IS THERE SUCH A THING AS IMPLICIT PROBLEM-SOLVING?

by

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This work is dedicated to the memory of

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ABSTRACT

After failing to solve items from the Remote Associates Test (RAT), subjects showed significant priming effects when the solutions were presented in a lexical-decision task (Experiment 1). Experiments 2 and 3 found no significant priming effect when subjects were asked merely to remember the RAT elements, or for targets that were associates of only two of the three elements in incoherent RAT items. Experiment 4 showed that identifying a correct solution took longer than lexical decision, and that the probability of correct identifications for a given item was uncorrelated to the priming effect for the item. Experiment 5 yielded item-difficulty norms for 68 RAT items as well as a replication of the priming effect observed for unsolved items in Experiment 1. In Experiment 6, a significant priming was observed for targets that were solutions to hard items but not for solutions to easy items. This research provides evidence for implicit problem-solving, which is nonconscious but not automatic, and is neither a perceptual nor a purely memory-related phenomenon.

CHAPTER 1

INTRODUCTION

The cognitive unconscious encompasses a wide range of phenomena that influence experience, thought, and action while remaining inaccessible to phenomenal awareness (Kihlstrom, 1993). While implicit memory has become a major issue in neuropsychological and cognitive research (Schacter, 1992), some aspects of the cognitive unconscious have received less attention.

Roediger (1990) has suggested that researchers studying implicit memory pay greater attention to the work taking place in related fields such as concept formation, social cognition, artificial grammar, motor-skill learning, perception and problem-solving. Otherwise, Roediger (1990) claims, "the study of implicit memory runs the risk of becoming an insulated enterprise" (p. 375).

In his brief discussion of problem-solving, Roediger (1990) mentions only the kinds of problems that would be described as routine. Routine problems can be solved by either retrieving the appropriate solution from memory or applying a familiar strategy. According to Roediger (1990), "the issue is whether subjects who have learned to solve a particular sort of problem will be able to use the solution when faced with another problem of the same type" (p. 375).

Another issue that is pertinent to the understanding of consciousness has to do with problems that subjects have not yet learned to solve. Problems that are solved without any pre-existing knowledge of the appropriate solution or strategy are defined as nonroutine. A nonroutine problem can be the kind of open-ended problem associated with creative thinking, or it can have a single solution that is not attained by following a pre-determined formula.

The present study focuses on the role of unconscious cognition in nonroutine problem-solving. Nonroutine problems are of interest for two reasons: First, the process of solving such problems differs from memory or perceptual phenomena in important ways, as we shall see. Also, nonroutine problems satisfy the methodological constraints imposed by cognitive approaches to the study of creative thinking, since these problems involve an element of creativity while converging on a single solution. Unlike other forms of creative thinking, nonroutine problem-solving can be measured reliably by determining whether or not the appropriate solution has been attained.

We introduce the term, implicit problem-solving, to describe the effect on experience, thought, and action of a solution to a nonroutine problem when the solution is not accessible to conscious awareness. This effect is a consequence of the specific activity of problem-solving and is attributable to a type of mental representation--i.e., a solution--that is neither a memory trace of a prior study episode nor a perceptual representation of an external stimulus. Implicit problem-solving is measured in terms of facilitated performance on a task that does not refer directly to the problem and that does not require awareness of the solution as such. This is in contrast to explicit problem-solving measures, which require both direct reference to the problem and awareness of the solution.

1.1 Nonroutine Problem-Solving Versus Memory Phenomena

A nonroutine problem can be solved in a routine manner. For instance, problems such as fragment completions (Warrington & Weiskrantz, 1970) and anagrams (McAndrews & Moscovitch, 1990) are commonly used as measures of implicit memory. In the context of an implicit memory study, the corresponding solutions or strategies are presented in a prior study episode, and exposure to this information facilitates problem-solving performance even though the problem makes no direct reference to the study episode. Since the memory of the strategy or the solution that was presented during the study episode is exerting an effect on problem-solving performance, it can be argued that the problems are being solved in a routine manner.

This does not mean, however, that the problems themselves are routine. In the absence of prior information about the strategy or the solution, the process of solving an anagram (e.g., OAPNR) or a fragment completion (e.g., _SS_SS__) is not simply a matter of memory retrieval. If it were, then the encoding specificity principle (Tulving & Thomson, 1973) would apply. The principle states that a retrieval cue is effective to the extent that it has been encoded previously in relation to the target information. Assuming that the problem acts as a cue for retrieval of the solution--i.e., the target information--the solution would already have to exist in memory with respect to the problem in order for the problem to be solved. If this relationship were already in memory, one might wonder how it got there. The problem would have to have been solved before, either by the problem solver or by someone who has taught the solution to the solver. In either case, the problem would, by definition, be a routine problem. The point is that nonroutine problem-solving cannot be reduced to mere memory retrieval.

Regardless of this fact, memory researchers continue to treat nonroutine problems as memory phenomena. Lockhart and Blackburn (1993) propose that the kind of problem-solving defined here as nonroutine be viewed as a form of remembering: "In the case of problem solving, the target of the memory retrieval process is an abstract concept; in the case of trivia questions it is a concrete fact" (p. 100). Weisberg (1992) argues that problem-solving "should be considered a cyclical process, involving retrieval of information from memory and the attempt to apply this information to the problem" (p. 427).

The difficulty that arises with these models is that the cue and the target information in nonroutine problem-solving are either unrelated or only weakly-related in the subject's memory prior to the problem-solving process. Also, this process appears to require the disruption of pre-existing associations involving the cue and the target, as illustrated in the restructuring example provided by Durso, Rea, & Dayton (1994). Neither the formation of new associations nor the disruption of old ones is consistent with a simple memory-retrieval account of nonroutine problem-solving.

In contrast, memory retrieval appears to be the only process involved in solving most types of routine problems. For example, the following general-information question, taken from a set of norms developed by Nelson and Narens

(1980), can be solved by merely finding a pre-existing association between the cue and the target: "What is the last name of the most popular pin-up girl of World War II?" (p. 359). In this problem, there is a one-to-one correspondence between the cue (i.e., the question) and the target (i.e., "Grable"), and the retrievability of the target is dependent on the pre-existence of this correspondence in memory. For a nonroutine problem such as the five-letter anagram, OAPNR, as many as 120 arrangements of the letters can be generated, although only one arrangement is a legitimate English word. Anagrams may be solved by randomly rearranging the letters and matching the output with one's mental lexicon, or by making inferences about the probability of certain letter sequences giving rise to the kinds of syllables found in English words. In either case, the process is not purely one of matching a cue with its corresponding target in memory, since this correspondence is unlikely to have existed in memory prior to the problem-solving episode.

Nonroutine problem-solving can also be distinguished from memory phenomena on a more empirical level. Unlike memory retrieval, the process of solving nonroutine problems is often accompanied by _insight_, a subjective experience characterized by suddenness and unexpectedness. Metcalfe

(1986) found that the experience of insight is associated with a pattern of metacognition that appears to be present only in nonroutine problem-solving. In this experimental design, subjects are instructed to give feeling-of-warmth judgments at regular intervals as they attempt to solve one of a set of insight problems. The feeling-of-warmth judgment is part of a protocol developed by Simon, Newell, and Shaw (1979) to evaluate their notion that a similarity-matching heuristic plays a role in general problem-solving. Using this judgment, the problem solver can assess his or her proximity to a specific goal state, in a manner analogous to the children's searching game in which players are told whether they are getting "warmer" (closer to the object) or "colder" (farther from the object).

In Metcalfe's (1986) study, subjects working towards the correct solution of a nonroutine problem showed no increase in their feelings-of-warmth until the solution was at hand. In contrast, subjects attempting to solve routine problems (e.g., trivia questions) had steadily increasing feeling-of-warmth judgments as they approached the correct solution (Metcalfe & Wiebe, 1987). This difference in the monitoring pattern for the two types of problems can be interpreted in one of two ways: 1) the process of solving nonroutine problems may be nonincremental, so that there is nothing to monitor until the instant that the solution is reached; or 2) the process may involve unconscious cognition that cannot be monitored with feeling-of-warmth judgments. The two interpretations can be differentiated using measures of implicit problem-solving, since these measures would be able to detect the presence of a solution that may not be accessible to conscious awareness.

1.2 Antecedents of Implicit Problem-Solving

The possibility that unconscious processes may play a role in creative or nonroutine problem-solving has been considered by a number of researchers (for reviews, see Bowers & Bowers, 1979; Dorfman, Shames, & Kihlstrom, in preparation; Shames & Bowers, 1992). Creative individuals have often described their work as the product of unconscious cognition (Madigan & Elwood, 1983). For the mathematician Poincare (1913), the experience by which the problem-solver becomes aware of a solution was "a manifest sign of long, unconscious prior work" (p. 389). This notion of unconscious work gave rise to Wallas' (1926) model of the creative process, which consisted of four stages: preparation, incubation, illumination, and verification. In this model, unconscious mental processes take place during the incubation period, which ends when the subject becomes aware of the solution.

The "unconscious work" hypothesis has fallen out of favor with research psychologists (Perkins, 1981). Incubation effects, defined as an increase in the probability of correctly solving a problem as a consequence of placing an incubation period between an initial and a subsequent period of conscious work on the problem (Posner, 1973), have been detected in some empirical studies, but have proven exceedingly difficult to replicate (Olton, 1979).

Also, theorists have tried to account for these effects without referring to unconscious cognition. Simon (1989) claims that the effects "can be explained without postulating that anything except forgetting occurs during the incubation period" (p. 484). In a similar vein, Smith and Blankenship (1991), who have obtained reliable incubation effects only in cases when subjects are given initially misleading information about a problem, argue that the function of an incubation period is to permit the interference produced by erroneous information to decay from subjects' memory. These authors maintain that "one of the greatest obstacles to research on incubation effects is an adherence to the common assumption that incubation must be the result of unconscious problem solving" (p. 62).

In fact, the study of incubation effects provides no direct information about unconscious processes, since these effects can only be observed when the subject becomes conscious of the solution. A more effective way of determining if any part of the process might be taking place outside of awareness is to use measures of implicit problem-solving. Two sets of experiments have taken this approach. In a study by Yaniv and Meyer (1987), subjects who were unable to generate a rare word when given the word's definition nonetheless demonstrated priming effects for the word on a lexical-decision task. Bowers et al. (1990) found that when subjects were shown pairs of word problems--each pair consisting of a coherent triad derived from the Remote Associates Test (RAT; Mednick & Mednick, 1967) and an incoherent triad (i.e., three unrelated words)--the subjects displayed greater-than chance accuracy in selecting the coherent triads on a forced-choice decision task.

Although both studies are pertinent to the current discussion, neither of them qualifies as a study of implicit problem-solving. In the Yaniv and Meyer (1987) study, subjects were asked to perform a rare-word definition task, which is more of a memory retrieval task than a true nonroutine problem. In the Bowers et al. (1990) study, the forced-choice decision task that was used is not an implicit test in the strictest sense, since it requires that subjects refer directly to the problem.

1.3 The Nature of Implicit Problem-Solving

In both sets of experiments that we have just described, the authors chose to interpret their results in terms of spreading activation models. Yaniv and Meyer (1987) proposed a memory-sensitization hypothesis, in which initial attempts to solve a problem partially activate information related to the solution. Although the level of activation is insufficient to make this information accessible to awareness, the solver becomes sensitized to external cues that can boost the activation of this information above the threshold required for awareness. According to Bowers et al. (1990), the features of a given problem activate a mnemonic network of relevant information, and as the activation begins to spread, it yields an implicit perception that the activated information is coherent with the problem. When "sufficient activation has accumulated to cross a threshold of awareness" (p. 74), the problem solver has the experience associated with attaining the solution.

With respect to implicit problem-solving, there are two potential findings that could prove difficult to accommodate within a spreading activation model. The first would be a functional dissociation between implicit and explicit problem-solving, which would indicate that the difference between the two phenomena is qualitative and not quantitative. This is analogous to the situation in the memory literature that has led Schacter (1987) to conclude: "The finding that implicit memory is unaffected by experimental variables that have large effects on explicit memory, and that performance on implicit tests is often statistically independent of performance on explicit tests, is inconsistent with a threshold model in which implicit and explicit tests differ only in their sensitivity to the strength of memory traces" (p. 511).

A second source of difficulty would arise if performance on an implicit task such as lexical-decision is observed only in the case when a subject is actively engaged in trying to solve a nonroutine problem but not when the subject is involved in a more passive task, such as studying the problem. The kinds of models described by Bowers et al. (1990) and by Yaniv and Meyer (1987) are based on the assumption that spreading activation is an automatic process. If this assumption were correct, then any cognitive task involving triads should lead to spreading activation from the three cue words to the target.

It has yet to be determined if the facilitated performance associated with implicit problem-solving is: a) robust; b) task-specific; or c) dissociable from explicit problem-solving. Assuming that these features are present, however, an alternative to a spreading activation model would need to be considered.

1.4 Overview of Experiments

The experiments reported in this article deal with a number of questions related to implicit problem-solving. If a solution to a nonroutine problem is inaccessible to conscious awareness, does it facilitate performance on an implicit task? Is this facilitation linked specifically to problem-solving or would other types of processing produce the same effect? How can we rule out the possibility that conscious processes are contributing to this effect?

The design used in these experiments combines the methodological strengths found in the work of Bowers et. al (1990) and of Yaniv and Meyer (1987). As in the former study, the nonroutine problems used here consisted of triads selected from the Remote Associates Test (RAT; Mednick & Mednick, 1967). The RAT was developed as a means of assessing creative personality based on Mednick's (1962) notion that the creative individual has the capacity to make associations that are unusual or remote. An example of the kind of problem found on the RAT is: "OFF TOP TAIL." The solution to this triad is "SPIN," a remote associate of all three cue words. RAT problems are considered nonroutine because they are not solved by mere memory retrieval but rather by finding a connection among three seemingly unrelated words.

As in Yaniv and Meyer (1987), the lexical-decision task (Rubenstein, Garfield, & Millikan, 1970) will be used as a test of implicit problem-solving. Subjects are asked to decide whether or not a letter sequence is a legal word, and priming is observed when subjects show a decreased latency for a target word--in this case a solution to a nonroutine problem that they have attempted to solve--in comparison to a control word. The lexical-decision task has been used to demonstrate a number of different effects, including semantic priming (Meyer & Schvaneveldt, 1971) and repetition priming (Forster & Davis, 1984; Scarborough, Cortese & Scarborough, 1977).

CHAPTER 2
EXPERIMENT 1

The objective in this experiment was to establish the existence of implicit problem-solving. We were interested in determining if a priming effect would be observed for solutions to problems that subjects were unable to solve explicitly.

2.1 Method

Subjects. Forty University of Arizona students in introductory psychology participated in exchange for a small bonus course credit. Subjects were randomly assigned to one of two experimental groups, A and B.

Apparatus. Items were presented on a Princeton Ultrasync color monitor controlled by a 386 IBM PC using the DMASTR software developed at Monash University and at the University of Arizona. The software synchronizes the timing of the display with the video raster. Standard lower case IBM test font was used for the instructions and upper case font was used for the triads and the lexical-decision items.

Stimuli and design. Stimuli were selected from Forms 1 and 2 of the Remote Associates Task (Mednick & Mednick), and from a set of similar triads constructed by Bowers, Regehr, Balthazard and Parker (1990). From this item pool, 36 triads and their corresponding solutions were selected and randomly assigned to one of two lists, 1 and 2. Subjects in Group A received the triads on List 1, while Group B subjects received List 2 triads. Both groups received the same 18 sequences of test stimuli in a lexical-decision task. Each sequence consisted of six items, including one target word, one control word, one filler word and three nonwords. For Group A, target words were the solutions to the List 1 triads that they had been asked to solve,and control words were solutions to List 2 triads that they had not seen; for Group B, who had been asked to solve List 2 triads, the identity of the target and control words was reversed, although the composition of the sequences remained unchanged. This design, similar to that used by Yaniv and Meyer (1987), permitted the same item to serve as both a target word and a control word across subjects. The presentation order of different stimulus types within a sequence was randomized to control for serial position effects.

Procedure. Subjects were tested individually in sessions lasting approximately 20 minutes. At the start of the session, subjects were given the opportunity to practice performing the experimental tasks. Four trials were presented for practice.

Subjects were given the following instructions: "In this experiment, you will be alternating your attention between two different word tasks. In the first task, three words will appear on the computer screen. Your job will be to think of the one word that these words have in common. For example, if the three words are, "POKE GO MOLASSES," you would try to think of the word "SLOW." "SLOW" is related to "POKE" (the expression "SLOWPOKE"), to "GO" ("SLOW" is a speed you can "GO"), and to "MOLASSES" ("SLOW" as "MOLASSES"). The computer will give you a few seconds to think of an answer. You should try to get the answer in the time you're given, but it's OK if you don't. We are more interested in seeing how you shift your attention from one task to the other. This is not a test of your ability to solve these problems.

Subjects were informed that the second task in the experiment would require them to decide if each of a series of items is a word or a nonword, and that it would be important for them to make their decisions as quickly and as accurately as they could. They were instructed to use the appropriate keys to signal "Yes" and "No," and then they were shown an example of the sequence of events that they would encounter in each trial of the experiment. Subjects were given four practice trials before beginning the experiment.

The following sequence of events took place during a typical experimental trial: The trial began when the subject pressed the space bar to indicate that s/he was ready. The question, "What word do these have in common?" appeared on the screen for one second prior to the onset of the triad, which stayed on the screen, one line below the question, for another five seconds. The screen was then cleared, and the following question appeared for one second, "Do you have the answer? (Y/N)." Again, the screen was cleared. The subject indicated a "Yes" response by pressing the right shift key and a "No" response by pressing the left shift key. Both keys were labeled appropriately.

The beginning of the lexical-decision task was signalled by the question, "Is each of the following a word? (Y/N)," which appeared on the screen only after the subject had responded to the previous question (response contingency). After two seconds the screen was cleared, and the first item in the six-item sequence appeared. The subject responded to each item by pressing the "Yes" key for a word and the "No" key for a nonword. Every response was followed by feedback, indicating whether the subject was "Correct" or "Wrong," as well as the reaction time expressed in milliseconds. The onset of the next item in the sequence was contingent on the subject's response to the previous item, and the stimulus duration for each item was 500 ms.

At the end of the six-item sequence, the following message appeared on the screen until the subject responded: "THIS IS THE END OF THE SEQUENCE. Press Space Bar to Continue."

Data analysis. The data were trimmed in the following manner. Reaction times for erroneous responses were omitted. This criterion removed less than 5% of the raw data. Subjects producing error rates greater than 20% on the lexical-decision task would have been omitted, although none of the subjects in our sample exceeded that limit. Reaction times greater than 1500 ms and less than 100 ms were excluded from the analysis, resulting in the removal of less than 1% of the raw data.

Data were conditionalized to evaluate the priming effects for solved and unsolved triads separately. For each of these two conditions, subjects and items were treated as random effects. Subject effects were analyzed by collapsing across items to compute subject means. Item effects were analyzed by collapsing across subjects to compute item means. Significance tests were run for item effects and subject effects with a repeated measures analysis of variance model. A probability level of $p < .05$ was used as the criterion for statistical significance.

Missing data were evident in two of the four analyses. Two subjects failed to solve any of the triads and were therefore excluded from the subject analysis for solved triads. Two items were omitted from the item analysis for solved triads because none of the subjects were able to solve the corresponding triad.

2.2 Results

The results for the solved and unsolved conditions are displayed in Table 1. With respect to the unsolved triads, we found a significant positive priming effect: for the subject analysis, $F(1,38)=20.90$, $p<.05$, $MSe=1369$, and for the item analysis, $F(1,34)=6.81$, $p<.05$, $MSe=2308$. However, there was no significant priming effect in the case of solved triads: for the subject analysis, $F(1,36)=1.25$, $p>.05$, $MSe=2486$, and for the item analysis, $F(1,32)=1.19$, $p>.05$, $MSe=13493$.

The proportion of unsolved triads was .61.

2.3 Discussion

There were two findings of interest in Experiment 1.

First, when the triads were not solved in the allotted time interval, subjects nonetheless showed significantly faster reaction times on a lexical-decision task for the solutions to the triads than for matched control items. This priming effect is consistent with the notion of implicit problem-solving, although there are plausible alternative accounts for this finding that we will discuss momentarily.

A second finding was that the priming effect observed for unsolved triads did not generalize to solved triads. This may simply have been an artifact of sample size. The subject and item means that were used in the analyses of the data for solved triads were computed by collapsing over a much smaller data set than in the case of unsolved triads. This discrepancy is due to the fact that most subjects were unable to solve a majority of the triads they were given. Approximately two-thirds of the triads remained unsolved after five seconds.

It is possible, however, that the unsolved triads produced a larger priming effect because of their inherent lack of resolution. Subjects continued to expend attentional resources on unsolved problems and thus may have remained more sensitized to the solution when it appeared before them. This effect is analogous to the Zeigarnik effect (Zeigarnik, 1927, cited in Baddeley, 1976, p. 269), a well-known memory phenomenon in which subjects show improved recall for interrupted tasks as opposed to tasks that they have completed. Zeigarnik attributed this effect to "unresolved tension" that somehow maintained the memory traces of interrupted tasks in a more accessible form.

Any further speculation concerning the nature of the observed difference between solved and unsolved problems should be contingent on the successful replication of the effect. One of the objectives of the following experiments is to determine under which conditions these findings replicate.

Implicit problem-solving, by definition, can only be observed in the absence of conscious awareness of the solution. While the priming effect observed in this experiment does constitute the kind of facilitation in performance associated with implicit problem-solving, we have not yet ruled out the possibility that subjects were aware of the solutions as they responded to these items on the lexical-decision task. Also, it has not been shown that the priming effect is specifically linked to the act of problem solving. This effect may simply be the sum of the semantic activation produced by each of the words comprising the triad, which would mean that this effect has little to do with the act of problem-solving per se. Alternative explanations for the priming effect we observed are considered in Experiments 2-4.

CHAPTER 3

EXPERIMENT 2

Experiment 1 showed that an attempt to solve a nonroutine problem produces a priming effect for the solution, even though the subject may be unaware of the solution. In Experiment 2, we considered the possibility that this effect is merely the sum of the semantic activation produced by each of the three cue words, rather than a specific outcome of the problem-solving act. Subjects in this experiment were asked to study the three words but were not informed that these words, when taken together, produce a coherent problem.

The magnitude of the priming effect observed in this experiment would provide a critical test of two alternative explanations. A significant priming effect would serve to disconfirm the hypothesis that the effect is associated with the act of problem-solving, since no problem-solving activity is taking place in this experiment. On the other hand, the absence of such an effect would be damaging to a spreading activation model because it would demonstrate that the unconscious cognition that produced the effect in Experiment 1 is not an automatic process but rather a task-specific phenomenon.

3.1 Method

Subjects. Forty University of Arizona students in introductory psychology participated in exchange for a small bonus course credit. Subjects were randomly assigned to one of two experimental groups.

Apparatus, stimuli, and design. These were the same as in Experiment 1.

Procedure. Instead of being asked to solve triads as in Experiment 1, subjects were instructed to study the three words comprising each triad in preparation for a subsequent old/new recognition task. Since there was no problem to solve, subjects were not asked, "Do you have the answer?" Instead, they advanced directly to the sequence of lexical decisions, after which they were shown a word and asked to perform an old/new recognition task.

The sequence of events differed from those in Experiment 1 in the following ways: After the subject initiated a trial by pressing the space bar, the statement, "Please study the following words," appeared on the screen for one second prior to the onset of the triad. At the end of the lexical-decision task,

the following question appeared on the screen, "Is this one of the three words you studied?" In nine of the 18 trials, a triad item was shown; the other nine trials used a filler word.

Data analysis. The analysis was the same as in Experiment 1, except that data were not conditionalized for solved and unsolved triads, since subjects were not asked to solve triads.

To compare the results of this experiment with the findings in the unsolved condition of Experiment 1, the data sets from the two experiments were collapsed together and analyzed in a 2 x 2 x 2 design (Experiment [1 vs. 2] x Group [subject or item] x Treatment Condition [primed vs. control]). The group variable reflects the counterbalancing procedure and was included solely to extract the variance due to counterbalancing. Two analyses were carried out, one using the subject means as the sampling unit and the other using item means. In the subject analysis, both the experiment and the group variables were nonrepeated measures, whereas in the item analysis, only the group variable was repeated.

3.2 Results

The main effect of treatment condition on lexical decision time is shown in Table 2. There was no significant priming effect: for the subject analysis, $F(1,38)=1.52$, $p>.05$, $MSe=892$, and for the item analysis, $F(1,34)=1.38$, $p>.05$, $MSe=756$.

The results from the unsolved condition in Experiment 1 are also included in Table 2 for the purpose of comparison. The interaction between experiment and treatment condition was significant in the subject analysis, $F(1,38)=7.75$, $p<.05$, $MSe=1131$, and approached significance in the item analysis, $F(1,34)=3.56$, $p=.067$, $MSe=1217$.

3.3 Discussion

In contrast to the problem-solving task in Experiment 1, instructions to study rather than solve the triads failed to produce a significant priming effect. A comparison to the findings for the unsolved condition in Experiment 1 showed a significant experiment x treatment interaction on the subject analysis but not the item analysis.

The fact that the interaction failed to yield significance in the item analysis may be due to the presence of an inflated error term in this analysis. It may not be appropriate to treat inter-item variability as random rather than systematic, since this variability is likely to be a function of item difficulty. In psycholinguistics research, the assumption that underlies any item analysis is that the items have been randomly selected from a population of similar items. This assumption may not be valid in the selection of word problems, which vary greatly in terms of difficulty.

The absence of a significant main effect in this experiment is inconsistent with any model in which semantic activation is expected to spread automatically from the cues to the target, regardless of the task. The effect seems to be specific to the act of problem-solving. If this is so, however, no effect should be detected when subjects are given insoluble triads such as the ones presented in the following experiment.

CHAPTER 4

EXPERIMENT 3

What happens when subjects are given problems that have no solution, i.e., incoherent triads? An incoherent triad can be produced by replacing one of the three words in the triad with a word that is unrelated to the original solution. Since two of the three triad members are still related to the solution, the priming effect observed in Experiment 1 should remain largely intact for incoherent triads if the effect is merely the sum of the activation produced by each triad member. On the other hand, if this effect is attributable to implicit problem-solving, it should dissipate for incoherent triads, since implicit problem-solving cannot take place for these triads.

4.1 Method

Subjects. Forty University of Arizona students in introductory psychology participated in exchange for a small bonus course credit. Subjects were randomly assigned to one of two experimental groups.

Design and apparatus. These were the same as in Experiment 1.

Stimuli. The stimuli were modified by substituting an unrelated word for one of the three cue words in each triad. The replacement word was matched for length and frequency with the triad member it replaced. The word to be replaced was selected randomly from each triad.

Procedure. The procedure was the same as in Experiment 1.

Data analysis. The analysis was the same as in Experiment 1, except that data were not conditionalized for solved and unsolved triads, since it was assumed that subjects were unable to solve any of the triads in this experiment. As in Experiment 2, the data from this experiment were collapsed together with the data from the unsolved condition in Experiment 1 to assess the treatment-by-experiment interaction.

4.2 Results

The main effect of treatment condition on lexical decision time is shown in Table 3. There was no significant priming effect: for the subject analysis, $F(1,38)=1.10$, $p>.05$, $MSe=842$, and for the item analysis, $F(1,34)=0.57$, $p>.05$, $MSe=1170$.

The results of the unsolved condition in Experiment 1 is also included in Table 3 for the purpose of comparison. The interaction between experiment and treatment condition was significant in the subject analysis, $F(1,38)=8.71$, $p<.05$, $MSe=1106$, but was not significant in the item analysis, $F(1,34)=2.48$, $p>.05$, $MSe=2002$.

4.3 Discussion

As in Experiment 2, the main effect of treatment condition in this experiment was not significant. A comparison to the findings for the unsolved condition in Experiment 1 showed a significant experiment-by-treatment interaction on the subject analysis but not the item analysis.

Had the priming effect reported in Experiment 1 been due simply to the spreading of activation from the words comprising each triad to the solution, then replacing one member of each triad with an unrelated word may not have been enough to eliminate the effect. However, a significant effect would have been damaging to the notion of implicit problem-solving, since the triads in this experiment were insoluble.

The absence of an effect is consistent with the premise that the priming effect from Experiment 1 is a measure of implicit problem-solving, although this finding does not rule out a spreading activation account. It is possible that the replacement of one member in each triad was just enough to make the priming effect statistically insignificant. On the other hand, the priming effect in this experiment was only 6 ms, which is substantially lower than the effect reported in Experiment 1.

CHAPTER 5

EXPERIMENT 4

By definition, implicit problem-solving occurs only when subjects are not aware that an item is a solution. If subjects are able to identify a solution during the lexical-decision task, then the priming effect produced by the solution cannot be considered an instance of implicit problem-solving. In the extreme, one could argue that a priming effect is observed only for those solutions that the subject identifies, leading to the conclusion that implicit problem-solving is never observed. For this argument to be valid, however, one would need to demonstrate that subjects are capable of identifying an item as a solution in the time it takes for them to make a lexical decision, and that priming effects are observed only for items that can be correctly identified as solutions.

Rather than making a lexical decision, subjects in this experiment were instructed to decide whether or not a given item is the solution to the triad they had just seen. The argument that a priming effect takes place only when subjects are able to identify a solution is subject to disconfirmation if it takes longer for subjects in this experiment to identify the solutions than it did for the subjects in

Experiment 1 to make lexical decisions on the same items. On the other hand, the implicit problem-solving hypothesis would be disconfirmed by a finding that the probability of correctly identifying solutions is correlated to the priming effect from Experiment 1, since such a finding would link the priming effect to conscious processes.

5.1 Method

Subjects: Forty University of Arizona students in introductory psychology participated in exchange for a small bonus course credit. Subjects were randomly assigned to one of two experimental groups.

Apparatus, stimuli, and design. These were the same as in Experiment 1.

Procedure. The procedure was modified from that used in Experiment 1 by replacing the lexical-decision with a recognition task, for which subjects were given the following instructions:

"By pressing the space bar, you will advance to the second task. In this task, six items will appear in sequence on the screen. For each item, you will decide if it's the solution to the problem you saw in the first task. You will be asked, `Is any of the following a solution?' If an item is the solution to the problem you just saw, press the `YES' key. If it is not the solution, press the `NO' key. Make your decision as quickly and as accurately as you can."

The sequence of events in each experimental trial remained unchanged from Experiment 1.

Data analysis. The mean reaction times obtained for each of the 18 triad solutions in this experiment included only solutions that subjects were able to correctly identify. These reaction times were compared to the mean lexical-decision reaction times from the item analysis in Experiment 1. Also, a linear regression was performed to determine if the proportion of correct identifications (PCI) obtained for each item in this experiment could account for the variance in the lexical-decision data for these items.

5.2 Results

The mean reaction time for the identification task was more than 1000 ms greater than the mean lexical-decision time observed for the set of unsolved items in Experiment 1 (Table 4). A comparison of these two reaction times produced a significant effect: $t(34)=20.47$, $p<.05$, $MSe=54210$. The correlation of the PCI with the priming effect for each item was .03, which was not significantly different from zero:

$t(34)=.15$, $p>.05$, $MSe=10109$.

5.3 Discussion

The findings in this experiment are inconsistent with a hypothesis that the priming effect in Experiment 1 is due to conscious identification of solutions on the lexical-decision task. Subjects do not have enough time during the response interval of the lexical-decision task to consciously identify a solution. This conclusion is supported by the fact that it takes subjects more than 1600 ms to make a correct identification, while reaction times on the lexical-decision task are only 500-650 ms.

Also, if subjects are able to identify solutions as they perform the lexical-decision task, then the priming effect for a given item should correlate with the PCI for that item. The rationale is that subjects should only show facilitation for solutions that they can identify. This does not appear to be the case, however, since PCI and item priming effects are uncorrelated.

CHAPTER 6

EXPERIMENT 5

There were two objectives in this experiment. One was to provide a replication of the Experiment 1 findings using a larger set of triads. The other was to obtain item-difficulty norms for the set of triads so that the effect of difficulty on priming can be assessed in Experiment 6.

6.1 Method

Subjects. Forty University of Arizona students in introductory psychology participated in exchange for a small bonus course credit. Subjects were randomly assigned to one of two experimental groups.

Apparatus and design. These were the same as in Experiment 1.

Stimuli. The stimulus set was expanded to 68 items, as shown in the Appendix.

Procedure and data analysis. These were the same as in Experiment 1. The item-difficulty score for each triad was computed by normalizing the proportion of "No" responses made by subjects when asked about the triad, "Do you have the answer?" A higher score would thus correspond to a more difficult triad.

6.2 Results

The results for solved and unsolved triads are presented in Table 5. We observed a significant positive priming effect in the unsolved condition: for the subject analysis, $F(1,38)=10.05$, $p<.05$, $MSe=1773$, and for the item analysis, $F(1,66)=8.71$, $p<.05$, $MSe=3650$. With respect to solved triads, there was also a significant effect: for the subject analysis, $F(1,38)=5.24$, $p<.05$, $MSe=2348$, and for the item analysis, $F(1,66)=4.73$, $p<.05$, $MSe=3985$.

Item-difficulty norms for the 68 triads are shown in Table 6. The proportion of unsolved triads was .53.

6.3 Discussion

The priming effect observed in Experiment 1 for unsolved triads in replicated here. This seems to be a robust effect on the order of 30 ms.

With respect to solved triads, however, the significant priming effect obtained here was a departure from the previous null finding. It is possible that solved and unsolved items are taken from the same item population, and that the larger stimulus set in this experiment yielded more accurate estimates of the population parameter. The difference in the priming effect observed for the two conditions in Experiment 1 (12 ms for solved items, 38 ms for unsolved items) would thus be attributable to sampling error.

Another possibility is that subjects in this experiment may have been overestimating their ability to solve triads. In Experiment 1, the proportion of triads that subjects reported as solved was .61, in comparison to .53 in this experiment. The difference in Experiment 1 between solved and unsolved triads may have dissipated in this experiment because subjects were identifying a higher proportion of unsolved triads as solved. The number of misidentifications may have increased for the larger stimulus set used in this experiment because of the increased effects of fatigue and boredom on subject accuracy during the more lengthy experimental session.

CHAPTER 7

EXPERIMENT 6

In this experiment priming effects were assessed as a function of item difficulty. Rather than rely exclusively on subjective reports to determine whether or not a triad had been solved, we selected a set of hard and easy items based on the item-difficulty scores obtained in Experiment 5, and then assumed that easy items are solved while hard items remain unsolved. Since difficulty scores are also based on subjective reports, one might argue that they would be susceptible to the same kinds of inaccuracies that would necessitate their use in the first place. However, items were selected for this experiment based on their relative difficulty, which should be equally affected for all items by any tendency on the part of subjects to overestimate or underestimate their ability to solve triads.

The kind of design used in previous experiments was particularly susceptible to the inaccuracies of subjective reports, since items may have been misidentified on this basis as either solved or unsolved. This potential for misidentification could prove damaging to the validity of our findings. For instance, if subjects are overestimating their performance, then a high proportion of unsolved triads would end up in the solved condition, thus washing out any differences that may have existed between the two condition. By assigning triads to easy and hard categories beforehand, we hope to avoid these kinds of problems.

7.1 Method

Subjects. Forty University of Arizona students in introductory psychology participated in exchange for a small bonus course credit. Subjects were randomly assigned to one of two experimental groups.

Apparatus and design. These were the same as in Experiment 1.

Stimuli. Of the 68 items used in Experiment 5, 18 hard items and 18 easy items were selected on the basis of their item-difficulty scores. All of the items had z-scores that were separated from the sample mean by at least .8 standard deviation units.

Procedure and data analysis. These were the same as in Experiment 1.

7.2 Results

The results for hard and easy triads are presented in

Table 7. There was a significant positive priming effect for hard triads: for the subject analysis, $F(1,38)=5.17$, $p<.05$, $MSe=5530$, and for the item analysis, $F(1,16)=4.62$, $p<.05$, $MSe=2616$. With respect to easy triads, no significant effect was observed: for the subject analysis, $F(1,38)=0.86$, $p>.05$, $MSe=3526$, and for the item analysis, $F(1,16)=0.50$, $p>.05$, $MSe=2663$.

The proportion of unsolved triads was .68 for hard items and .35 for easy ones.

7.3 Discussion

The findings in this experiment are consistent with the pattern of results observed in Experiment 1. This consistency is due to the fact that subjects are able to solve the easy problems but not the hard ones, so that the easy versus hard distinction appears to overlap greatly with the solved versus unsolved distinction made previously.

There remains a discrepancy in the fact that a significant priming effect was observed for solved triads in Experiment 5 but not for easy triads in this experiment or for solved triads in Experiment 1. Subjects reported having solved a greater proportion of the triads in Experiment 5 when compared to Experiment 1 or to hard triads in this experiment. Inaccuracies in the subjective reports used to distinguish solved and unsolved triads could have contributed to the effect by increasing the number of unsolved triads that were misidentified as solved triads in Experiment 5. However, it is difficult to explain why such inaccuracies would not also appear to the same extent in Experiment 1. The larger item set used in Experiment 5 had an impact of some kind on the priming effect for solved items, either yielding more accurate estimates of the population means or impairing subject performance in identifying solved versus unsolved triads.

CHAPTER 8

GENERAL DISCUSSION

The priming effect observed for unsolved triads in Experiments 1 and 5, and for hard triads in Experiment 6, is consistent with the notion of implicit problem-solving, since the solution to a nonroutine problem exerts an effect on lexical-decision task performance even though the solution itself appears to be inaccessible to conscious awareness. Our interpretation of this finding is that unconscious cognition takes place at intermediate stages of the problem-solving process before the subject becomes aware of the solution.

The findings with respect to problems that the subject has already solved are more difficult to interpret. A significant priming effect was observed for solved triads in Experiment 5 but not for solved triads in Experiment 1 or for easy triads in Experiment 6. It could be that the larger stimulus set in Experiment 5 yielded more accurate priming effects. On the other hand, the fact that the proportion of triads that subjects reported to have solved was higher in Experiment 5 than in the other two experiments indicates that subjects may have been overestimating their ability to solve triads in this experiment.

Why should it matter whether or not a significant priming effect is observed for solved triads? The answer is that a nonsignificant priming effect for solved triads could be interpreted in terms of a dissociation between implicit and explicit problem-solving, since unsolved triads would be showing a priming effect that does not appear for solved triads. If such a dissociation were to exist, then the kinds of spreading activation models that have been proposed in other studies of problem-solving would not fully account for our data. It might be possible to explain a priming effect for unsolved problems by postulating that activation levels which are too low to cross a threshold of awareness are still high enough to produce priming effects. But spreading activation cannot account for the absence of a significant priming effect in the case of solved problems. Threshold models only make sense if solutions that have enough activation to cross an awareness threshold also give rise to priming effects. Otherwise, one has to consider the possibility that the distinction between consciously solving a problem and showing a priming effect for the solution is not merely due to a quantitative difference in activation but rather to a qualitative difference in the forms of problem-solving associated with the two tasks.

Another source of concern for activation models has to do with the task-specific nature of the priming effects we have observed. Priming effects in this study were significant only when subjects were shown triads and asked to find a solution, but not when subjects were asked to study the same three words without knowing that these words comprise a problem or when one of the three words was unrelated to the other two, making the triad insoluble. This pattern of results leads us to conclude that the cognitive processing associated with the priming effects we observed is not necessarily automatic, even though it may be unconscious (for a discussion of this distinction, see Kihlstrom, 1987). The distinction is an important one, since the activation models we have been discussing are based on the assumption that activation spreads automatically when a subject encounters a word problem, regardless of the kind of task that the subject performs on the problem.

As Posner and Snyder (1975) have defined them, automatic activation processes are "those which may occur without intention, without any conscious awareness and without interference with any other mental activity" (p. 81). These are contrasted with conscious strategies, in which subjects "program their conscious attention to (1) receive information from a particular input channel or area of memory and (2) perform particular operations upon received information" (p.

73).

Other researchers concur with two of Posner and Snyder's (1975) criteria for automaticity, namely that a process must take place regardless of the subject's intention and must consume few or no attentional resources (for a review, see Kihlstrom, 1990). Logan (1980) maintains that automatic and attentional processes are similar in that they both involve the assignment of weights to information in the stimulus environment based on the salience of the information. However, the two types of processes can be differentiated on the following basis:

"Automatic weights are assumed to be constant in sign (facilatory or inhibitory) and magnitude over situations, purposes, and intentions, reflecting their relative permanence. In contrast, attentional weights are assumed to vary in sign and magnitude over situations as purposes and intentions dictate, reflecting their strategic flexibility" (Logan, 1980; p. 528).

It is important to note that strategic flexibility is not an exclusive feature of conscious awareness, and that the use of conscious strategies does not necessarily give rise to conscious processes. The intention to solve a problem may result in the deployment of cognitive resources without the subject being aware of how those resources are deployed. For instance, a subject attempting to solve a triad such as "OFF TOP TAIL" is unaware that "SPIN" is the solution but nonetheless shows a priming effect for "SPIN" on a lexical-decision task. The subject has clearly intended to solve the problem, and there is evidence that the process is strategically-controlled rather than automatic, since the priming effect is only observed in the problem-solving condition (Experiment 1) but not in the study condition (Experiment 2). However, the subject is not conscious of the solution during the lexical-decision task.

To summarize, then, the results of the present study lead us to consider the following possibilities:

<u>1) Implicit problem-solving is nonconscious.</u> It is unlikely that the priming effect we observed for unsolved triads is due to the subjects becoming aware of the solution during the lexical-decision task, since reaction times to triad solutions on an identification task (Experiment 4) were over 1000 milliseconds longer than the lexical-decision reaction times for the same items. Our interpretation of this finding is that the time it takes for subjects to make a lexical decision is insufficient for them to identify the solution consciously. This interpretation is supported by the absence of a correlation between the mean priming effect for a given item and the probability of a correct

identification for that item (Experiment 4).

2) Implicit problem-solving is not automatic. The priming effect reported in Experiment 1 dissipates when subjects are instructed to perform a task other than problem-solving (Experiment 2) or when the triads are incoherent so that problem-solving cannot take place (Experiment 3). This task-specificity is consistent with the notion of strategic flexibility described by Logan (1980). If the effect we observed were the result of an automatic process, it would remain constant regardless of any changes in the subject's intention or strategy.

3) Implicit problem-solving is neither a perceptual nor a purely memory-related phenomenon. Our priming effect is not a repetition effect, since subjects have not had a prior exposure to a perceptual representation of the solution during any of the experiments. Neither is it a typical semantic priming effect. Although the three cue words in each triad are semantically-related to the target, the degree of association is extremely weak. In fact, these kinds of problems are constructed by selecting cues that are only remote associates of the target (Mednick & Mednick, 1967). When subjects were asked to study the cues as they would in the context of a memory experiment, the priming effect for the target was nonsignificant (Experiment 2). We conclude

from this that the effect observed in Experiment 1 is not just a semantic memory effect but is specifically linked to the task of problem-solving.

A fourth possibility that remains highly speculative is that implicit problem-solving is a qualitatively different phenomenon than explicit problem-solving. Evidence for a dissociation between the two forms of problem-solving is inconclusive, leaving this issue to be resolved by future studies.

The research we have reported may open up a number of interesting questions about problem-solving. A great deal more work is needed to determine if implicit problem-solving generalizes to different kinds of nonroutine problems, such as anagrams and fragment completions. It would be worthwhile to look for dissociations between implicit and explicit problem-solving. The relationship between implicit problem-solving and metacognition should be explored. We are also interested in investigating the effect of different strategies on implicit problem-solving. The mechanism by which nonroutine problems are solved is essentially unknown. Computer modeling may provide valuable information about the underlying mechanism, and there is insight to be gained from the study of brain-damaged patients. In essence, this is a wide open field of study.

REFERENCES

Baddeley, A. D. (1976). The psychology of memory. New York: Basic Books.

Bowers, K. S., Regehr, G., Balthazard, C. G., & Parker, K. (1990). Intuition in the context of discovery. Cognitive Psychology, 22, 72-110.

Bowers, P. G., & Bowers, K. S. (1979). Hypnosis and creativity: A theoretical and empirical rapprochement. In E. Fromm & R. E. Shor (Eds.), Hypnosis: Developments in research and new perspectives (2nd ed., pp. 351-379). New York: Aldine.

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

Dorfman, J., Shames, V. A., & Kihlstrom, J. F. Intuition, incubation and insight. Manuscript in preparation.

Durso, F. T., Rea, C. B., & Dayton, T. (1994). Graph-theoretic confirmation of restructuring during insight. Psychological Science, 5, 94-98.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. Journal of Experimental Psychology: Learning, Memory, and Cognition, 10, 680-698.

Kihlstrom, J. F. (1987). The cognitive unconscious. Science, 237, 1445-1452.

Kihlstrom, J. F. (1990). The psychological unconscious. In L. A. Pervin (Ed.), Handbook of personality: Theory and Research (pp. 445-464). New York: The Guilford Press.

Kihlstrom, J. F. (1993). The continuum of consciousness. Consciousness and Cognition, 2, 334-354.

Lockhart, R. S., & Blackburn, A. B. (1993). Implicit processes in problem solving. In P. Graf & M. E. J. Masson (Eds.), Implicit memory: New Directions in cognitive development, and neuropsychology (pp. 95-115). Hillsdale, NJ: Lawrence Erlbaum.

Logan, G. D. (1980). Attention and automaticity in Stroop and priming tasks: Theory and data. Cognitive Psychology, 12, 523-553.

Madigan, C. O., & Elwood, A. (1983). Brainstorms and thunderbolts. New York: Macmillan.

McAndrews, M. P., & Moscovitch, M. (1990). Transfer effects in implicit tests of memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 772-788.

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

Mednick, S. A., & Mednick, M. T. (1967). Examiners manual: Remote Associates Test. Boston: Houghton Mifflin.

Metcalfe, J. (1986). Premonitions of insight predict impending error. Journal of Experimental Psychology: Learning, Memory, and Cognition, 12, 23-634.

Metcalfe, J., & Wiebe, D. (1987). Intuition in insight and noninsight problem solving. Memory and Cognition, 15, 238-246.

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. Journal of Experimental Psychology, 90, 227-234.

Nelson, T. O., & Narens, L. (1980). Norms of 300 general-information questions: Accuracy of recall, and feeling-of-knowing ratings. Journal of Verbal Learning and Verbal Behavior, 19, 338-368.

Olton, R. M. (1979). Experimental studies of incubation: Searching for the elusive. Journal of

Creative Behavior, 13, 9-22.

Perkins, D. N. (1981). The mind's best work. Cambridge, MA: Harvard University Press.

Poincare, H. (1913). Mathematical creation. In The foundations of science. (G. H. Halstead, trans.) New York: Science Press.

Posner, M. I. (1973). Cognition: An introduction. Glenview, IL: Scott, Foresman and Co.

Posner, M. I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Eds.), Information processing and cognition. Hillsdale, NJ: Lawrence Erlbaum.

Roediger, H. L. (1990). Implicit memory: A commentary. Bulletin of the Psychonomic Society, 28, 373-380.

Rubenstein, H., Garfield, L., and Millikan, J. A. (1970). Homographic entries in the internal lexicon. Journal of Verbal Learning and Verbal Behavior, 9, 487-494.

Scarborough, D. L., Cortese, C., and Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. Journal of Experimental Psychology: Human Perception and Performance, 3, 1-17.

Schacter, D. L. (1987). Implicit memory: History and current status. Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, 501-518.

Schacter, D. L. (1992). Consciousness and awareness in memory and amnesia: Critical issues. In A. D. Milner & M. D. Rugg (Eds.), The neuropsychology of consciousness. San Diego: Academic Press.

Shames, V. A., & Bowers, P. G. (1992). Hypnosis and creativity. In E. Fromm & M. R. Nash (Eds.), Contemporary hypnosis research (pp. 334-363). New York: The Guilford Press.

Simon, H. A. (1989). The information-processing explanation of Gestalt phenomena. In H. A. Simon (Ed.), Models of thought (Vol. II). New Haven: Yale University Press.

Simon, H. A., Newell, A., & Shaw, J. C. (1979). The process of creative thinking. In H. A. Simon (Ed.), Models of thought (pp. 144-174). New Haven: Yale University Press.

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

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. Psychological Review, 80, 353-373.

Wallas, G. (1926). The art of thought. New York: Franklin Watts.

Warrington, E. K., & Weiskrantz, L. (1970). Amnesia: Consolidation or retrieval? Nature, 217, 972-974.

Weisberg, R. W. (1992). Metacognition and insight during problem solving: Comment on Metcalfe. Journal of Experimental Psychology: Learning, Memory, and Cognition, 18, 426-431.

Yaniv, I., & Meyer, D. E. (1987). Activation and metacognition of inaccessible stored information: Potential bases for incubation effects in problem solving. Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, 187-205.

TABLE 1

Mean Lexical-Decision Times (ms) for Target Words in the Solved and Unsolved Conditions in Experiment 1

Condition	RT	Error rate (%)	Priming
Solved			
Primed	593	1.4	12
Control	605	2.4	
Unsolved			
Primed	571	2.0	38
Control	609	3.4	

Note. RT = reaction times.

TABLE 2

Mean Lexical-Decision Times (ms) for Target Words in Experiment 2 and the Unsolved Condition in Experiment 1

Condition	RT	Error rate (%)	Priming
Experiment 2			
Primed	560	3.5	9
Control	569	5.5	
Unsolved			
Primed	571	2.0	38
Control	609	3.4	

Note. RT = reaction times.

TABLE 3

Mean Lexical-Decision Times (ms) for Target Words in Experiment 3 and the Unsolved Condition in Experiment 1

Condition	RT	Error rate (%)	Priming
Experiment 3			
Primed	574	4.1	6
Control	580	3.7	
Unsolved			
Primed	571	2.0	38
Control	609	3.4	

Note. RT = reaction times.

TABLE 4

Mean Reaction Times (ms) for Identification Task in Experiment 4 and Lexical Decision Task for Primed Items in the Unsolved Condition in Experiment 1

Condition	RT	SD	t(34)
Identification	1697	323	20.47*
Lexical Decision	571	88	

Note. RT = reaction times; * denotes significance at p<.05.

TABLE 5

Mean Lexical-Decision Times (ms) for Target Words in the Solved and Unsolved Conditions in Experiment 5

Condition	RT	Error rate(%)	Priming
Solved			
Primed	567	3.4	25
Control	592	3.9	
Unsolved			
Primed	570	3.7	30
Control	600	3.9	

Note. RT = reaction times.

TABLE 6

Probabilities and Normalized Item-Difficulty Scores for Triads Used in Experiment 5

Triad Number	Probability of Unsolved Triads	Item-Difficulty Score(Normalized)
1	.50	-0.19
2	.70	+1.06
3	.70	+1.06
4	.25	-1.75
5	.70	+1.06
6	.65	+0.75
7	.45	-0.50
8	.80	+1.56
9	.65	+0.75
10	.30	-1.56
11	.50	-0.19
12	.50	-0.19
13	.55	+0.13
14	.40	-0.81
15	.45	-0.50
16	.65	+0.63
17	.30	-1.44
18	.40	-0.81
19	.20	-2.06
20	.60	+0.44
21	.30	-1.44
22	.45	-0.50
23	.15	-2.38
24	.70	+1.06
25	.35	-1.13
26	.55	+0.13
27	.60	+0.44
28	.55	+0.13
29	.75	+1.34
30	.65	+0.63
31	.45	-0.50
32	.50	-0.19
33	.70	+1.06
34	.50	-0.19

TABLE 6 (Continued)

Probabilities and Normalized Item-Difficulty Scores for Triads Used in Experiment 5

Triad Number	Probability of Unsolved Triads	Item Difficulty Score(Normalized)
35	.60	+0.44
36	.75	+1.34
37	.65	+0.63
38	.55	+0.13
39	.45	-0.50
40	.60	+0.44
41	.40	-0.81
42	.20	-2.06
43	.70	+1.06
44	.55	+0.13
45	.55	+0.13
46	.50	-0.19
47	.45	-0.50
48	.65	+0.63
49	.40	-0.81
50	.70	+1.06
51	.80	+1.69
52	.40	-0.81
53	.60	+0.44
54	.90	+2.31
55	.45	-0.50
56	.45	-0.50
57	.40	-0.81
58	.40	-0.81
59	.65	+0.63
60	.65	+0.63
61	.40	-0.81
62	.60	+0.44
63	.40	-0.81
64	.50	-0.19
65	.45	-0.50
66	.40	-0.81
67	.70	+1.06
68	.30	-1.44

TABLE 7

Mean Lexical-Decision Times (ms) for Target Words Corresponding to the Solutions for Hard and Easy Items in Experiment 6

Condition	RT	Error rate(%)	Priming
Easy			
Primed	573	2.8	12
Control	585	3.6	
Hard			
Primed	575	5.0	38
Control	613	4.4	

Note. RT = reaction times.

APPENDIX A

Materials Used in Experiment 5

Number	Triad	Solution	Source
1	WICKED BUSTLE SLICKER	CITY	RAT1
2	JUMP KILL BLISS	JOY	RAT1
3	COTTON BATHTUB TONIC	GIN	BOWERS
4	WIDOW BITE MONKEY	SPIDER	RAT1
5	CLOTH SAD OUT	SACK	BOWERS
6	THREAD PINE PAIN	NEEDLE	BOWERS
7	SURPRISE WRAP CARE	GIFT	BOWERS
8	BLANK WHITE LINES	PAPER	BOWERS
9	STOP PETTY SNEAK	THIEF	RAT1
10	GOLD STOOL TENDER	BAR	BOWERS
11	CHERRY TIME SMELL	BLOSSOM	RAT1
12	STRAP POCKET TIME	WATCH	BOWERS
13	SANDWICH GOLF FOOT	CLUB	BOWERS
14	SQUARE CARDBOARD OPEN	BOX	BOWERS
15	LICK SPRINKLE MINES	SALT	RAT1
16	ATHLETES WEB RABBIT	FOOT	RAT1
17	COIN QUICK SPOON	SILVER	BOWERS
18	BLOOD MUSIC CHEESE	BLUE	RAT1
19	BROKEN CLEAR EYE	GLASS	BOWERS
20	HALL CAR SWIMMING	POOL	BOWERS
21	BASS COMPLEX SLEEP	DEEP	RAT1
22	CHAMBER STAFF BOX	MUSIC	RAT1
23	FALLING ACTOR DUST	STAR	BOWERS*
24	MAGIC PLUSH FLOOR	CARPET	BOWERS
25	CRACKER UNION RABBIT	JACK	BOWERS
26	COLOR NUMBERS OIL	PAINT	BOWERS
27	BIG LEAF SHADE	TREE	BOWERS

28	MOUSE SHARP BLUE	CHEESE	RAT1
29	SHOPPING WASHER PICTURE	WINDOW	RAT1
30	LAPSE VIVID ELEPHANT	MEMORY	RAT1
31	HIGH BOOK SOUR	NOTE	BOWERS
32	NOTCH FLIGHT SPIN	TOP	BOWERS
33	NOTE DIVE CHAIR	HIGH	RAT1
34	BARREL ROOT BELLY	BEER	BOWERS

Note. BOWERS = Bowers, Regehr, Balthazard, & Parker (1990); RAT1 = Form 1 of Mednick & Mednick (1967); * = modified from the original.

APPENDIX A (Continued)

Materials Used in Experiment 5

Number	Triad	Solution	Source
35	STRIKE SAME TENNIS	MATCH	BOWERS
36	BUMP THROAT SUM	LUMP	BOWERS
37	ZONE STILL NOISE	QUIET	BOWERS
38	SILK CREAM EVEN	SMOOTH	BOWERS
39	SQUARE TELEPHONE CLUB	BOOK	BOWERS
40	ENVY GOLF BEANS	GREEN	RAT1
41	BALD SCREECH EMBLEM	EAGLE	RAT1
42	SKUNK KINGS BOILED	CABBAGE	RAT1
43	INCH DEAL PEG	SQUARE	RAT1
44	CHOCOLATE FORTUNE TIN	COOKIE	RAT1
45	SPEAK MONEY STREET	EASY	BOWERS
46	WALKER MAIN SWEEPER	STREET	RAT1
47	ACHE HUNTER CABBAGE	HEAD	BOWERS
48	ROCK TIMES STEEL	HARD	BOWERS*
49	WATER TOBACCO STOVE	PIPE	BOWERS
50	STALK TRAINER KING	LION	RAT1
51	STICK LIGHT BIRTHDAY	CANDLE	BOWERS
52	MANNERS ROUND TENNIS	TABLE	BOWERS
53	MEASURE DESK SCOTCH	TAPE	BOWERS
54	SORE SHOULDER SWEAT	COLD	RAT1
55	TICKET SHOP BROKER	PAWN	BOWERS
56	PURE BLUE FALL	WATER	BOWERS
57	PLAYING CREDIT REPORT	CARD	BOWERS
58	ROOM BLOOD SALTS	BATH	RAT1
59	BOARD MAGIC DEATH	BLACK	RAT1
60	PUSS TART SPOILED	SOUR	RAT1
61	RABBIT CLOUD HOUSE	WHITE	BOWERS
62	INK HERRING NECK	RED	BOWERS

63	OFF TRUMPET ATOMIC	BLAST	BOWERS
64	BLADE WITTED WEARY	DULL	BOWERS
65	SNACK LINE BIRTHDAY	PARTY	BOWERS
66	SALT DEEP FOAM	SEA	BOWERS
67	FOOT COLLECTION OUT	STAMP	BOWERS
68	TIME HAIR STRETCH	LONG	BOWERS

Note. BOWERS = Bowers, Regehr, Balthazard, & Parker (1990); RAT1 = Form 1 of Mednick & Mednick (1967); * = modified from the original.