory tests, participants completed a battery of neuropsychological tests to assess individual differences in memory span, problem-solving ability, and vocabulary, and their relationship to problem solving and memory performance. First, participants completed Raven's Progressive Matrices (Raven, 1990) as a measure of fluid intelligence and non-verbal problem-solving ability. Next, the WAIS-III Digit Span test (Wechsler, 1997) was administered to assess working memory capacity. Finally, the Extended Range Vocabulary Test (Educational Testing Services, 1976) was completed as a measure of vocabulary knowledge.

Subsequently, subjects completed questionnaires asking about strategies used, demographics and health history, and other factors that could affect testing performance. The entire experimental session lasted approximately one hour.

Results

Norming Data

We calculated the percentage of participants who correctly solved each RAT problem, as well as the mean response time for each problem, including only cases in which the problem was correctly solved. This normative data is provided in Table 1. By averaging solution rates within each problem type, we found that association problems were correctly solved by 50.6% of participants, compound problems by 22.0% of participants, and mixed problems by 35.9% of participants. A one-way ANOVA was used to test for differences between the mean percentages of participants solving problems of each of the three types. Solving percentages differed significantly across the three problem types, $F(2, 67) = 3.304$, $p < .05$. Independent samples t-tests revealed a significant difference between solution rates for association and compound problems $t(29) = 2.699$, $p = .011$. A marginally significant difference between solution rates for compound and mixed problems was also found $t(41.09) = -1.974$, $p = .055$. Mixed and association solution rates were not significantly different $t(54) = 1.515$, $p = .136$.

Average response time for correctly solved problems was 4.2 seconds for association, 4.8 for compound, and 4.4 for mixed. One-way ANOVA yielded no significant differences in average accurate response time for the three problem types, $F(2, 58) = 1.269$, $p = .29$. Graphs comparing the problem types in terms of percentages of participants solving the problems and average response times are shown in Figure 1.

The number of subjects who correctly solved a problem was significantly negatively correlated with mean accurate response time ($r = -.479$, $p < .001$), meaning that the faster the average response time for a problem was, the more people solved it. Looking at the relationship between these two variables within the different problem types, we found that accurate response time was significantly correlated with the number of participants who solved the problem for association ($r = -.749$, $p = .001$) and mixed types ($r = -.373$, $p = .027$), but not for compound types ($r = .149$, $p = .661$).

Correlations between the number of times each problem was correctly solved, mean accurate response time for each problem, and a number of psycholinguistic and lexical variables were calculated. Our aim was to examine various word properties and determine which significantly affect problem solvability and response time. We wanted to ascertain what sort of cues led to faster, more accurate answers, and which solution words were more easily discovered. Psycholinguistic and lexical characteristics for each of the problem cue words and solutions were generated through online databases. Concreteness, familiarity, imageability, and meaningfulness norms were taken from the MRC Psycholinguistic Database (Version 2.00). Data on word length (number of letters), number of phonemes, number of morphemes, number of syllables, part of speech, Kucera and Francis (KF) frequency norms, Hyperspace Analogue to Language (HAL) frequency norms, standardized mean lexical decision latency, proportion of accurate lexical decision responses, mean naming latency, and standardized mean naming latency for each word were taken from the English Lexicon Project (Balota et al., 2007).

For one set of correlations, lexical data were averaged across the three cue words in each problem to create measures of average problem characteristics. Here, mean accurate response time was negatively correlated with the average number of phonemes (r = -.29, p = .024) and average number of morphemes in a problem (r = -.253, p = .049). The shorter the words in the problem, the longer it took for participants to solve the problem. When the data were broken down based on problem type, we found that this inverse relationship between response time and cue word length was only significant for mixed problems. For mixed problems, mean accurate response time was negatively correlated with word length (r = -.431, p = .01), number of phonemes (r = -.483, p = .003), and number of syllables (r = -.356, p = .036). Cue words from compound and association problems showed no significant correlations in this domain. The fact that more mixed problems were included in testing than compound and association types may have led to this significance.

We also computed these correlations using the properties of the solution words. Here, the number of subjects correctly solving a problem was negatively correlated with standardized mean lexical decision latency (r = -.256, p =.033) and positively correlated with word imageability (r = .396, p =.001). Again, correlations were also calculated based on problem type grouping. For association problems, number of subjects who correctly solved a problem was positively correlated with the solution word's concreteness (*r* = .632, *p* = .009) and imageability (*r* = .846, *p* < .001). Mean accurate response time for association problems was correlated negatively with concreteness (*r* = -.782, *p* = .001) and imageability (*r* = -.744, *p* = .002). Interestingly, compound solution words were correlated with completely different characteristics. For compound problems, the number of subjects who correctly solved a problem was correlated positively with solution word frequency (*r* = .587, *p* = .027) and familiarity (*r* = .578, *p* = .038), and negatively correlated with standardized mean lexical decision latency (*r* = -.754, *p* = .002). Additionally, accurate response time for compound problems was negatively correlated with accurate lexical decision response (*r* = -.755, *p* = .007). Solvability statistics for mixed problems were not significantly correlated with any solution word properties.

Solvability and Memory

To examine the relation between problem solvability and memorability, we performed paired t-tests examining memory for correctly solved versus unsolved RAT problems. First, we compared the number of recalled words from correctly solved problems to the number correctly recalled from unsolved problems. A paired samples t-test was run using raw numbers of recall from solved and unsolved problems. The analysis revealed that significantly more words had been recalled from correctly solved problems (*M*=9.7, *SD*=6.17) than from unsolved problems (*M*=7.13, *SD*=6.62); *t*(59) = 2.616, *p* = .011.

However, since the number of RAT problems each participant correctly solved or did not solve was different, this meant there were different numbers of solved or unsolved problems the participant could possibly recall. To account for this difference in set size, we divided the number of words each participant had recalled from correctly solved RAT problems by the total number of words from RAT problems they had correctly solved. This created a percentage which will from here on be referred to as a “scaled solved recall score”. Likewise, we divided the number of words each participant had recalled from unsolved RAT problems by the total number of words from their unsolved RAT problems. This is the “scaled unsolved recall score”. A paired samples t-test revealed a significant difference between the scaled solved recall score (*M*=12.8%, *SD*=7.3%) and scaled unsolved recall score (*M*=5.4%, *SD*=4.6%); $t(59) = 8.486$, $p < .001$. (See Figure 2a for a graphical comparison.) This shows that, accounting for set size, words from correctly solved RAT problems were still recalled significantly more often than words from unsolved RAT problems.

The calculations were more challenging for recognition. While 210 cue words were shown during the RAT, only 48 of these “old words” were shown along with the 48 new words on the recognition task. A paired samples t-test revealed a significant difference between the mean number of recognized words from correctly solved problems (*M*=12.53, *SD*=3.71) and the mean number of recognized words from unsolved words (*M*=20.52, *SD*=5.76); $t(59) = -8.393$, $p < .001$. However, this difference is most likely due to the fact that participants failed to solve significantly more RAT problems than they successfully solved, meaning that there were more words from unsolved problems (*M*=133.2, *SD*=19.6) than words from correctly solved problems (*M*=76.8, *SD*=19.6) that could possibly be recognized; $t(59) = -11.12$, $p < .001$. We calculated scaled solved recognition scores by dividing the number of recognized words from accurately solved problems by the total number of solved RAT words. Scaled unsolved recognition scores were calculated by dividing the number of recognized words from unsolved problems by the total number of unsolved RAT words. A paired samples t-test using these scaled scores revealed no significant differences between recognized correctly solved words (*M*=16.5%, *SD*=4%) and recognized unsolved words (*M*=15.5%, *SD*=4%); $t(59) = 1.406$, $p = .165$. (See Figure 2b for graphical comparison.) While not significant, the mean in this case was greater for correctly solved words.

Neuropsychological Tests

Neuropsychological correlation data can be found in Table 2. RAT scores were significantly positively correlated with performance on Raven's Progressive Matrices, the Extended Range Vocabulary Test, and Backward Digit Span. This means that better RAT performance is associated with greater fluid intelligence, higher working memory capacity, and larger vocabulary knowledge. In terms of memory for solved versus unsolved problems, performance on the Forward Digit Span test was negatively correlated with recall and recognition percentages for solved, but not unsolved words. This actually suggests that subjects with lower short term memory capacities better recognize items from solved problems, although the backward digit span data did not support this idea. ERVT performance was also negatively correlated with scaled solved recognition scores.

Discussion

Normative Study

One goal of this study was to collect normative data on RAT problems of different types. We hypothesized that there would be variability in problem solvability, measured by accurate problem response times and number of participants able to correctly solve them. While problems varied in terms of solvability rate and accurate response time, on average, association problems had significantly higher correct solution rates than mixed problems, and compound problems had the lowest solution rates. Furthermore, association problems were solved fastest, followed by mixed and compound types, although this effect was not statistically significant. These patterns show that for this problem set, association problems were easiest to solve, and compound ones were the most difficult, with mixed problem types falling in between. These clear variations in accurate response time and number of participants correctly solving problems of different types uphold our hypothesis that solvability varies across problems.

We also predicted differences in RAT problem solvability based on differences in problem word characteristics. Analyses supported this prediction, revealing several correlations between lexical/psycholinguistic variables and the number of times a problem was solved. High concreteness and imageability of the solution word was important for solving association problems quickly and accurately, while high frequency and familiarity proved important for solving compound problems, and solvability of mixed problems did not appear to be contingent on solution word characteristics. When word variable data was averaged across the three problem cue words, mixed type problems were correctly solved faster when problems contained longer words in terms of number of letters, phonemes, and syllables. For association and compound problem types, although certain solution word characteristics had a significant impact on the number of participants correctly solving problems, averaged cue word characteristics did not appear to play as significant a role.

These results showed interesting differences in factors affecting solvability of association problems versus compound problems, suggesting differences in problem solving approaches utilized in solving these different types of RAT problems. Imageability refers to the capacity of a word to evoke imagery or a mental picture, and concreteness is the extent to which a word refers to a physical object, material, or person (Paivio, Yuille, & Madigan, 1968). Paivio (1971) proposed that these factors may affect perceptual threshold, percent correct, or reaction time measures of word recognition and knowledge. The present study showed that physical concreteness and ability to picture a word were especially important in solving association type problems. This is consistent with the idea that imageability and concreteness both index referential meaning, the association between word and image. On the other hand, this study showed that familiarity, or the rated frequency of word usage and exposure, is associated with accurate solution of compound word RAT problems. Paivio (1971) explained familiarity as an index of representational meaning, or the availability of a verbal code for psychological processing. It appears that the ability to mentally picture a solution object is more important for solving association problems, while compound problem solving ability is based more on the actual word and availability of its verbal code. Solving strategies for association problems most likely involve visualizing solution possibilities related to the cue words, with less importance placed on the actual verbiage. Strategies for compound problems would involve more emphasis on the physical solution word, its verbal code, and the participant's familiarity with the word, rather than the mental imagery associated with it.

There were few limitations to the norming component of this experiment. However, a larger number of participants may have been beneficial to give our results more power. Also, it may have been useful to include more pure association and compound problems.

As mentioned earlier, RAT problems are commonly used to study creativity and problem solving. They have also been used in explorations of success and failure, psychopathologies and emotion (Bowden & Jung-Beeman, 2003b). RAT problem usage is convenient in that they can be solved quickly, are physically compact, and easy to score. By providing a list of problems and normative data, this study aims to encourage future usage of RAT problems in the aforementioned research areas, as well as novel areas, such as memory. The solvability and response time data will make interpreting results easier in the future, and the new information on solvability differences between association, compound, and mixed problem types may prove useful for comparisons and investigations of different types of problem solving.

Solvability and Memorability

Another objective of this study was to examine memory of solved versus unsolved problems. We hypothesized that successfully solved RAT problems would be better remembered on subsequent tests of free recall and recognition than problems which participants were not able to solve. The data from the recall portion of our study supported this hypothesis. Correcting for set size of correctly solved and unsolved RAT problems, significantly more correctly solved than unsolved problems were recalled on average. The design of the recognition task made interpretation of results more complicated. There was no significant difference between solved and unsolved problems in terms of scaled scores, although numerically more solved problems were recognized. Comparing raw number of recognized words from solved and unsolved problems actually revealed a significantly higher number of recognized unsolved words. However, this calculation is biased by the fact that participants left significantly more problems unsolved than they were able to correctly solve, meaning that there were many more unsolved words that could later be recognized. Given the difficulty in interpreting recognition scores, we will focus our interpretation on the relationship between solvability and recall, as this was our most reliable measure.

Previous investigations into memorability of solved and unsolved problems have yielded mixed results due to differences in experimental setup, conditions, and method of problem solving testing. However, many past studies have suggested or reported findings consistent with the results of our recall test. A meta-analysis conducted in 2007 indicated a robust and consistent generation effect across the literature (Bertsch et al., 2007). The project analyzed the results of over 86 studies including more than 17,000 subjects, and using methodologies of various types and difficulties. Results revealed a .40 standard deviation advantage in subsequent memory performance for information that had been generated or solved, rather than simply read. Although not specifically examining solved versus unsolved problem memory, the finding of the generation effect is relevant to the study at hand since solving a problem involves actively generating information, while failing to solve it typically involves less. However, this generation effect applies specifically to recall of solved solution words. High recall of solved cue words is more directly explained by the depth of processing achieved during solution generation, a concept which will be further addressed later.

Past literature has also demonstrated a positive relation between comprehension and later tests of memory (Bransford & Johnson, 1972; Dooling & Lachman, 1971). Dooling et al. (1971) found that subjects understanding the theme of a phrase of passage performed better on word recognition tests, especially when the word was semantically associated with the theme. This suggested the importance of understanding or discovering an overarching theme in a passage (or in the case of our RAT problems, between words) for subsequent recognition memory. Bartlett (1932) also found that findings conforming to a memory schema or organized around a single complete idea were more likely to be remembered. This is consistent with the present study in that participants who solved problems were likely able to mentally organize and associate the cue words with a single theme and solution word, and were therefore better able to remember the words than participants who were unsuccessful at producing the correct answer. Pachauri (1935) found completed/solved problems to be more memorable than interrupted/unsolved problems, and posited that successfully completed problems become a whole entity, “fixed in the mind”, which allows for easier memory.

More directly related is Topolinski and Strack's finding that words from coherent word triads were recalled significantly more than words from incoherent triads (Topolinski & Strack, 2008). In their study, "incoherent" triads were sets of three unrelated words. It was impossible for subjects to find a common associate or semantic link between the three. These incoherent triads were unsolvable, and thus similar to the unsolved words in our study. Our findings were consistent since both studies revealed poorer recall performance for unsolved/incoherent problems. A likely explanation for why words from coherent triads/correctly solved problems were better recalled is that there is more spreading activation along semantic network pathways when participants are able to successfully link the cue and answer words together. This is mainly true for association type problems, which may explain their higher solution rate as well. This process can be helpful for memory during both encoding and retrieval .

Craik and Lockhart (1972) related the process of spreading activation to a concept dubbed "elaboration coding". They explained that depth of processing is key for memory encoding and retrieval. Words that are more deeply processed via elaboration, semantic association, and cognitive analysis will have a stronger memory trace, and will be more easily accessed during subsequent tests of memory (Craik & Lockhart, 1972). The depth of processing model could explain why items from solved words were more likely to be recalled in our study. This would imply that solved problems are more deeply processed due to idea elaboration or associations formed during problem solving. The process of solving creates a stronger trace for words from solved problems than words from unsolved problems, allowing for easier retrieval during the recall task.

While our recall results support the idea that correctly solved problems are more deeply processed, and therefore more easily recalled than unsolved problems, our recognition results were complicated and limited due to experimental design. Subjects were only exposed to a random sampling of 48 old RAT words during the recognition task, in addition to the 48 new words. Comparing the raw, unscaled numbers of solved and unsolved recognition words would not be accurate. In order to account for solved and unsolved RAT sample size during analyses, we divided the number of recognized words from solved and unsolved problems by the total number of words from solved and unsolved RAT problems, respectively. However, since all of the RAT words were not shown on the recognition task, participants may have been exposed to a biased number of possible solved or unsolved words during recognition, so this measure is not 100% accurate. In order to test all of the RAT cue words on recognition, 210 old and 210 new words would have been required in the recognition task—an overwhelming number for participants. However, as the primary purpose of this study was to obtain normative problem data, cutting down on problem number would not have been in the study's best interest either. Future studies may find it beneficial to adjust the recognition task design to see if results more in line with those of the recall task are attained when more exact methods are used.

It may also be interesting to examine the relation between problem solvability and memorability in a more diverse group of participants, as this study was limited to young university students with high education levels. A possible future direction could be to examine this relationship in participants of different ages, or to see if the same effect exists in clinical populations such as those dealing with cognitive impairment, schizotipia, or memory problems. Neuroimaging could be used to determine the brain regions activated during problem solving/encoding, and also retrieval of solved and unsolved items. Insight problem solving is typically associated with right hemisphere activation (Bowden & Jung-Beeman, 2003a), however it could be interesting to investigate bihemisphere engagement due to aging, as well as any differences in memory for solved versus unsolved problems in older adults.

Furthermore, analysis of the neuropsychological tests revealed correlations between RAT problem solving performance and intelligence, vocabulary, and working memory capacity. This demonstrates that verbal problem solving ability is generally related to other measures of cognitive ability. In future studies, it would be interesting to further explore other factors such as creativity, reasoning, and attention to determine their relation to one's ability to solve different types of RAT problems.

Overall, more research is needed to confirm and expand our findings. Future investigations may have implications for current theories of memory and problem solving. Problem solving in the real world is a relatively poorly understood process at present, especially in terms of the relationship between problem solvability and memory. Studying these concepts in the lab may lead to improvements in problem solving strategies which could be implemented in real world settings such as schools and workplaces. Understanding the impact problem solving has on later memory may also lead to useful techniques for maintaining or improving memory.

References

Baddely, A.D., Elridge, M., & Lewis, V. (1981). The role of subvocalisation in reading. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 33A*, 439-454.

Baddeley, A.D., & Hitch, G.J. (1974). Working memory. In G.H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 8, pp. 47-89). New York: Academic Press.

Balota, D.A., Yap, M.J., Cortese, M.J., Hutchinson, K.A., Kessler, B., Loftis, B., Neely, J.H., Nelson, D.L., Simpson, G.B., & Treiman, R. (2007). The English lexicon project. *Behavior Research Methods, 39*(3), 445-459.

Bartlett, F.C. (1932). *Remembering: A study in experimental and social psychology.* Cambridge: Cambridge University Press.

Bertsch, S., Pesta, B.J., Wiscott, R., & McDaniel, M.A. (2007). The generation effect: A meta-analytic review. *Memory & Cognition, 35*(2), 201-210.

Bousfield, W.A. (1953). The occurrence of clustering in the recall of randomly arranged associates. *Journal of General Psychology, 49*, 229-240.

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

Bowden, E.M., & Jung-Beeman, M. (2003b). Normative data for 144 compound remote associate problems. *Behavior Research Methods, Instruments, & Computers, 35*(4), 634-639.

Bransford, J.D., & Johnson, M.K. (1972). Contextual prerequisites for understanding: Some investigators of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior, 11*(6), 717-726.

Collins, A.M., & Loftus, E.F. (1975). A spreading activation theory of semantic processing. *Psychological Review, 82,* 407-428.

Craik, F.I.M., & Lockhart, R.S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*, 671-684.

Dominowski, R.L., & Dallob, P. (1995). Insight and Problem Solving. In R. Sternberg & J. Davidson (Eds.), *The nature of insight*. (pp. 33-62). Cambridge, MA: MIT Press.

Dooling, D.J., & Lachman, R. (1971). Effects of comprehension on retention of prose. *Journal of Experimental Psychology, 88*(2), 216-222.

Dougal, S., & Schooler, J.W. (2007). Discovery misattribution: When solving is confused with remembering. *Journal of Experimental Psychology: General, 136,* 577-592.

Educational Testing Services. (1976). Kit of factor-referenced tests. Princeton, NJ: Author.

Glass, A.L., Eddy, J.K., & Schwanenflugel, P.J. (1980). The verification of high and low imagery sentences. *Journal of Experimental Psychology: Human Learning & Memory, 6,* 692-704.

Goldstein F. C., & Levin H. S. (1987). Disorders of reasoning and problem-solving ability. In M. Meier, A. Benton, & L. Diller (Eds.), *Neuropsychological rehabilitation*. London: Taylor & Francis Group.

Greeno, J.G. (1978). Natures of problem-solving abilities. In W. Estes (Ed.), *Handbook of learning & cognitive processes: V. human information* (pp. 239-270). Oxford, England: Lawrence Erlbaum.

Hambrick, D.Z., & Engle, R.W. (2003). The role of working memory in problem solving. In J. Davidson & R. Sternberg (Eds.), *The psychology of problem solving* (pp. 176-206). Cambridge, UK: Cambridge University Press.

Hasher, L., & Zacks, R.T. (1988). Working memory, comprehension, and aging: A review and a new view. In G.H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 22, pp. 193-225). San Diego, CA: Academic Press.

Horn, J.L., & Masunaga, H. (2000). New directions for research into aging and intelligence: The development of expertise. In T.J. Perfect & E.A. Maylor (Eds.), *Models of cognitive aging* (pp. 125-159).

Howe, M.L., Garner, S.R., Dewhurst, S.A., Ball, L.J. (2010). Can false memories prime problem solutions? *Cognition, 117,* 176-181.

Koriat, A., Goldsmith, M., & Pansky, A. (2000). Toward a psychology of memory accuracy. *Annual Review of Psychology, 51*, 481-537.

Kostovsky, K. (2003). Problem solving—large/small, hard/easy, conscious/nonconscious, problem-space/problem-solver. In J. Davidson & R. Sternberg (Eds.), *The psychology of problem solving* (pp. 373-383). Cambridge, UK: Cambridge University Press.

Lovett, M.C. (2002). Problem solving. In D. Medin & H. Pashler (Eds.), *Stevens' handbook of experimental psychology: Memory and cognitive processes* (pp. 317-362). New York: John Wiley & Sons, Inc.

McFarlin, D.B., & Blascovich, J. (1984). On the remote associates test (RAT) as an alternative to illusory performance feedback: A methodological note. *Basic and Applied Social Psychology, 5*(3), 223-229.

Mednick, S.A. (1962). The associative basis of the creative process. *Psychological Review, 69,* 220-232.

Metcalfe, J. (1986). Feeling of knowing in memory and problem solving. *Journal of*

Experimental Psychology: Learning, Memory, and Cognition, 12, 288-294.

MRC Psycholinguistic Database: Machine Usable Dictionary (Version 2.00) [Online database]. Retrieved from http://www.psy.uwa.edu.au/MRCDataBase/uwa_mrc.htm

Newell, A., Shaw, J.C., & Simon, H.A. (1958). Elements of a theory of human problem solving. *Psychological Review, 65,* 151-166.

Pachauri, A.R. (1935). A study of gestalt problems in completed and interrupted tasks. *British Journal of Psychology, 25*, 365-381.

Paivio, A. (1971). *Imagery and verbal processes.* New York: Holt, Rinehart & Winston.

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology Monograph, 76*(1.2).

Patalano, A.L., & Seifert, C.M. (1994). Memory for impasses during problem solving. *Memory & Cognition, 22*(2), 234-242.

Raven, J., Raven, J. C., & Court, J. H. (1998). Manual for Raven's Progressive Matrices and Vocabulary Scales. Section 4: The Advanced Progressive Matrices. San Antonio, TX: Harcourt Assessment.

Schulman, A.I. (1975). Encoding processes and the memorability of events. In A. Kennedy & A. Wilkes (Eds.), *Studies in long term memory* (pp. 43-56). New York: John Wiley & Sons.

Schwartz, B.L. (2011). *Memory: Foundations and applications.* Thousand Oaks, CA: SAGE Publications.

Seifert, C.M., Meyer, N.D., Patalano, A.L., & Yaniv, I. (1995). Demystification of Cognitive Insight. In R. Sternberg & J. Davidson (Eds.), *The nature of insight*. (pp. 65-124). Cambridge, MA: MIT Press.

Smith, S.M., & Blankenship, S.E. (1991). Incubation and the persistence of fixation in problem solving. *The American Journal of Psychology, 104*(1), 61-87.

Storm, B.C., Angello, G., & Bjork, E.L. (2011). Thinking can cause forgetting: Memory dynamics in creative problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37,* 1287-1293.

Thompson, T. (1992). Remote associate problem sets in performance feedback paradigms. *Personality and Individual Differences, 14*(1), 11-14.

Topolinski, S., & Strack, F. (2008). Where there's a will—there's no intuition. The unintentional basis of semantic coherence judgments. *Journal of Memory and Language, 58*, 1032-1048.

Washington University. (2009). English Lexicon Project [Online database]. Retrieved from http://elexicon.wustl.edu/

Weisberg, R.W., & Alba, J.W. (1981). An examination of the alleged role of "fixation" in the solution of several "insight" problems. *Journal of Experimental Psychology: General, 110,* 169-192.

Wieth, M., & Zacks, R. (2011). Time of day effects on problem solving: When the non-optimal is optimal. *Thinking & Reasoning, 17*(4), 387-401.

Wechsler, D. (1997). WAIS-III administration and scoring manual. The Psychological Corporation, San Antonio, TX.

Weiten, W. (2007). *Psychology: Themes and Variations, Seventh Edition*. Belmont, CA: Thomson Wadsworth.

Yaniv, I., & Meyer, D. (1987). Activation and metacognition of inaccessible stored information: Potential bases for incubation effects in problem solving. *Journal of Experimental Psychology, 13*, 187-295.

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Table 1

Remote Associate Problems and Normative Data

Problem Type	Cue Words	Solutions	% of Participants Accurately Solving Problem	Mean Accurate Response Time (sec)	*SD*
Association	slither-venomous-fangs	Snake	100	2.87	1.44
	bark-beware-kennel	Dog	95	2.97	1.23
	quack-pond-waddle	Duck	95	3.18	1.51
	pasteurized-cow-drink	Milk	95	2.83	1.42
	sheep-clip-sweater	Wool	82	4.63	1.09
	go-grass-irish	Green	72	4.07	1.38
	twinkle-celebrity-bethlehem	Star	63	4.69	1.14
	trip-asleep-autumn	Fall	62	5	1.35
	cough-flame-cigarette	Smoke	57	4.23	1.59
	scissors-incision-meat	Cut	45	4.94	1.38
	ebony-soot-pitch	Black	35	4.04	1.25
	food-butterflies-pump	Stomach	22	3.99	1.06
	bolt-loaf-squirrel	Nut	20	5.71	1.28
	colander-effort-stress	Strain	12	5.38	1.68
	leather-conceal-lair	Hide	7	4.77	
	kitchen-prevent-duel	Foil	0	0.00[a]	
	team-elected-nation	Member	0	0.00[a]	
Compound	surprise-line-birthday	Party	62	5.39	1
	swept-mill-blown	Wind	43	4.39	1.44
	brow-glass-level	Eye	40	5.42	0.87
	ship-outer-crawl	Space	35	4.58	1.01
	car-fog-french	Horn	30	4.25	1.59
	motion-poke-down	Slow	22	4.3	2.03
	soap-shoe-tissue	Box	20	4.6	1.75
	man-order-air	Mail	18	4.66	1.06
	wood-liquor-luck	Hard	15	4.9	0.5
	water-pen-soda	Fountain	12	5.15	0.6
	arm-coal-peach	Pit	7	5.13	1.51
	skunk-kings-boiled	Cabbage	3	0.00[b]	
	key-wall-precious	Stone	2	0.00[b]	
	type-ghost-story	Writer	0	0.00[a]	
Mixed	honey-swarm-sting	Bee	97	3.11	1.5
	curiosity-nap-whiskers	Cat	92	3.38	1.36
	shelf-read-worm	Book	90	3.94	1.58
	bride-reception-ring	Wedding	88	3.25	1.18
	dunes-castle-beach	Sand	87	3.66	1.32

love-felt-broken	Heart	85	4.33	1.49
mouse-sharp-american	Cheese	75	4.34	1.75
elderly-fashioned-timer	Old	72	4.42	1.7
rose-blood-anger	Red	68	3.84	1.47
chocolate-fortune-tin	Cookie	67	4.68	1.52
sky-ocean-mood	Blue	65	4.18	1.19
greeting-index-joker	Card	62	4.3	1.54
bald-screech-emblem	Eagle	48	4.42	1.39
candle-dawn-feather	Light	45	5.1	0.99
athletes-paw-rabbit	Foot	37	4.1	1.37
widow-bite-monkey	Spider	37	4.51	1.14
cob-joke-pop	Corn	33	5.28	0.97
bottom-spinning-table	Top	30	4.5	1.35
daffodil-fever-caution	Yellow	28	4.84	1.42
keel-show-row	Boat	27	5.8	1.54
elephant-lapse-vivid	Memory	25	4.52	1.3
volume-speaker-noise	Loud	23	4.18	1.45
residence-sick-brew	Home	20	4.61	0.95
stop-petty-sneak	Thief	17	4.32	1.08
desert-ice-spell	Dry	13	5.65	1.02
curry-tropics-stuff	Hot	13	4.95	2.34
jam-drug-signal	Traffic	13	6.26	
bass-complex-sleep	Deep	8	2.22	
base-cricket-dance	Ball	7	0.00[b]	
unbroken-gramophone-tape	Record	7	2.15	
liver-church-recital	Organ	5	0.00[b]	
lick-sprinkle-mines	Salt	5	4.47	
jump-kill-bliss	Joy	3	5.02	
bell-iron-tender	Bar	2	0.00[b]	
hens-flashlight-artillery	Battery	2	3.45	
cherry-time-smell	Blossom	2	0.00[b]	
wash-cheap-truck	Dirt	2	4.94	
stalk-trainer-king	Lion	2	6.97	
slug-swell-misty	Sea	2	5.98	

Note. A mean accurate response time of 0 seconds for a problem signifies that either: [a]No participants accurately solved the problem, or [b]participants accurately solved the problem, but only after the 7-second viewing time frame had passed.

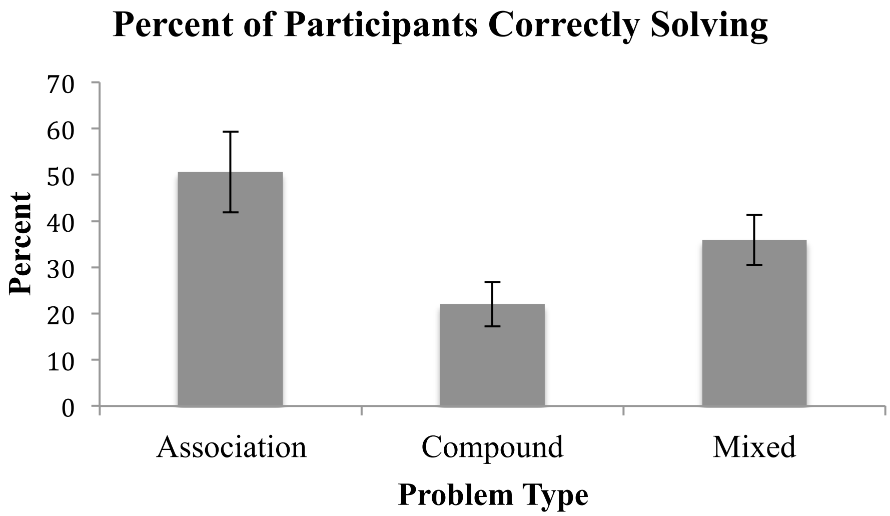
Table 2

Neuropsychological Data

				Scaled Recall Score		Scaled Recognition Score	
	RAT Score	Recall	Recognition	Solved	Unsolved	Solved	Unsolved
Raven's Progressive Matrices	.382**	-.143	-.123	-.088	-.240	-.220	-.015
ERVT	.467**	.152	-.113	-.085	.195	-.256*	-.037
Digit Span Forward	.231	-.110	-.026	-.263*	.008	-.261*	.082
Digit Span Backward	.288*	.157	.142	-.067	.245	-.082	.168

Note. Correlation values, r of participants' neuropsychological test scores and RAT, recall, and recognition performance. $^{**}p < .01$. $^{*}p < .05$.
RAT score refers to the total number of problems correctly solved, recall is the number of correctly recalled words, and recognition is the total number of "old words" correctly recognized. Scaled recall scores were calculated by dividing the number of recalled words from correctly solved (or unsolved) words by the total number of words from solved (or unsolved) RAT problems. Scaled recognition scores were calculated in the same manner.

a.



b.

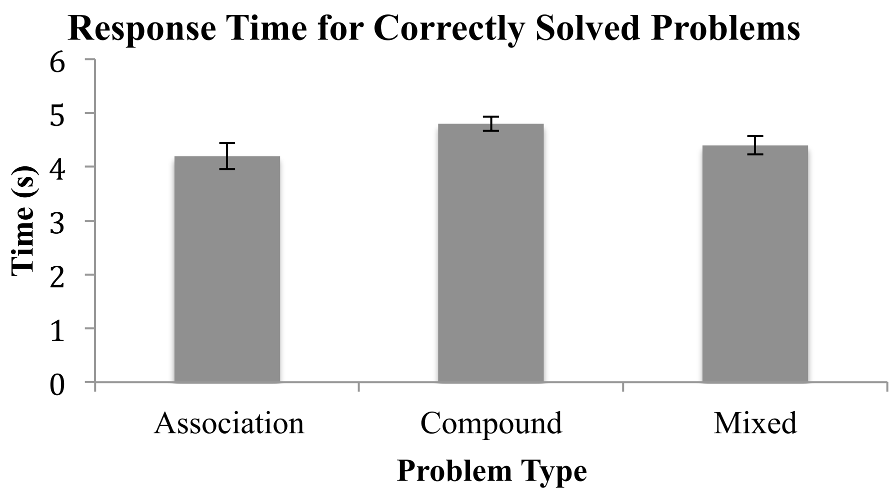


Figure 1. Comparisons between RAT problem types. (a) Average percentage of participants correctly solving problems of each type. (b) Average response time for correctly solved problems of each type.

a.

b.

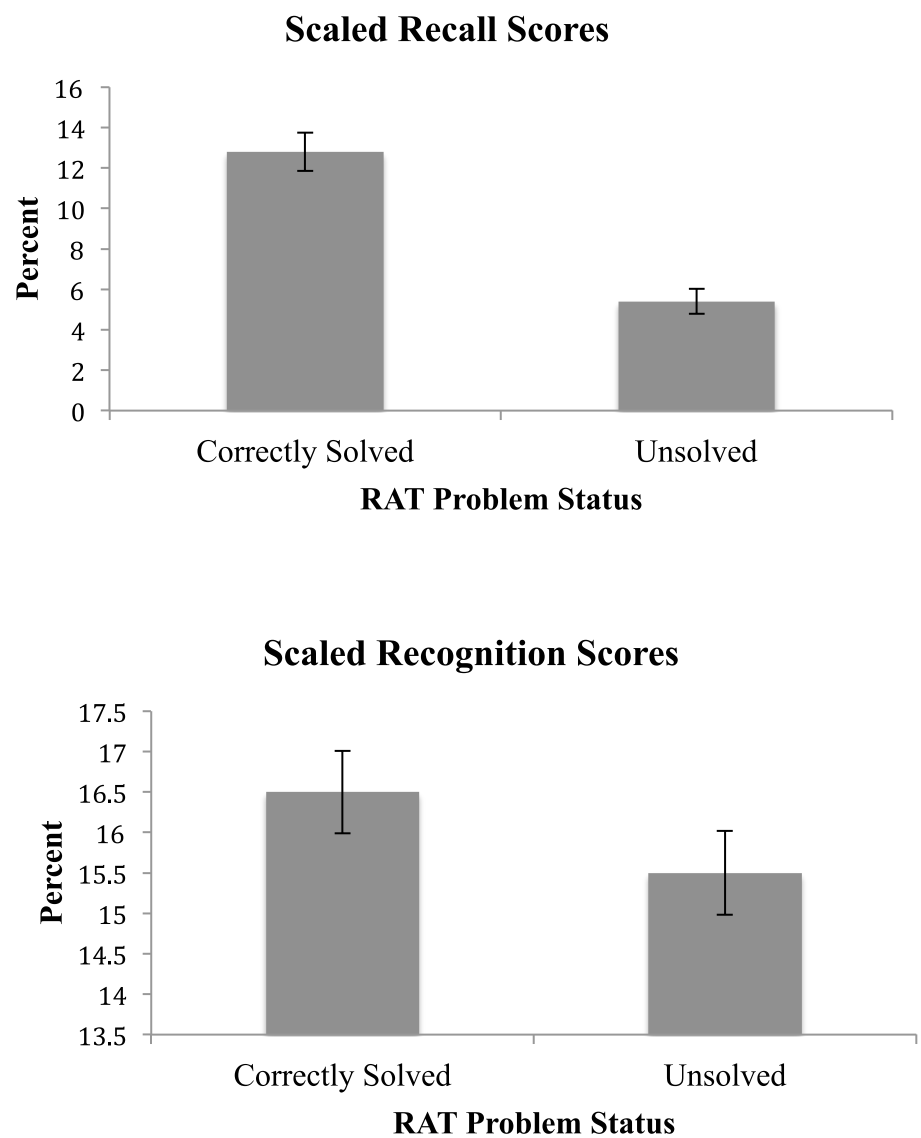


Figure 2. Measures comparing memorability of RAT words based on their solved status. (a) Scaled scores for recall of correctly solved and unsolved RAT words. (b) Scaled scores for recognition of correctly solved and unsolved RAT words.