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Fixation and incubation effects in problem-solving

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FIXATION AND INCUBATION EFFECTS

IN PROBLEM SOLVING

BY

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DEDICATION

This dissertation is dedicated to my family, especially my parents. Thanks for everything.

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ABSTRACT

FIXATION AND INCUBATION EFFECTS
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In four experiments, the effects of fixation and suppression processes in problem solving ability were investigated. Previous research has shown that efficient suppression mechanisms are integral to verbal ability (e.g., Gernsbacher & Faust, 1991; Gernsbacher, Varner, & Faust, 1990; Hartman & Hasher, 1991). The present set of experiments demonstrated that such a mechanism is also a component of problem solving ability. The efficiency with which participants were able to suppress inappropriate meanings of ambiguous words was used as a measure of suppression skill. Experiment 1 established that participants who were able to make use of previously-presented information to solve difficult insight problems were also more efficient at suppressing the inappropriate word meanings. Experiment 3 showed that participants who scored highly on the Remote Associates Test (RAT) were better able to suppress the inappropriate meanings, in comparison to low RAT solvers.

Experiments 1 - 4 investigated fixation effects. Experiment 1 demonstrated that fixation to incorrect responses on the insight problems is not easily attenuated when these incorrect responses have been generated by the subject. Experiment 2 showed that this

fixation effect is not attenuated even with the inclusion of an incubation period between a first solution trial, in which the initial incorrect response is generated and a subsequent trial, in which the same problems are again presented, along with clues to solution.

Experiments 3 and 4 showed that fixation can be attenuated when initial incorrect solutions to RAT items are suggested by the experimenter. This is in contrast to Experiments 1 and 2, in which initial incorrect responses were generated by the participants. These attenuation effects were evidenced by increased solution rates to the RATs after an incubation period.

These experiments also investigated the degree to which individuals of varying ability levels benefit from a period of incubation. Previous research has shown mixed results in this regard. The present findings are also inconclusive. Experiment 3 showed that high-ability problem solvers benefited more from the incubation period than did low-ability problem solvers, while Experiment 4 revealed no differences in the incubation effects for individuals of varying problem solving ability.

INTRODUCTION

From the earliest days of psychological research, investigators have speculated on the processes of thinking and problem solving. These early approaches were dominated by two somewhat opposing approaches (see Newell & Simon, 1972 and Woodworth & Schlosberg, 1954 for reviews). One, articulated notably by Thorndike (1898) attributed successful problem solving to a process of trial and error, by which an animal or person finds solution to a problem by eliminating potential incorrect responses. Thorndike (1901) also concluded that while all of the species that he tested used the same associative processes, some species such as monkeys, formed associations much more quickly than did the others. Alternatively, Kohler (1925) and other Gestalt psychologists alleged that problems are solved suddenly, after a restructuring of the problem has taken place. An important distinction between the two theories is that solving problems by trial and error necessarily depends upon past experience, while the insight approach emphasizes the immediate circumstances, such as composition and organization of the "problem field."

Thorndike (1898) developed a number of problems that embodied that concept of trial and error learning. According to the trial and error framework, an animal has available to it a given set of responses, and a variety of circumstances will influence response selection in any particular case. For example, when first placed in his "puzzle box," Thorndike's cats tried many diffuse struggling responses, such as clawing, pulling, and kicking in attempting to escape the box. Escape was possible when the animal came upon the necessary response. Importantly, Thorndike noted that the responses made by the cats were not indiscriminant, but were similar to the types of behaviors that had previously resulted in escape from enclosed places. This is supported by his observation that the cats did not emit every possible behavior, but rather confined their attention to the slots and moving parts of the box, which previously proved successful in similar situations. Further, when Thorndike (1911) made escape from the puzzle box contingent upon non-stereotypical "escape" responses, such as licking, he found that the cats took far longer to emit the correct response. He concluded that such responses were not transferred to the puzzle box situation because they were not within the animal's repertoire of likely escape solutions.

Kohler (1925), working with chimpanzees and other apes, presented his subjects with a series of novel problems, one of which was retrieving bananas that were outside of the reach of a caged chimpanzee. Available to the chimp were two sticks, both of which were too short to reach the bananas. According to Kohler, the chimps initially tried to use each stick to retrieve the bananas. When this approach proved unsuccessful, the chimps stopped working on the problem for a period of time before making the sudden realization that the sticks could be pushed together to create a tool of sufficient length to accomplish the task. Kohler maintained that it was not simply the past history of stick use that triggered solutions, but rather a restructuring of the problem that led to an immediate solution.

Subsequent research, however, has proven, whatever the merits of Kohler's arguments about "insight," that prior experience plays an important role in problem solving. Birch (1945) showed that solutions to the Kohler problems were dependent upon the past history of the chimps. He presented the banana problem to chimps that were raised in captivity and therefore had no past experience with using sticks as tools. Birch found that none of the chimps was able to solve the problem. However, all of the chimps solved the problem easily after they were provided with the opportunity to play with similar sticks on several occasions. Birch concluded that past experience is a necessary requisite to solving novel problems.

Recent research with humans draws similar conclusions (e.g., Weisberg, 1993; Weisberg & Alba, 1981). There can be no doubt that prior experience plays a crucial role in any account of problem solving. Immediately antecedent experiences have been shown to both facilitate solutions, in studies of transfer (e.g., Gick & Holyoak, 1980, 1983; Maier, 1931) and hinder or block solutions, in studies of fixation (e.g., Duncker, 1945; Luchins, 1942). And of course, the participants in these experiments bring a long history of experience to the laboratory that can be summarized in so-called subject variables, such as intelligence, age, flexibility of thought, expertise, ability to suppress extraneous information, and motivation. While these variables might be referred to as subject variables, because they describe attributes that one brings to a problem solving situation, researchers have also been interested in ways in which the problem solving situation can be experimentally manipulated. For example, the mathematical problems used by Luchins (1942) served to direct solvers to a particular rule for obtaining the desired quantities. Other such manipulations have included varying instructions, presenting extraneous information along with the problem to be solved, providing participants with clues to solving problems, and introducing varying time delays ("incubation" periods) between successive solution attempts.

The research reported in this dissertation looks at human problem solving within this broad trial and error framework. It should be noted that more modern conceptions of problem solving describe the process as a search through "problem space" (Newell & Simon, 1972). The problem space includes the presented problem and the goal, as well as the problem solver's knowledge. Thus, this conceptualization is functionally equivalent to the trial and error terminology. The problems used are traditional ones of a verbal nature and presuppose that individuals do have the appropriate responses within their verbal repertoire. They are among those that Newell and Simon (1972) called well-defined problems, given that the parameters are clearly specified and there is a specific goal, or solution, to each problem. The overall objective of my project is to examine the interrelationship of several experimental manipulations, as well as certain subject variables, on problem solutions. Details of the factors relevant to this dissertation will be considered in the following chapters.

CHAPTER I

PROBLEM SOLVING

This chapter provides a review of research relevant to the problems and methodologies used in the present set of experiments. These include conceptual transfer, insight riddles, and the Remote Associates Test. Subsequent chapters outline the variables that are used to predict success on these types of problems.

Conceptual Transfer

Conceptual transfer involves the access of relevant knowledge to solve problems. A number of investigations of this issue have demonstrated that problem solvers fail to spontaneously transfer available information to new situations (e.g., Gick & Holyoak, 1980; Needham & Begg, 1991; Perfetto, Bransford & Franks, 1983; Ross, Ryan, & Tenpenny, 1989; Weisberg, DiCammilo, & Phillips, 1978). Many of these studies have used problems similar to those developed by German psychologist, Karl Duncker, who in 1945 demonstrated that solvers will proceed through a series of steps when working out the solutions to the difficult problems with which he presented them. Two of his scenarios have become classics in the problem solving literature.

The first is the candle problem, in which participants were presented with the task of finding a way to mount a candle to a wall, using only the candle, a box of matches, and some nails. He found that participants were generally unable to solve the problem, which involved dumping the matches from the box, nailing the box to the wall, and using the matches to light the candle until there was enough wax to mount the candle in the box. Duncker referred to the inability to solve this problem as "functional fixedness," or the idea that we generally think of only the customary use for a particular object, and therefore, not the novel use that is necessary to solve this type of problem. In this case one must conceptualize using the box as a holder for the candle, rather than as a container (Glucksberg & Weisberg, 1966).

The second of Duncker's problems is the radiation problem. In this problem, participants read a story that described a cancer procedure in which a tumor had to be destroyed with radiation. The caveat was that the amount of radiation passing through the healthy tissue on the way to the tumor would destroy these cells as well. Participants were asked to devise a way that the tumor could be destroyed, while leaving the surrounding tissue unharmed. The correct solution was to attack the tumor with smaller doses of radiation, from a number of points, thereby administering the required dosage to destroy the cancer, while leaving the healthy tissue intact. Again, Duncker found that participants were very unlikely to solve this problem.

Gick and Holyoak (1980) and Weisberg et al. (1978) revisited Duncker's problems, and provided clues to solving them. Weisberg et al. presented the candle problem. Prior to being faced with this problem, participants were given the task of memorizing a series of paired associates. For experimental groups, one of these pairs was, "candle-box." Results showed that these participants were no more likely to solve the candle problem than controls who memorized the pair, "candle-paper." Only a second experimental group, who were given the hint that one of the previously-memorized pairs would be helpful to solution, were able to solve the problem. Weisberg et al. concluded that simply possessing relevant information is not sufficient for effective solution, but that one must also realize that the information is relevant.

Similarly, Gick and Holyoak (1980) administered the radiation problem. Before being presented with this problem, participants read a similar problem in which a farmer was faced with the dilemma of providing a large amount of water to his crops, without creating erosion problems by having too much water going through his field via any one pathway. The farmer had the idea of providing several small irrigation systems to the field, thereby sparing the flooding that would be caused over just one path. Surprisingly, Gick and Holyoak's participants did not spontaneously use the information from the farmer problem to solve the radiation problem, although the time between presentation of the two problems was only several minutes. When they were instructed to use the farmer information, nearly all of the participants solved the problem.

Other research has shown that solvers will transfer, but again, only if they are explicitly instructed to do so (e.g., Landrum, 1990; Perfetto et al., 1983; Ross et al., 1989; Spencer & Weisberg, 1986; Stein, Way, Benningfield, & Hedgecough, 1986; Weisberg et al., 1978). Perfetto et al. presented a series of statements about a specific protagonist or object. An example is, "A man who lived in a small town in the U.S. married 20 different women of the same town. All are still living and he has never divorced any of them. Yet, he has broken no law. Can you explain?" In some conditions, the statements were proceeded by a clue statement. In this example the clue was, "A minister marries several people each week." This statement was intended to provide participants with the information necessary to solve the problem. These clue sentences were presented in the initial part of the experiment. As an orienting task, the participants were asked to judge the sentences according to their truthfulness. In the subsequent problem solving phase, participants in the informed group were told that the acquisition sentences would help them to solve the problems, while the uninformed group was not given this hint. Consistent with Gick and Holyoak's (1980) results, participants did not solve these problems spontaneously. That is, they did not transfer the clue information to solve the puzzle unless they were explicitly told to do so.

Fixation Effects in Transfer Paradigms

A secondary finding by Perfetto et al. (1983) was that participants who initially had been uninformed of the necessity to transfer the clue information to solve the puzzles were often still unable to solve the same problems on a second trial, when they were given these instructions. However, they were able to use this clue information to solve puzzles presented on this trial that they had not previously seen. In this procedure the participants who had originally been in the uninformed group were retested. This time, they were informed of the relationship between the clue statements and the puzzles. They were again presented with the original puzzles to solve, as well as some new puzzles that had not been included in the first trial. The clue statement contained a relevant clue for each of these puzzles.

Perfetto et al. (1983) found that participants solved the new problems, but that they continued to experience difficulty in solving the problems that they had received in the first trial. The authors concluded that participants were unable to solve the original problems in the second session because they had previously generated their own responses to these puzzles, which they continued to think were appropriate even after they were informed of the correct response. It should be mentioned that each of the puzzles could have one or more plausible, though incorrect, solutions that were not the responses that were supplied by the experimenter. For example, the minister puzzle might suggest the conclusion that the man was a bigamist living in Utah, although this possibility was ruled out in the puzzle. Further, the participants were informed that the clues supplied in the first part of the experiment were appropriate for solving the puzzles.

Perfetto et al. (1983) concluded that the participants encoded the wrong responses on the first reading of the puzzles, and retrieved these responses during the second reading. This conclusion is supported by the finding that the participants did use the supplied clues to solve the new puzzles in the second trial. Therefore, the clues were available to participants, but the inability to make use of them was limited to the riddles for which incorrect responses had already been generated. This item-specific fixation has been replicated in subsequent work with the same riddle materials (Adams, Kasserman, Yearwood, Perfetto, Bransford, & Franks, 1988; Perfetto, Yearwood, Franks, & Bransford, 1987).

In a follow-up study, Perfetto et al. (1987) tested their conclusion that the process of generating solutions to the riddles interfered with the access of the relevant acquisition sentence when solving on Trial 2. In this experiment, the "generate" group attempted to solve the riddles on Trial 1, while the "read" simply read the riddles, which were accompanied by the solutions of a yoked participant in the generate condition. Both groups attempted to use the acquisition sentences to solve the riddles on Trial 2. Results showed that generate group solved relatively fewer of the "old" riddles on Trial 2 than did the read group. This supports Perfetto et al.'s (1983) earlier theory that Trial 1 solution attempts interfered with accessing of the acquisition sentences for "old" riddles on Trial 2.

Other researchers (e.g., Duncker, 1945; Ross, 1984; Ross & Kennedy, 1990) have made similar claims. For example, Ross & Kennedy forwarded a theory of "reminding" that is specific to problem solving. This theory states that we solve problems through a process of reminding, by which we automatically access previous information that shares features with the problem to be solved. With regard to Perfetto et al.'s (1983) findings, it is possible that when participants attempt to solve the same riddles on Trial 2, they are reminded of their first solution attempt, which includes their original incorrect responses. Therefore, these incorrect responses block the access to the appropriate clue information.

While much literature has focused on a general lack of spontaneous transfer, other research has shown evidence for transfer in some participants. The following section entails a discussion of studies that have identified certain attributes of problem solvers who are able to successfully transfer relevant information when faced with a novel problem.

Spontaneous Transfer and Problem Solving Ability

The previous section outlined several studies demonstrating that simply possessing necessary information is not sufficient to facilitate problem solving, but that participants must also recognize that this information is relevant to the problem (Perfetto et al., 1983; Stein et al., 1986). These studies have shown that participants are very unlikely to spontaneously access the relevant information. However, there has been little research to investigate the characteristics of the small number of solvers who do exhibit spontaneous transfer (e.g., Gick & Holyoak, 1983; Lockhart, Lamon, & Gick, 1988; Novick, 1988; Spencer & Weisberg, 1986; Stein et al., 1986).

Gick and Holyoak (1983) presented two stories that were very similar in structure to the radiation problem. Participants first read each story and summarized it. They were then asked to describe how the two stories shared similarities. Participants were then presented with the radiation problem. As in the other studies of transfer, some participants were instructed that the previously-presented stories would aid in solving the radiation problem, while others were not informed of this relationship. Results showed that the informed group had higher solution rates than uninformed group. However, within both groups there was a relationship between the quality of the description of similarity between the two initial problems and the likelihood of solving the radiation problem. For example, in the uninformed group, 90% of the participants who provided a high-quality similarity description produced a solution to the radiation problem. A high-quality description was one that described ways in which the two problems shared structural similarities. These included a goal of a large quantity of something reaching a particular central location, the limitation that all of the force could not be delivered along the same route, and a solution that involved breaking the total force into smaller quantities that met at the desired location. This was referred to as the convergence solution.

Gick and Holyoak (1983) concluded that one aspect of being a good problem solver is the ability to "see" the structural similarities between analogous problems. Subsequently, Holyoak and colleagues (e.g., Holyoak, 1985; Holyoak & Thagard, 1989) have formulated the pragmatic schema model of analogical transfer, which states that successful problem solvers develop an abstract schema for working out problems of a similar nature. In the case of the Gick and Holyoak results, individuals who developed an appropriate schema for comparing the two example problems were able to utilize that schematic information and appropriately transfer it to solve the radiation problem. This "appropriate schema" involved recognizing the underlying structural similarities between the two examples. In contrast, poor problem solvers, those who did not spontaneously transfer solution to the radiation problem, focused on the surface similarities between the two example problems.

Other researchers (e.g., Chen, 1995; Chen, Yanowitz, & Daehler, 1995; Chi, Feltovich, & Glaser, 1981; Novick, 1988) have forwarded similar theories that apply to various domains of problem solving. These theories share the basic supposition that expert problem solvers focus on structural similarities between analogous problems in various domains, while novice problem solvers focus on surface similarities. For example, Chi et al. showed this effect in physics experts and novices.

Accessing Remote Associates in Problem Solving

Another common task that has been used to measure problem solving performance is the Remote Associates Test (RAT), which involves a series of items, each made up of three words that are related to each other in some way. The task is to determine the common bond between the three words. An example is this: SNOW, DOWN, OUT. This would require a response of "fall", since each test word goes with "fall," (i.e., snowfall, downfall, fall out). The solution to each of these items is a word that has only a weak connection to each of the three words; that is, the solution is remotely associated to each of the words. Therefore, in order to solve each item, it is necessary to look beyond the dominant meaning of each of the three words, and focus on the less-dominant meaning that is somehow remotely associated to the other words via its connection to a fourth word.

Mednick (1962) devised the RAT as a measure of creativity. He believed that people who are able to make these remote associates should also be more creative in general because, according to Mednick's conceptualization of creativity, a creative process is one that makes use of novel solutions to situations. While the RAT was conceptualized by Mednick as a measure of creativity, its usefulness as a predictor of this ability has been limited (Andrews, 1975; see Nickerson, 1985 for a review). However, the RAT has proven to be a reliable indicator of verbal ability (Katz, 1983), making it suitable for use as a measure of verbal problem solving.

Simonton (1988) forwarded a theory of creative problem solving that is modeled after Mednick's work. This theory states that original ideas result from the random combination of remotely-associated ideas. In Simonton's view, successful problem solvers possesses a "looser" set of connections between concepts than do less creative people and are therefore less rigidly bound to systematic associations. Simonton hypothesized that this flexibility of thought allowed such a problem solver to access the necessary solution to the RAT because it is possible to look beyond the dominant meanings of the words comprising the RAT items.

From the above discussion, it is possible to draw a connection between ability on the RAT and performance on the riddles that were described previously. In both cases, it is necessary for the solver to "look beyond" the dominant meanings of concepts and make use of the less obvious meanings to solve the problem at hand. For example, in order to solve the "minister" problem, one must look ignore the dominant meaning of "marry," that is, to be wed, and instead access the less common meaning, to perform a marriage ceremony. Similarly, to solve a RAT item, it is necessary to attend to the less common meaning of the three RAT words. The current set of experiments includes an attempt to relate the skill to solve RAT items to the ability to solve the previously-described riddles. It is expected that these abilities are positively correlated.

In general, researchers have claimed that good problem solvers, and more specifically, successful transfers, possess specific skills, such as the ability to recognize structural similarities between similar types of problems, and the ability for non-rigid thinking. The current dissertation includes an investigation of another characteristic of participants who possess high problem solving ability. This trait, the ability to suppress extraneous information, is discussed in the next chapter.

CHAPTER II

INTERFERENCE AND SUPPRESSION

This section will provide an overview of the literature and theories regarding the role of suppression efficiency in comprehension skill. Previous researchers have shown that suppression ability is integral to certain cognitive skills, such as verbal comprehension. The present dissertation extends this work to investigate the impact of suppression skill on problem solving ability.

The Stroop Task

Much of the research on interference effects in cognitive processes stems from the early work of J. R. Stroop (1935), who demonstrated that the time necessary to name the colors of words could be affected by the meanings of the words. Stroop required participants to quickly name the ink color in which words were printed. The words themselves were color names (e.g., the word, "red" printed in green ink). Stroop found that reading times were longer if the words and the ink colors were incompatible. He concluded that participants experienced interference from the word meanings when trying to name the ink colors.

Performance on Stroop-like tasks has long been used as a measure of reading ability in children (e.g., Comalli, Wapner, & Werner, 1962; Merrill, Sperber, & McCauley, 1981; Rosinski, Golinkoff, & Kukish, 1975). These studies have demonstrated that children suffer the greatest interference on this task just after they have learned to read. Performance then improves and stabilizes in early adulthood. A decrease in performance, that is, an increase in the interference effect on the Stroop task, is evidenced in late adulthood (Hasher, Stoltzfus, Zacks, & Rympa, 1991; McDowd & Oseas-Kreger, 1991).

Negative Priming

In 1966, Dalrymple-Alford and Budayr provided an interesting extension of the Stroop Effect. Participants were presented with the Stroop Task, as described above. However, in this experiment, each word was the name of the following color on the list. For example, BLUE printed in yellow ink was followed by RED printed in blue ink, then GREEN printed in red ink, etc. In this way, participants had to name the ink color for the word that they had ignored on the previous trial. Results showed that the time necessary to name the ink colors on this task was even slower than on the standard Stroop Task. Dalrymple-Alford and Budayr concluded that participants had to suppress the name of each word in order to name the ink color. Therefore, when the just-suppressed word had to be activated to name the following ink color, the response times were longer, in comparison to trials when the ink color was unrelated to the previous word.

Tipper (1985) originated the term, "negative priming," to describe this effect. He defined negative priming as the increase in response time as a result of a prior presentation of the target, compared to a condition in which the target had not previously been presented and ignored. This can be compared to priming, in which response times to just-attended stimuli are facilitated. Tipper and colleagues (e.g., Tipper, 1985; Tipper &

Cranston, 1985) provided evidence for this effect in a series of experiments.

Tipper and Cranston (1985) presented participants with a series of superimposed letters. One set of the letters was printed in red ink and the other set was printed in green ink. The required task was to read the red letters out loud while ignoring the green letters. The measurement of interest was the time necessary to read a control condition in which only the red target letters were presented, versus the time taken to read the ignored prime condition, which consisted of target letters that had been presented as distractors on the previous trial. That is, the red letters on this trial were the green letters on the previous trial. If participants were successful inhibitors, then they would experience difficulty naming the targets on the ignored prime condition. Results supported these predictions.

Subsequently, researchers have shown negative priming effects in many other selective-attention tasks, such as picture naming (Tipper, 1985), semantic categorization (Tipper & Driver, 1988), and counting (Driver & Tipper, 1989). Researchers have also used the Tipper task to investigate the role of inhibition skills in older adults' diminished abilities in divided attention tasks (e.g., McDowd & Oseas-Kreger, 1991). These researchers demonstrated negative priming in younger adults, but a lack of negative priming in the older adults. These results are taken as evidence for the Inhibition Hypothesis forwarded by Hasher and Zacks (1988), which states that older adults suffer a loss of inhibition abilities, and that this loss is the basis for older adults' diminished performance in selective attention tasks. Gernsbacher and colleagues (e.g., Gernsbacher, 1990; Gernsbacher & Faust, 1991: Gernsbacher, Varner, & Faust, 1990) have formalized a theory of comprehension that builds upon this work on interference. This work is discussed in detail below.

Suppression and the Structure Building Framework

In a series of experiments, Gernsbacher and colleagues (Gernsbacher et al., 1990; Gernsbacher & Faust, 1991) demonstrated that low-skilled readers perform at lower levels than high-skilled readers in a number of cognitive tests. These tasks included the ability to suppress information that was initially accessed during comprehension, but that was subsequently shown to be unrelated to the context of the material. Reading skill was measured by the Multi-Media Comprehension Battery (Gernsbacher & Varner, 1988). This battery consists of six stories, two of which are presented in written form, two in spoken form, and two in the form of nonverbal pictures. After reading each story, the participants were asked twelve questions about the story. Gernsbacher and Varner found that comprehension scores on the written and oral sections were highly correlated with comprehension of the nonverbal stories. Therefore, they have concluded that these skills may be grouped together into what they called a "general comprehension skill." Based on their overall findings, the researchers concluded that general comprehension skill includes the ability to comprehend both linguistic and nonlinguistic information.

Additionally, Gernsbacher et al. (1990) devised a theory of memory that they termed the Structure Building Framework. According to this framework, there are several processes involved in the construction of mental representations that are necessary for comprehension. During comprehension, memory nodes are activated by incoming information. Once activated, these memory nodes will further transmit information concerning the processing of the information. Two mechanisms in this system, enhancement and suppression, control the activation level of the memory cells. When the information transmitted by the memory nodes is relevant to the structure that is currently being built, enhancement serves to increase the level of activation of those nodes. Analogously, when the information is not useful for the structure, the suppression mechanism serves to decrease the activation level of those nodes. Further, Gernsbacher et al. claim that enhancement and suppression are not limited to language production, but that they are general cognitive mechanisms that are involved in the structure building of nonlinguistic tasks as well.

These researchers provided evidence for such a framework. For example, Gernsbacher et al. (1990) showed that low-skilled readers demonstrated a deficient ability to suppress the inappropriate meaning of ambiguous words. High- and low-skilled readers were presented with sentences that ended with ambiguous words. An example of such a sentence is as follows: "He dug with the spade" (or, "He dug with the shovel"). In the first sentence, "spade" is ambiguous because it might refer to either a garden tool or to a playing card. After reading each sentence, a test word was presented. In this example, the test word was "ACE." The task was to decide whether or not the test word fit the meaning of the sentence. The test word was presented at two intervals, either immediately (100 ms) after the presentation of the sentence, or 850 ms after the sentence. At the 100 ms interval, both high- and low-skilled readers had equal difficulty rejecting the test word that corresponded to the inappropriate meaning of the target word, suggesting that both groups of readers accessed both the context-appropriate meaning, as well as the context-inappropriate meaning. However, at the 850 ms interval, only the low-skilled readers demonstrated this difficulty. Based on these findings, Gernsbacher et al. concluded that low-skilled readers are less able to suppress the inappropriate meanings of ambiguous words.

Gernsbacher and Faust (1991) extended these findings to other tasks, both linguistic and nonlinguistic. For example, in a linguistic task, they showed that low-skilled readers are less efficient at suppressing the inappropriate forms of homophones. The procedure was similar to that used by Gernsbacher et al. (1990). Readers were presented with sentences that ended with a word that was a homophone. For example, they read "He had lots of patients." The test word, "CALM" was not related to this word, but it was related to the other member of the homophone pair, "patience," which was never actually presented. Gernsbacher and Faust compared response times to reject test words from these sentences, versus the time to reject the word after reading control sentences with non-homophone final words, (e.g., "He had lots of students"). The difference between these two decision times showed the amount of activation for the incorrect form of the homophone. Again, the results showed that both the high- and low-skilled readers had high activation of the incorrect homophone after 100 ms, but only low-skilled readers showed continued activation after a one-second interval.

Of particular importance to the proposed set of experiments, Gernsbacher and Faust (1991) have shown that suppression of inappropriate schematic information is also a critical aspect in comprehending nonlinguistic information. They based their research on previous work that has shown that participants will access and use schematic information when making judgments about objects in a scene that depicts a common venue, such as a farm or an office (e.g., Biederman, Bickle, Teitelbaum, & Klatsky, 1988; Brewer & Treyens, 1981). Biederman et al. presented participants with pictures of objects that might typically appear in a particular situation. One group of objects included things that might be found on a farm. Another group included common items that one might encounter in a kitchen. Participants were then presented with a single picture of an item. The required task was to report whether or not the given object had appeared in the original scene. Biederman et al. found that the participants were more likely to incorrectly report that a item that is common to the original scene, but that had not been presented in the scene, had actually been presented. For example, participants were more likely to incorrectly report that a tractor had been presented in the farm scene than in the kitchen scene.

Similarly, Brewer and Treyens (1981) found that participants recalled objects that were consistent with their schema for a situation, even if the object had not been presented to them. These researchers asked participants who arrived for their experiment to wait in an office, supposedly waiting for the experiment to be set up in another room. After a brief period, participants were taken to another room and asked to recall as many of the objects as they could that were in the office where they had been waiting. Brewer and Treyens found that participants were most likely to remember the objects that were consistent with their "office schema." That is, they remembered seeing the desk and chair, but were less likely to recall the coffee pot or wine bottle. Also, many of the participants remembered having seen objects that had not been in the room, but that would be consistent with the schema for an office, such as books. Both Biederman et al. (1988) and Brewer and Treyens interpreted their results as evidence for the activation of a particular schema when that schema is appropriate.

Gernsbacher and Faust (1991) have reanalyzed Biederman et al.'s (1988) results, using a suppression paradigm. They reasoned that low-skilled readers should suppress the distractor stimuli less efficiently than the high-skilled readers should, if the suppression mechanism that controls linguistic information is the same mechanism that controls nonlinguistic information. Gernsbacher and Faust conducted a partial replication of the Biederman et al. study, with the addition of a suppression measure. They measured the time that participants took to reject the distractor items when these items were likely to be found in the scenario (e.g., the time taken to reject "tractor" when it had not actually been presented in a farm scene) versus the time necessary to reject the distractor item when it was not common to the previously viewed scene (e.g., when the distractor item was "tractor" and the scene had been a kitchen scene). The difference between these two response times was the measure of the activation of the common distractor item. Gernsbacher and Faust found that both high- and low-skilled readers demonstrated high activation of the common distractors when the test was given 50 ms after the viewing of the scene. However, only the low-skilled readers showed continued activation one second after viewing the scene. Gernsbacher and Faust concluded that the low-skilled readers have less efficient mechanisms in place for these nonlinguistic tasks, as well as for the linguistic tasks. Further, they concluded that a single mechanism underlies both of the task types.

To summarize, Gernsbacher and colleagues have concluded that a general cognitive mechanism is responsible for their varied findings. They suggested that this general mechanism might underlie the deficits that the low-skilled readers have been shown to display. The present set of experiments will investigate the role that such a mechanism might play in problem solving ability.

The impetus for extending Gernsbacher et al.'s (1990) research to problem solving comes from three sources. The first is Gernsbacher et al.'s claim of a general cognitive mechanism, as described above. If, as the researchers claim, suppression efficiency is integral to cognitive ability in general, then poor problem solvers should demonstrate reduced suppression efficiency in comparison to more successful problem solvers. A related source is research involving reading skills in children (e.g., Fowles & Glanz, 1976; Merrill et al., 1981; Yuill & Oakhill, 1991), which is discussed below. The third source is the literature on the relationship between problem solving skill and tendency for conceptual transfer in problem solving (Novick, 1988; Stein et al., 1988). The first and last of these issues have already been addressed. The second source is the topic of the next section.

Developmental Research

As mentioned previously, performance on Stroop-like tasks has been used as a measure of reading ability in children (e.g., Comalli, et al., 1962; Merrill et al., 1981; Rosinski & Golinkoff, 1976). For example, Merrill et al. (1981) presented skilled and less skilled fifth grade comprehenders with a modified Stroop task. This involved reading one sentence at a time and then naming the color of a target word that appeared immediately (one second) after the sentence was removed. The target word was appropriate, inappropriate, or neutral with regard to the meaning of the sentence. One set of sentences was:

Appropriate meaning: The man moved the piano.
Inappropriate meaning: The man played the piano.
Neutral: The girl watched the rain.

In this example, the target word was HEAVY. Results showed that skilled readers exhibited interference in color naming when the target word was contextually related to the sentence, compared to the time required to name the color of the target word when that word was inappropriate with regard to sentence meaning. In this example, skilled readers responded more slowly to HEAVY when it followed, "The man moved the piano," than when it followed, "The man played the piano." However, the less skilled comprehenders did not show this pattern. These individuals exhibited interference when the target word was related to the contextually inappropriate sentence. That is, the naming times for the target word following the two semantically similar sentences did not differ for the less skilled comprehenders. In contrast, the skilled comprehenders responded as quickly to the target word when it was related to the contextually inappropriate meaning of the sentence as they did when the sentence was neutral with regard to the target word.

Merrill et al. (1981) also measured color naming time latency following single word contexts. In this procedure, participants read only the sentence final word (SFW) for each experimental sentence before naming the same target word. For example, they read either the word, "piano," or "rain," and then named the color of the target word that followed. Results for this single-word context showed a different pattern. Both the skilled and less skilled comprehenders displayed interference from the related SFW, compared to the neutral word.

Taken together, the results of the sentence condition and the word condition demonstrate that poor comprehenders process sentences differently than good comprehenders. Specifically, it is suggested that poor comprehenders process sentences in much the same way that they process single words, while good comprehenders form a better representation of the sentence meaning, which necessarily includes disregarding word information that is not useful to maintaining the overall meaning of the sentence. Put another way, poor comprehenders do not make efficient use of things such as context in processing individual words in a sentence. Merrill et al. (1981) concluded that the poor comprehenders are more bound to the surface features of sentences, such as the exact wording of the sentences. Evidence for this claim lies in the finding that the poor comprehenders processed the words similarly, regardless of whether the word was presented in isolation or as part of a sentence context. Further, Gernsbacher et al. (1991) argued that such results can be attributed to the poor comprehenders being unable to suppress the inappropriate meaning of the SFW, such as PIANO, even when the context does not suggest that meaning.

A related line of work revealed that children (mean age = 8 years) who were identified as poor comprehenders were less able to understand puns containing ambiguous words (Yuill & Oakhill, 1991). For example, the children heard riddles such as, "How do you know there was fruit on Noah's Ark? ...because the animals came in pairs." The poor comprehenders had difficulty understanding such riddles, as measured by their ability to retell the riddles and explain why they were funny. However, these children performed as well as good comprehenders in a test that measured their ability to understand ambiguous words. In this test, the children were presented with a word orally and asked to give two different definitions of the word. One example was, pear-pair. Yuill and Oakhill concluded it was not a matter of the poor comprehenders being less able to notice the ambiguities, but rather, it might be that the poor comprehenders were less able to determine which meaning was appropriate in the context of the pun.

There is a similarity in this work with children and in Gernsbacher et al.'s (1990) findings with adults, in that both lines of research have shown that the low-ability comprehenders are not simply less able to understand the various meanings of the words that they encounter. Therefore, Gernsbacher et al.'s conclusion of an inefficient suppression might be applicable to the Yuill and Oakhill (1991) findings. Gernsbacher and Robertson (1995) claim that the poor comprehenders in this study do access both meanings of the ambiguous word, but are then unable to decide which one is appropriate for making sense of the information at hand.

Gernsbacher (1994) conducted a follow-up the Merrill et al. (1981) study, using an adult population. As in previous work, participants were divided into high- and low-skilled comprehenders based on their performance on the Multi-Media Battery (Gernsbacher & Varner, 1988). Participants read one of three prime sentences that ended in a homophone. They then read a target sentence that was paired with the prime sentence. An example is below:

Prime sentences:	SAME meaning: She lit the match. NEUTRAL meaning: She saw the match. DIFFERENT meaning: She won the match.
Target sentence:	She blew out the match.

After reading each sentence, participants decided whether or not the sentence made sense by responding yes or no. Response times of interest were those to the target sentences after reading neutral prime sentences, in comparison to after reading same meaning primes or different meaning primes. Results showed that both high- and low-skilled comprehenders experienced relative benefits from the same meaning primes. This is shown by decreased response times to the target sentences after participants read the same meaning primes. However, only the high-skilled comprehenders experienced costs from the different meaning primes. These participants showed significantly slower response times to the target sentences when the target sentences followed a different meaning prime, in comparison to when the target sentence followed a neutral prime. The low-skilled comprehenders did not exhibit this effect. Response times to target sentences were not different following the neutral and different meaning primes. These findings show that both high- and low- skilled comprehenders show enhancement when the target followed same meaning primes, but only the high-skilled comprehenders show suppression of the different meaning primes.

This study demonstrated that high-skilled comprehenders efficiently enhanced the relevant meanings of homophones when reading sentences and suppressed the irrelevant meanings of the homophones. Therefore, these readers make use of sentence context more efficiently than do low-skilled readers. Low-skilled readers, on the other hand, process words in sentences in a similar fashion to the children who were identified as poor comprehenders in the Merrill et al. (1981) study. That is, the poor comprehenders keep active all meanings of the individual word meanings, rather than only the meaning that is implied by the sentence.

This phenomenon has significance for the present set of experiments. As was discussed in the previous section on problem solving, much research in problem solving has investigated the degree to which individuals are able to make use of surface and structural features of information that is known to be available to them when they are faced with a problem solving situation. As was outlined in the chapter on problem solving, a number of researchers have shown that poor problem solvers tend to focus on surface features of available information, while more skilled problem solvers focus on the structural features of the problem at hand (e.g., Novick, 1988; Stein et al., 1986). I will argue that Gernsbacher's suppression task, which is conceptually very similar to that used by Merrill et al. (1981), will be a useful diagnostic tool for identifying not only poor readers/suppressors, but also for identifying poor problem solvers. This is based on the assumption that focusing on individual word meanings is similar to attending to surface features of problems. That is, focusing on surface features of problems can be compared to attending to individual word meanings, while focusing on structural features of problems can be compared to attending to the underlying meaning of sentences.

Also of interest in the current paper is individuals' ability to discard information that is known to be incorrect when attempting to solve problems. A common method of investigating this ability has been to provide a period of time between successive attempts to solve problems. It is expected that such a duration will serve to diminish the activation of incorrect responses so that participants can access correct solutions, if those solutions are within the individual's domain of knowledge. This is called an incubation procedure. The literature involving incubation is the topic of the next chapter.

CHAPTER III

INCUBATION

This chapter first provides a summary of the concept of incubation as a general phenomenon. As is discussed, the very existence of this construct has been the subject of contentious debate. Regardless, a number of researchers have investigated the usefulness of incubation intervals, with varying degrees of success.

History and Theories of Incubation

Incubation can be defined as an improvement in solution rate after a period during which an unsolved problem has been put aside. Incubation has been the subject of numerous anecdotal reports of discovery. For example, Archimedes is said to have suddenly come upon his realization that the volume of irregular objects could be determined by water displacement as he settled into his bath (Gleitman, 1995). Wallas (1926) proposed that an incubation period was essential for all problem solving. During this period, earlier-considered ideas are worked on unconsciously, leading to an illumination, in which the solution to the problem is suddenly realized.

This "unconscious processing" theory of incubation has been criticized by researchers who point out that the evidence for this phenomenon is based largely on self-reports (Weisberg, 1993). Weisberg cites numerous unsuccessful attempts to demonstrate the existence of incubation in various fields, including art, literature, and science (e.g., Olton & Johnson, 1976; Patrick, 1935, 1937). Weisberg concludes that problems are solved in an incremental fashion, based on trial and error.

In contrast to the unconscious processing theory of incubation, Smith and Blankenship (1989) have forwarded a blocking theory of incubation. According to this theory, the inability to access relevant information is the result of this information being obstructed by other, related information that is incorrectly accessed. Incubation effects are the result of this incorrect information no longer being available to the solvers on a subsequent attempt to solve the problem. That is, activation of the target response is made possible when the competing information is no longer blocking the individual's access to this target.

An alternative explanation for incubation was suggested by Yaniv and Meyer (1987). This is the Memory-Sensitization Hypothesis, which states that even when a problem is unsuccessfully solved, some partial activation of the target solution takes place. This activation sensitizes the individual to later accidental run-ins with related information that might serve to raise the target information to the level at which it will be activated by the individual. Further, as time passes, the likelihood that this chance encounter will take place also increases. Support for each of these theories is presented in the next section.

Empirical Research

Empirical investigations of incubation effects have been few (e.g., Jones & Langford, 1987; Murray & Denney, 1969; Olton, 1979; Patrick, 1986; Smith & Blankenship, 1989, 1991; Yaniv & Meyer, 1987). Further, the finding of incubation effects in these studies has varied. For example, Patrick (1986) found incubation effects, but only in high-skilled problems solvers. Murray and Denney's (1969) findings of incubation effects were limited to low-skilled problem solvers. Smith and Blankenship (1991), in five experiments, found varied effects of ability level on incubation.

In a test of their blocking hypothesis, Smith and Blankenship (1989) employed a clever methodology. This procedure involved inducing a fixated state in participants. Using this procedure, participants were fixated on inappropriate responses to a series of picture-word puzzles that Smith and Blankenship referred to as rebuses. An example of such a rebus is "timing tim ing." The solution to this is "split second timing." The rebuses were presented on two trials. On the first trial, a misleading clue was presented along with the rebus. The purpose of this clue was to fixate the participants on the misleading response, and thereby block the appropriate response. For example, one rebus was "you just me," which represents "just between you and me." The misleading clue in this example was "beside."

On the initial experimental phase, participants attempted to solve these rebuses. This phase was followed by one of two second phases. In the control condition, participants were immediately presented with the same rebuses to solve. In the incubation conditions, participants performed a demanding math test for several minutes and then attempted to solve the rebuses a second time. Results showed that the incubation group exhibited superior performance on the second trial, while the control group did not. That is, an incubation effect was found. Further, when tested for their memory for the misleading clues, the incubation participants showed poor memory for the distractors, while the controls did not. Taken together, these findings led to Smith and Blankenship's (1989) conclusion that incubation effects are the result of a reduced activation level of inappropriate information. In other words, participants who no longer recalled the distractors showed incubation effects.

These findings raise the possibility that individuals who are shown to possess inefficient suppression mechanisms, as measured by the Gernsbacher et al. (1990) task, will solve fewer problems, and will also demonstrate decreased benefit from an incubation period, compared to individuals who exhibit efficient suppression mechanisms. This result is anticipated because it is expected that the poor suppressors will have the misleading clue information available to them for an extended period of time, making the access of the appropriate answers less likely. This is conceptually similar to the expectation for the previously-described riddle experiments. That is, the poor problem solvers will be those who exhibit poor suppression skills and these individuals will benefit less from an incubation interval than will more highly skilled problem solvers.

One theoretical issue that might appear to be problematic is the fact that Gernsbacher et al.'s (1990) measure of suppression show the perseveration effect for only a brief period of time. In this study the effect has been shown to continue for a duration of one second in the poor suppressors. The present set of experiments will investigate the possibility that suppression failure is the cause of more long-term deficiencies. This assumption is not without precedent in the literature (e.g., Hartman & Hasher, 1991; Merrill & Sperber, 1981; Yaniv & Meyer, 1987).

Hartman and Hasher (1991) conducted a test of the Inhibition Hypothesis in older and younger adults. Their procedure involved presenting young and old adults with sentences that were missing the final word. These sentences were high-cloze sentences, (i.e., the final word was highly suggested by the sentence). For example, one sentence read "She ladled the soup into her _____." The task was to predict the ending of each sentence. Subsequently, the participants were presented with the actual last word in the sentence. They were told to remember only this word, and not the word that they had predicted, but that had been disconfirmed. In the above example, the supplied word was "lap," and the disconfirmed word was "bowl."

Hartman and Hasher (1991) then administered an indirect memory test to investigate the activation level of both the disconfirmed words (e.g., "bowl") and the target words (e.g., "lap"). Participants were presented with sentences for which the final word was missing. They read the sentences out loud and completed each sentence with the first word that came to mind. These sentences were constructed in pairs, such that one sentence in each pair had the earlier-disconfirmed ending as the most likely ending. The other was most likely to be completed by the word that had actually been presented in the first part of the experiment. For example, one pair was: "Scotty licked the bottom of the BOWL," and "The kitten slept peacefully on her owner's LAP," with the likely endings presented in caps here. In this way, activation of the presented and disconfirmed endings was determined by the time taken to produce the sentence final words.

Results showed that the older adults showed activation of both words, while the younger adults showed activation of only the target words. Hartman and Hasher (1991) concluded that older adults' inhibitory mechanisms were impaired, and therefore, they were less able to inhibit the extraneous information. Of particular importance to the present set of experiments, the increased activation of the inappropriate response had a rather lengthy duration. Hartman and Hasher measured this activation with a five-minute delay between the completion of the initial task and the onset of the indirect memory test.

In a similar fashion, Yaniv and Meyer (1987) found activation of primed information after a thirty-minute period. These researchers used a tip-of-the-tongue (TOT) paradigm similar to that pioneered by Brown and McNeill's (1966) classic work. Similar to the Brown and McNeill studies, Yaniv and Meyer presented participants with definitions of rare words, such as "sextant" and "Damascus." In instances that participants did not produce the target word, they reported how confidently they thought that they did know what the word was. That is, they reported whether they were experiencing a TOT state. This was followed by a lexical decision task, which included the rare words as well as control words for each of the rare words. Finally, participants were given an old-new recognition task on which they had to decide whether the words on this task had previously appeared on the lexical decision task.

Two results are of particular relevance. First, response times on the lexical decision task and the old-new recognition task were faster for the target words than for the control words both when the participants correctly produced the rare word, and when the participants reported a TOT for the rare word. This suggests that activation of the target words continued for at least a thirty-minute period. Second, in the TOT condition, participants reported a feeling-of-knowing rating (Metcalfe, 1986) for the required word. These subjective ratings were inversely related to reaction times in the lexical decision and new-old recall tasks. That is, words that elicited stronger feeling-of-knowing ratings resulted in faster reaction times for the two indirect memory tests. Yaniv and Meyer (1987) concluded that the target words are available even after this long duration of thirty minutes, regardless of whether the word had actually been accessed in the TOT portion of the test. These indirect memory tests seem especially powerful with respect to the feeling-of-knowing rating, given that previous researchers have voiced concerns over whether participants might try harder on direct memory tests when they know that they have given a high feeling of knowing judgment for a particular item (e.g., Gruneberg, Monk, and Sykes, 1977).

While Yaniv and Meyer's (1987) data provide a basis for assuming that activation can persist for a long period of time, it should be noted that these researchers attribute their results to quite a different mechanism of incubation than the one posited by Smith and Blankenship (1989). That is, while Smith and Blankenship conclude that incubation effects are due to the blocking of appropriate information at a given time and the subsequent lowering of the activation level of this extraneous blocking information, Yaniv and Meyer's Memory-Sensitization Hypothesis assumes an incubation mechanism that is similar to what has been the prevailing wisdom concerning incubation. According to the hypothesis, even when a problem is not solved, the solution is activated to some degree. As time passes, the individual is likely to encounter similar information that serves to activate the target information.

These two hypotheses do not seem to be completely at odds with one another. It might be that, as the activation level of competing responses is decreased with passing time, the likelihood of encountering some triggering stimulus is increased. Yaniv and Meyer (1987) took no measure of the words that the participants may have considered, but not produced, in the no recall condition. Therefore, the degree to which distractors might have been active at both the TOT phase and the indirect memory testing phases is unknown.

To summarize, the Smith and Blankenship (1989) blocking paradigm provides a method of inducing fixation subsequently examining the benefit of various incubation intervals in overcoming this fixation. This method will be utilized in the present set of experiments, both by using the Smith and Blankenship methodology and by relating the paradigm to other problem solving materials, such as the previously-mentioned riddles. Further, the Yaniv and Meyer (1987) data, and the Hartman and Hasher (1991) data, provide a basis for the assumption that suppression effects can be expected at longer time durations than have been previously demonstrated (e.g., Gernsbacher et al., 1990). It is predicted that these long-term effects will be present to a greater degree in those individuals who demonstrate inefficient suppression ability in the Gernsbacher et al. paradigm. Specifically, inefficient suppressors will not benefit from the decrease in activation level of incorrect responses that is normally afforded by period of incubation. Conversely, it was expected that the efficient suppressors will make use of the incubation period to discard the incorrect solutions. The following section furnishes a justification for relating the usefulness of an incubation period to problem solving and suppression abilities.

Incubation and Problem Solving Ability

Past researchers have demonstrated incubation effects using a variety of problem solving tasks (e.g., Dominowski & Jenrick, 1972; Jones & Langford, 1987; Murray & Denney, 1969; Olton, 1979; Patrick, 1986; Smith & Blankenship, 1989, 1991; Yaniv & Meyer, 1987). However, the finding of differential effects of incubation on competent versus poor problem solvers has been inconsistent. Murray and Denny found incubation effects, but only in low-skilled problem solvers. Patrick's incubation effects were limited to the high-ability solvers. Smith and Blankenship (1991) found mixed results, with some of their five experiments showing greater incubation benefits for good problem solvers, and other problems resulting in greater benefit for the poor solvers.

Smith and Blankenship (1991) related their findings of incubation to the difficulty of the tasks administered in each of their experiments. They concluded that "incubation might be most likely to occur when easy-to-solve problems are initially thwarted by fixation," (p. 83). They further speculate that the problem solving ability of the individual might be one determiner of whether incubation would be beneficial to solution. In other words, incubation intervals are most beneficial to low-skilled problem solvers when the task of interest is relatively easy. This is a reasonable conclusion, given that problem solving could not be enhanced if the problems were simply too difficult for the individuals to solve.

In an early study of incubation effects, Murray and Denny (1969) presented their participants with Saugstad's "ball problem" (Saugstad and Raaheim, 1957). This problem required participants to devise a method of transferring a number of steel balls from one area of a room to another, using the objects available to them. These objects include several types of tools, including some string, a pulley, etc. Prior to attempting this task, participants were categorized as high- or low-ability problem solvers according to their scores on the Gestalt Transformation Test, which is a essentially a measure of susceptibility to functional fixedness. Each of twenty problems requires the participant to choose the one of five given items that could best be used for a particular function. For example, from the choices; tree, cigarette, shirt, bicycle, eyeglasses, from which could one make a hose?

Results showed that the low-ability problem solvers benefited from an interrupted period of problem solving, in which they performed a demanding filler task. Conversely, high-ability solvers performed better under a continuous session of working on the problem. Murray and Denny (1969) concluded that the low-ability solvers may have benefited from the interrupted session because they were more prone to blocking effects from the usual uses for the objects that were to be used to solve the problem. In accordance with Smith and Blankenship's conjecture, Murray and Denny speculated that the interruption by the filler task might have served to weaken the effect of the fixated responses in these low-ability solvers. With regard to the high-ability solvers, the interruption of work disrupted their ability to solve the problem. Murray and Denny concluded that this effect was the result of the high-ability solvers not fixating on the stereotypical uses of the objects, and therefore that interruption only served to disrupt the "fluidity" of their solving process.

Smith and Blankenship (1991) followed-up their earlier work, using the Remote

Associates Test (RAT) as a measure of problem solving ability. Participants were presented with a series of three-word RAT items, for which they were required to produce the common words. These RAT items were presented two times to all participants. For fixation conditions, on the first trial the items were accompanied by distractor words that were meant to fixate the participants. For example, the RAT item; LICK, SPRINKLE, MINES was accompanied by the words, "tongue," "rain," "gold." The solution to this example is "salt." Participants were told that the accompanying words were similar to the correct solution, and that they should use these words to help them solve each RAT item. Participants in the no-fixation conditions solved the RAT items without the presence of the distractors. On the second trial, all participants were presented with the same RAT items to be solved a second time. On this trial, no distractors were presented to any groups. The control group had no time interval between the two tests, while the incubation group was given a filler test to perform before the onset of the retest. This entailed reading a compelling short story for which the participants expected to answer comprehension questions.

Two effects of interest were found. The first was that the participants who were fixated on incorrect responses exhibited an incubation effect. That is, their solving performance was significantly greater on the second trial than on the first. This supports Smith and Blankenship's (1989) blocking theory, in that incubation results from the removal of the fixating information. Second, participants who had low scores on the initial RAT exhibited the greatest incubation effects. However, in four subsequent experiments, the effects of ability level on incubation were mixed. In one experiment

(Experiment 2), the incubation effect was limited to the medium-ability participants. In another (Experiment 5), the effect was demonstrated only in the high-ability participants. As mentioned earlier, Smith and Blankenship concluded that incubation effects are evidenced when easy-to-solve problems are presented, along with some distracting information.

While Smith and Blankenship's (1991) findings varied with respect to the relationship between problem solving and incubation, previous research has shown that high-ability problem solvers benefit more from an incubation period than low-ability problem solvers do (Patrick, 1986). Patrick also used the RAT as a problem solving measure. He concluded that high-ability problem solvers benefit more from an incubation period than low-ability solvers because the high-ability solvers use the interruption as a means of breaking away from incorrect solutions and getting a "fresh start" when the problem is re-presented. Low-ability solvers, on the other hand, return to the same incorrect responses that they produced on the first presentation of the problem. The present hypothesis concurs with Patrick's analysis. It is expected that high-ability problem solvers will make better use of the incubation period because these individuals will be better able to consider new solutions after a time away from working on them.

Past researchers have provided explanations for the failure of participants to solve problems in a non-incubation condition, using a variety of problem solving tasks (e.g., Goldman, Wolters, & Winograd, 1992; Peterson, 1974; Rundus, 1973; Smith & Vela, 1991). In a free recall task of a list of words, Madigan (1976) had participants recall the studied list items several times. He found that items that were not recalled on early recall attempts were successfully recalled on later tests, a phenomenon referred to as reminiscence. This effect has been demonstrated numerous times in the literature (e.g., Roediger & Thorpe, 1978). Madigan posited that participants experienced output interference in the list recall task, such that retrieval of some of the items blocked access to additional items. According to Madigan, reminiscence results when participants are retested and the activation of the previously-recalled items has decreased.

Rundus (1973) coined the term, "stopping rule," to describe the reminiscence effect. This rule states that participants will stop their attempts to retrieve additional list items after they have failed to retrieve any new items for some period of time. In other words, they will abandon the retrieval process when they surmise that further retrieval attempts will not be successful. Smith and Vela (1991) suggested that the stopping rule might be applied to fixation and incubation effects observed in the problem solving literature. They posit that an incubation period serves to reduce the activation level of competing responses, or fixators, thus allowing access to other possible solutions at retesting.

Attenuation of Fixation Effects in Incubation Paradigms

As was shown in the previous section, the effects of the distractors in the RAT experiments were short-lived. Solution rates increased significantly after the incubation periods. When provided with a second chance to solve the RAT items, in the absence of distracting words, participants were able to do so. This effect is in contrast to the results of the riddle experiments. In those experiments, participants did not exhibit a release from the fixating effects of their initial solutions to the riddles. The current experiments investigated fundamental differences in these two types of problems that might contribute to these differential attenuation effects.

CHAPTER IV

EXPERIMENTS

The preceding discussion provides a context for the present set of experiments. The overview of the suppression and verbal comprehension literature provides a foundation for the claim that ineffective suppression mechanisms contribute to problem solving deficits. To this end, Experiments 1 and 3 included an administration of the suppression measure developed by Gernsbacher et al. (1991). It was expected that performance on this task will be related to performance on a series of problem solving tasks. Experiment 1 investigated the relationship between suppression efficiency and ability to solve insight riddles similar to those used by Perfetto et al. (1983). Experiment 3 examined the possibility of a similar relationship between suppression efficiency and performance on the RAT test. The riddles task and the RAT task are conceptually similar if one considers that both rely on the ability to make remote associations. For the RAT task, this is based on ability to realize ways that words are related to each other via their independent associations to other words. In the riddles task, solvers must recognize the relationship between the clue sentences and the riddles.

Experiments 2 and 3 examined the degree to which the fixating effects of incorrect responses could be attenuated by the introduction of an incubation period. Experiment 2 made use of the riddles in this endeavor, while Experiment 3 used the RAT items.

Additionally, Experiments 3 and 4 investigated the effects of problem solving ability on the usefulness of an incubation period.

Finally, Experiment 4 examined the degree to which fixation effects can be manipulated by instructions. Participants were instructed either to attend to the distractors or were encouraged to ignore them. This provided a method of delineating between strategies employed when solving the RAT items and the effects of the distractors, per se.

Because the experimental tasks used in the present dissertation are varied, Table 1 is included to aid the reader in keeping track of the task(s) administered in each experiment.

Table 1. Objectives and Tasks Administered: Experiments 1 - 4.

Experiment	Measures	Objectives
1	a) Insight Riddles b) Suppression Task	Predict problem solving performance from suppression skill.
2	a) Insight Riddles	Determine if fixation to riddle solutions can be attenuated by means of an incubation period.
3	a) RAT b) Suppression Task	Predict problem solving performance from suppression skill. Relate problem solving performance to incubation effects.
4	a) RAT	Investigate the attentional component involved in ignoring extraneous stimuli.

Experiment 1

In this experiment, participants were presented with two tasks. These were the ambiguous words task devised by Gernsbacher et al. (1990), and a version of the riddle task used by Perfetto et al. (1983). The primary objective of this experiment was to determine if performance on the problem solving task was predictive of performance on the suppression task. In support of Gernsbacher et al.'s general suppression mechanism, it was expected that all readers would experience difficulty in rejecting ambiguous target words at the 100 ms delay. It was further expected that readers who demonstrated poor problem solving skills would continue to experience difficulty on the ambiguous words task, even at the 850 ms delay. Participants who show high performance on the problem solving task are not expected to show this difficulty at the 850 ms delay.

Problem solving ability was assessed in two ways. The first was by measuring participants' ability to spontaneously transfer the information provided in the clue sentences when presented with the riddles. The second was a measurement of their ability to make use of the clue information after being informed to do so. These measures were used because it has been demonstrated that individuals are not likely to spontaneously access such information (e.g., Perfetto et al., 1983). Therefore, using only the spontaneous transfer measure to define problem solving ability would likely not yield results of interest.

Experiment 1 followed up on Gernsbacher et al.'s (1990) findings. It was expected that high-ability problem solvers, at least those who were able to access the clue information in the informed condition, should experience diminished difficulty in rejecting the ambiguous target words at the long-delay interval. Such a finding would lend support to Gernsbacher's claim that suppression is a general cognitive mechanism.

The riddle procedure was very similar to that used by Perfetto et al. (1983). Several modifications were made to the riddle task for the present experiment. There were four groups of participants. All groups were presented with two trials of the riddles. The first trial contained half of the riddles and the second trial contained all of the riddles. The baseline group solved the riddles without first being presented with the clue sentences. All other groups were presented with the acquisition sentences prior to the first presentation of the riddles. The informed group was informed of the relationship between the acquisition sentences and the riddles before the first trial of riddle solving. There were two groups who were not informed of this relationship. The first of these groups was identical to the uninformed group in the previous experiments. This group was informed of the relationship between the riddles and the acquisition sentences after the first solution trial. This group will be referred to as U-I, to show that they were uninformed on Trial 1 and informed on Trial 2. The second uninformed group was never informed of this relationship between the acquisition sentences and the riddles. This group will be referred to as the U-U group, to show that they were informed neither on Trial 1, nor on Trial 2.

To reiterate, the major changes in the riddle procedure in comparison to previous experiments were the addition of the second uninformed (U-U) condition, and presenting the baseline group with the riddles on two trials. These changes were made to test a phenomenon not addressed in the previous experiments using these materials, but that has been demonstrated in other studies that have investigated practice effects in problem solving (e.g., Goldman et al., 1992; Lung & Dominoski, 1985). Goldman et al. investigated the effects of incubation periods on the solution rates of anagrams. They found that longer incubation periods did increase these solution rates. Of particular importance to the present set of experiments, their results also suggested a general effect of improvement on these types of problems. That is, the data showed a trend for increased performance in overall ability to solve anagrams, although the analysis was not significant. This was shown by individuals' performance on new anagrams (those that had not previously been presented) increasing during the incubation trials. In other words, participants solved more anagrams on Trial 2 than they did on Trial 1, and this effect was observed in both the old (previously presented) and the new anagrams. This suggests that they might have become more skilled in their anagram solution ability. Although this generalized improvement effect was not found to be significant in the Goldman et al. study, the authors suggested that such a phenomenon might be considered in future studies of incubation.

The present experiment provided an investigation of Goldman et al.'s (1992) observation in two ways. The first was by examining the degree to which participants in the baseline group show improvement from Trial 1 to Trial 2. Given that the baseline group had no clue sentences to rely on, any increase in solution rate from Trial 1 to Trial 2 might be seen as a general increase in their ability to solve these types of riddles. The second method was similar to the first. By including the U-U group, a determination could be made regarding the degree to which uninformed group might show improvement in solution rate from Trial 1 to Trial 2, in the absence of explicit instructions to use the clues.

Method

Participants. Eighty University of New Hampshire undergraduates participated in order to receive credit for Introductory Psychology. Twenty participants were randomly assigned to each of four experimental groups. These four groups were based on the riddle condition that participants were presented with; baseline, U-I, U-U, and informed. All participants also completed the ambiguous words task.

Materials. The puzzle materials were taken from Gardner (1978). These were similar to those used by Perfetto et al. (1983) and were composed of eleven insight riddles and corresponding clue sentences, along with three filler riddles that did not have relevant clue sentences. An example of the riddles is as follows: "A minister marries several people each week." This sentence served as a clue for the riddle, "A man who lived in a small town in the U. S. married 20 different women of the same town. All are still living and he has never divorced any of them. Yet, he has broken no law. Can you explain?" For Trial 1 presentation, the riddles were divided into two sets of equal difficulty, A and B, based on pilot studies. Each of these sets consisted of five of the riddles, along with three filler riddles. Additionally, the final riddle in each set was this item, "A man was caught in the rain with no hat or umbrella. There was nothing over his head and his clothes got soaked, but not a hair on his head got wet. How is this possible?" The clue sentence for this riddle was, "After taking a shower a bald man does not have to dry his hair." This riddle was not included in the analysis, but was included to demonstrate to informed groups the relationship between the riddles and the clue sentences. Therefore, each set contained a total of 9 riddles. Each set was further divided into two subsets by randomizing the order of presentation of the riddles in the set. These materials are included in Appendix A.

The suppression task devised by Gernsbacher et al. (1990) was also administered. These materials include short sentences that end in either an ambiguous word or in a non-ambiguous word. For example, one sentence was, "He dug with the spade," or "He dug with a shovel." A test word followed each sentence. This word was related to the "other" meaning of the ambiguous word. In the given example, the test word is "ACE," which is related to the non-presented meaning of "spade," but not to the meaning used in the sentence context. Eighty filler sentences also were used. These sentences were similar to the experimental sentences, except that the test word was related to the meaning of the sentence. For example, the sentence, "She liked the flower," was followed by the test word, "ROSE." The experimental sentences all required a "no" response, while the filler sentences required a "yes" response. Four stimulus sets were constructed. Across these sets, each of the experimental sentences occurred once in each of the four experimental conditions; 100 ms ambiguous, 100 ms unambiguous, 850 ms ambiguous, and 850 ms unambiguous.

Procedure. Participants were randomly assigned to one of the four experimental groups, based on the riddle condition that they received. They were tested individually in an experimental session that lasted approximately 45 minutes. Participants were first presented with the suppression task. In this task, sentences were presented one word at a time on an IBM 486 computer. Each sentence was followed by a test word that appeared either 100 ms later (immediate interval) or 850 ms later (delayed interval). The test word was capitalized and surrounded by asterisks, for example: **ACE**. Each word in the sentences was presented for a duration equal to a constant of 300 ms plus 16.7 ms per character. The interval between each word was 150 ms. Participants were instructed to response "yes" if the test word matched the meaning of the sentence that they just read and to respond "no" if the test word did not do so. They responded "yes" by pressing the "z" key with the left index finger, or "no" by pressing the "/" key with the right index finger. Participants were provided with feedback after each trial. This task required approximately 15 minutes for completion. The dependent variable was recorded as the time required to respond "yes" or "no."

After completing the suppression task, all participants except those in the baseline group were presented with the eleven clue sentences on a Macintosh SE computer. An additional two sentences were presented as fillers, one at the beginning and the other at the end of the list of sentences, for a total of thirteen acquisition sentences. Participants' task was to rate the truthfulness of each sentence. Participants were instructed to read each sentence carefully and rate how truthful the sentence was, on a scale from 1 (never true) to 5 (always true). Subsequent to the rating task there was a three-minute filler period in which participants were asked for their student ID cards and their names were recorded on attendance sheets. This filler period was designed to create a separation between the rating task and the presentation of the riddles.

Each group was presented with the riddles on two separate trials. On the first trial, five of the experimental riddles were presented. The first three were filler riddles, also taken from Gardner (1978). These were included to further separate the rating task from the riddles. In total, there was approximately a six-minute delay between completion of the rating task and the presentation of the experimental riddles. All participants were told that they were would read a series of puzzles that had difficult solutions and that their task was to try to provide a solution for each riddle. The riddles were then presented one at a time. Participants had one minute to type in their response to each riddle. Participants in the informed group were told that the previous sentences would help in solving most of the problems. Neither uninformed group was told of this relationship.

On the second presentation trial, participants were told that they would again be presented with the same riddles to solve, along with some additional riddles. Participants in the informed group and in the U-I group were told that the sentences that they rated previously could serve as clues to helping them solve most of the problems. To make this point clear, the experimenter read the "bald" riddle aloud and the corresponding acquisition sentence from the rating task. The bald riddle was not included in the data analysis and was not included on Trial 2. U-U participants were not informed of the usefulness of the acquisition sentence prior to Trial 2 solving. These participants were simply told that they would receive another trial of the same riddles, along with some additional riddles.

All participants were asked if they had previously seen any of the riddles and if they had any prior knowledge of the experimental procedure. This resulted in elimination of one participant from the baseline group, one from the informed group, and two participants from each of the uninformed groups. These participants were replaced with additional participants.

Results

Solutions to the riddles and response times in the suppression task were recorded. For the suppression data, responses that were incorrect, were more than three deviations from the mean, or were greater than 2,000 milliseconds were discarded. This resulted in elimination of less than 9% of the data. For all results reported in this dissertation, analyses were considered significant at a 0.05 alpha level. All planned comparisons used a Bonferroni procedure with a familywise error rate of 0.05.

Riddle Performance. Preliminary analysis of the riddle data looked for differences between the two sets A and B of Trial 1 riddles. This analysis revealed no differences in solution rates for the two sets of riddles. Therefore, all data were analyzed together. Mean percentages for both trials are presented in Table 2.

Trial 1 data and Trial 2 data were analyzed separately. Trial 1 data for groups U-I and U-U provided a measure of spontaneous transfer, given that participants had not yet been informed of the relationship between the clue sentences and the riddles. A one-way, between subjects ANOVA was performed on Trial 1 data. This analysis revealed a significant main effect of group, F (3, 76) = 15.3, MSe = 1.27. Planned comparisons confirmed that the informed group solved more riddles than all other groups. Between the informed and the baseline groups, t (18) = 6.58, informed and the U-I group, t (18) = 3.08, and informed and the U-U group, t (18) = 4.48. Also, the baseline group solved fewer riddles than the U-I group, t (18) = 3.50, but the comparison between the baseline and U-U groups did not reach significance, t (18) = 2.10, p = .23. Thus, the only unexpected finding was that U-I participants solved significantly more riddles on Trial 1

Table 2. Mean Solution Percentages for Riddle Trials 1 and 2: Experiment 1

	Trial 1		Trial 2			
			Old		New	
Condition	M	SD	M	SD	M	SD
Baseline	6.0	9.4	5.0	8.7	16.0	19.6
U-I	31.0	27.4	40.0	24.4	51.0	21.4
U-U	21.0	19.9	27.0	20.2	44.0	18.6
Informed	53.0	29.2	62.0	25.2	51.0	25.6

than did the baseline group. This provides evidence for spontaneous transfer in this group.

Trial 2 data were analyzed using a 2 (old/new) by 4 (group) mixed ANOVA. This revealed a significant main effect of the old/new variable, F (1, 76) = 5.99, MSe = .76. There was also a main effect of group, F (3, 76) = 22.2, MSe = 1.56. Of particular interest, there was a significant interaction between these two variables, F (3, 76) = 4.49, MSe = 3.41.

An analysis of simple main effects showed that both groups of uninformed participants solved significantly more new problems than old problems on Trial 2. For U-U, t (19) = 4.68, and for U-I, t (19) = 2.15. For the baseline group, the difference was very close to significant, in the direction of more solutions to new than old problems, t (19) = 2.02, p = .06. Finally, the informed group solved more old problems than new, but this difference did not approach significance, t (19) = 1.27, p = .22. Thus, the data for this old/new variable replicate the results of Perfetto et al., for the uninformed groups.

Suppression And Problem Solving Ability. Also of interest was the relationship between the suppression task data and participants' problem solving ability. This ability was measured in two ways. The first was participants' ability to make use of the clues sentences without being instructed to do so (spontaneous transfer). The second was the ability to make use of the clue sentences after having been instructed to do so (informed transfer). These analyses are described separately.

Suppression and Spontaneous Transfer Ability. Data from the two uninformed conditions (U-I and U-U) performance on Trial 1 of the riddle task were used to categorize participants into two groups; those who showed evidence for spontaneous transfer and those who did not. Successful transferrers were defined as participants who scored above the median on Trial 1. The no-transfer group solved below the median on Trial 1. This division resulted in 14 participants in the transfer group and 26 participants in the no-transfer group.

Mean reaction times for the two groups of participants at each delay interval of the ambiguous words task are shown in Table 3. Separate 2 (transfer ability) x 2 (degree of ambiguity) ANOVAs were used to analyze the amount of interference that participants experienced at each delay interval. That is, the difference between participants' mean reaction time to reject ambiguous words at the 100 ms interval was compared to their mean reaction time to reject unambiguous words at 100 ms. Likewise, this comparison was made for the 850 ms interval.

At the 100 ms interval, both groups of participants suffered significant interference from the ambiguous sentence-final word (SFW). A main effect of ability level was found, with the high ability transfer group displaying faster overall reaction times, $\underline{F}$ (1, 38) = 17.4, MSe = 43,483. There was also a significant main effect of degree of ambiguity, $\underline{F}$ (1, 38) = 37.3, MSe = 2,068. The interaction between these factors approached, but did not reach significance, $\underline{F}$ (1, 38) = 3.90, MSe = 2,068, $\underline{p}$ >.05. Simple effects tests revealed a significant difference for the no-transfer group between the ambiguous and unambiguous conditions at this delay, $\underline{t}$ (25) = 5.50. The transfer group showed the same effect, $\underline{t}$ (13) = 2.87. Thus, both the transfer and no-transfer groups displayed an increase in response time to the target word when the SFW was ambiguous with respect to the target word.

Table 3. Mean Reaction Times for Spontaneous Transfer and No-Transfer Groups at 100 and 850 ms Delays: Experiment 1

	Delay Interval					
	100 ms			850 ms		
Ability	Ambig	Unambig	Diff	Ambig	Unambig	Diff
High	738	693	45	640	625	15
Low	960	874	86	890	830	40

The data for the 850 ms level also revealed a main effect of ability level, F (1, 38) = 16.2, MSe = 58,124. A significant main effect of degree of ambiguity was found, F (1, 38) = 14.3, MSe = 1,766. Importantly, an interaction effect was found at this delay interval, F (1, 38) = 5.17, MSe = 1,766. Analysis of simple main effects showed that the no-transfer participants exhibited a significant difference in reaction times between the ambiguous and unambiguous conditions at this delay, t (25) = 4.35. The high-ability transfer participants did not exhibit differential response rates, t (13) = 1.83, p = .09.

In sum, these results demonstrate that the no-transfer participants are much slower to respond overall. These individuals also take longer to reject the ambiguity, especially at the 850 ms duration.

Regression analysis. An alternative way of examining these results was through a multiple regression analysis, which was applied to the data from the 850 ms delay condition. The number of riddles solved on Trial 1 was the dependent variable. The were two predictor variables. The first was the difference in response time between the ambiguous and unambiguous conditions. The second was the average response time for the ambiguous and unambiguous conditions. These predictor variables were chosen in an effort to examine the relative effects of the ambiguity manipulation and of overall speed of response.

This analysis revealed that the two variables together accounted for 27.5% of the variance (23.5% adjusted) in riddle solutions. Only the average response time variable contributed significantly to the regression, t (37) = 3.29. The difference variable did not make a significant contribution, t (37) = 1.11.

<u>Suppression and Informed Problem Solving Ability</u>. A separate set of analyses was conducted for the informed trials of the riddles. These analyses included Trial 2 solution rate for the U-I group and the informed group. Thus, these data were used as a measure of informed problem solving ability. Participants were again divided into high and low scorers, on the basis of performance on Trial 2. Participants scoring above the mean were classified as high scorers, while low scorers were those who scored below the mean on Trial 2. This classification was conducted separately for each of the three groups. This resulted in 19 participants in the low ability group and 21 in the high ability group. Mean reaction times for each group at both the 100 ms and 850 ms delay interval are shown in Table 4.

Separate 2 (problem solving ability) x 2 (degree of ambiguity) ANOVAs were again used to analyze the amount of interference that participants experienced at each delay interval. The analysis from the 100 ms delay is reported first. This analysis revealed a main effect of ability level, with the high-ability problem solving group displaying faster overall reaction times, $\underline{F}$ (1, 38) = 8.61, MSe = 41,287. There was also a significant main effect of degree of ambiguity, with faster response times to the unambiguous versus ambiguous words, $\underline{F}$ (1, 38) = 56.2, MSe = 1,638. The interaction between these factors also reached significance, $\underline{F}$ (1, 38) = 5.25, MSe = 1,638. Planned comparisons showed that both groups experienced significant interference in the ambiguous condition. For the high-ability solvers, $\underline{t}$ (18) = 5.66, and for the low-ability group, $\underline{t}$ (20) = 4.80.

The data for the 850 ms level also revealed a main effect of ability level, $\underline{F}$ (1, 38) = 9.44, MSe = 59,818. A significant main effect of degree of ambiguity was found, $\underline{F}$ (1,

Table 4. Mean Reaction Times for High- and Low-Ability Informed Problem Solvers at 100 and 850 ms Delays: Experiment 1

	Delay Interval					
	100 ms			850 ms		
Transfer Ability	Ambig	Unambig	Diff	Ambig	Unambig	Diff
High	795	748	47	690	676	14
Low	950	861	89	878	823	55

38) = 14.8, MSe = 1,556. As in the 100 ms delay condition, an interaction effect was found at this interval, $F(1, 38) = 5.29$, MSe = 1,556. Analysis of simple main effects showed that the low-ability problem solvers continued to show significant differences between the ambiguous and unambiguous conditions at the 850 ms delay, $t(18) = 3.19$. This analysis approached but did not reach significance for the high-ability informed solvers, $t(20) = 2.04$, $p = .06$.

The differences in reaction times in the ambiguous and unambiguous conditions are larger for the no-transfer versus the transfer groups. This supports the prediction that the suppression task is an appropriate marker of problem solving ability. However, the differences in the overall reaction times for these two groups of participants are also compelling.

Regression analysis. To further explore the differential impact of the difference scores between the ambiguous and unambiguous conditions, and of overall response speed, a multiple regression was conducted for the 850 ms duration. The number of riddles solved on Trial 2 was the dependent variable. Results showed that the two variables accounted for 18.9% of the variance (14.6% adjusted). As was the case in the spontaneous transfer analysis, only the average speed variable contributed significantly to the regression, $t(37) = 2.5$. The difference variable did not approach significance, $t(37) = .12$

Discussion

Riddles Results. Results of Experiment 1 are in accordance with major predictions. One surprising finding was that of significant spontaneous transfer in U-I condition. This is contrary to earlier findings by Perfetto et al. (1983) and others (e.g., Ross et al., 1989; Weisberg et al., 1978; but see Bowden, 1985). However, there was no evidence of transfer in group U-U. Several other results of the riddle experiment replicate earlier findings of Perfetto et al.

Of particular interest to the present set of experiments, the Trial 2 solution rate for "old" problems was lower for the initially uninformed group than for the informed participants, who were aware of the relationship between the acquisition sentences and the riddles on Trial 1. This finding was predicted from results of the previous studies. In this respect, U-U participants showed a pattern of Trial 2 solving similar to that of the U-I group. That is, U-U group displayed improvement from Trial 1 to Trial 2, and this improvement was largely confined to the "new" riddles. These effects were somewhat surprising, given that the U-U group was never informed of the relationship between the acquisition sentences and the riddles. This suggests that U-U group somehow became "informed," or aware, of this relationship without being explicitly informed. This finding will be discussed further in the general discussion.

Suppression Efficiency and Spontaneous Transfer. Two results relating suppression efficiency to problem solving are more pertinent to the primary focus of this dissertation. The first compared suppression ability to spontaneous transfer. The second compared suppression ability to the ability to solve the riddles when participants were informed of the relationship between the acquisition sentences and the riddles. The former ability might be characterized as the ability to recognize that some particular information is relevant for solving a problem at hand and using that information accordingly. The latter process involves the ability to make use of information when its relevance is already known. Numerous studies have shown that simply possessing necessary information is not sufficient to facilitate solving, but that individuals must also access that information at the appropriate time (e.g., Perfetto et al. 1983; Spencer & Weisberg, 1986; Stein et al., 1986). These studies have shown that individuals are very unlikely to spontaneously access the relevant information unless they are explicitly instructed to do so. In contrast, the present experiment did show evidence for spontaneous transfer in the U-U condition.

The present experiment also showed evidence for a relationship between the facility for spontaneous transfer in the riddle experiment and performance on the suppression task, given that the interaction between transfer ability and level of ambiguity was very close to significant. Both groups, those who demonstrated spontaneous transfer and those who did not, experienced difficulty in rejecting the ambiguous test words at the 100 ms delay condition. However, only the no-transfer participants continued to experience difficulty in rejecting the ambiguous words at the 850 ms delay. This supports Gernsbacher et al.'s (1990) results and suggests that the suppression measure is an appropriate predictor of spontaneous transfer ability.

There was also a significant difference between the participants who did show transfer and those who did not, with regard to overall reaction time on the suppression task. The transfer participants demonstrated significantly faster reaction times at both delay durations than the no-transfer participants. This finding replicates Gernsbacher et al.'s (1990) results comparing reaction times for their high-and low-ability readers using these same materials.

Suppression Efficiency and Informed Problem Solving Ability. The results comparing suppression performance for the high- and low-ability participants in the informed solving conditions very closely parallel the results of the spontaneous transfer conditions. For both the high- and low-ability informed solvers, there were increased response times to the target word when the SFW was ambiguous with regard to the target word. The interaction of ability level and ambiguity reached significance at the 850 ms delay, with the high-ability informed solvers displaying reduced differences in reaction times at this delay, in comparison to the low-ability informed solvers.

The present experiment shows a similar relationship between the suppression measure and informed problem solving. This result might be analyzed through the scope of the general suppression mechanism posited by Gernsbacher and colleagues (e.g., Gernsbacher et al., 1990; Gernsbacher & Robertson, 1995). Those experiments showed that less-skilled readers are less able than high-skilled readers to suppress inappropriate meanings of ambiguous words (as was replicated here), less-skilled readers are less able to suppress inappropriate meanings of homophones, etc. It is important to note that these experiments also showed that less-skilled readers were not inferior to high-skilled readers in their ability to maintain activation of appropriate meanings of ambiguous words (Gernsbacher & Faust, 1991; Gernsbacher & Robertson, 1995). This suggests that the less-skilled readers are not experiencing difficulty with rejecting the ambiguous word because they do not appreciate the meaning of the sentence. Rather, the deficiency seems to lie in the inability to discard irrelevant information in an efficient manner.

This conclusion can be directly applied to the riddles used in the present study.

For example, consider the minister riddle. In order to successfully solve this riddle, one must look beyond the most common meaning of words such as, "marry," and "divorce." While any college student would be able to report the multiple meanings of such words if asked to do so, that does not ensure that all of them would consciously access these multiple meanings in the context of this riddle. From the present results, it seems that individuals who exhibit poor suppression ability on the on-line task developed by Gernsbacher and colleagues are less able than their high-ability counterparts to reject the more familiar meanings of common words, such as "marry," in an off-line task.

This process is similar to that proposed by Gick and Holyoak (1983) in their description of good versus poor problem solvers. They showed that successful problem solvers focused on structural similarities between base analogs and target problems when solving the radiation problem, for example. Poor problem solvers, on the other hand, focused on surface similarities between the base and target. In relation to the present set of experiments, it is assumed that realizing the proper word meanings indicated in each riddle is central to making use of the clue sentences (Bowden, 1985; Lockhart et al., 1988; Stein et al., 1986). Given that the present experiment showed that poor suppressors performed poorly on the riddle task, one might conjecture that they focus only on the usual meaning of those words as specified in the riddle. There was very little surface similarity between the riddles and corresponding clue sentences, given that they shared few common words, as shown by Bowden (1986) and Stein et al. (1988). Therefore, in order to solve, that is; to access the correct information, even when directed to do so, participants would have to perceive the structural similarity between the two sources of information.

Experiments 3 and 4 further explored this possibility, using a different set of problem solving materials. In these experiments, the Remote Association Test (RAT) (Mednick, 1962) was used as a measure of the ability to ignore useless information when solving problems. This allowed for the investigation of the role that suppression ability might play in the ability to make remote associations. Specifically, these experiments determined whether high-skilled suppressors would also be better able to solve RATs.

In sum, the present experiment showed that poor suppression ability is correlated with poor ability to solve the riddles, in both the spontaneous and informed conditions. Past research that has focused on the characteristics of those individuals who do exhibit such skills (e.g., Gick & Holyoak, 1983; Novick, 1988). The present results suggest that suppression ability should be added to the list of factors that contribute to skillful transfer, both spontaneous transfer and directed. Experiment 3 will determine if the suppression task can predict further predict problem solving ability on the RAT.

Experiment 2 investigated the possibility that the deleterious effects of incorrect solutions to the riddles on Trial 1 can be attenuated if the time between presentation of Trial 1 and Trial 2 is increased. It is predicted that solution rate to the "old" riddles will be greater when the participants have been provided with an incubation period. This is expected because it is assumed that the activation level of the incorrect responses will decline during the incubation period.

Experiment 2

In this experiment, participants were presented with the same ten riddles used in Experiment 1, in two separate trials. As in Experiment 1, the participants attempted to solve one-half of the experimental riddles on Trial 1. Participants attempted to solve all of the riddles on Trial 2. The second trial was either immediately after Trial 1, or after a 15-minute incubation period.

Method

Participants. Participants were 32 University of New Hampshire undergraduates who participated in order to receive credit for Introductory Psychology. Sixteen participants were assigned each of the two experimental groups.

Materials. Materials used were the same riddles and clue sentences that were used in Experiment 1. Additionally, participants completed a paper and pencil version of the Remote Associates Test. This test was comprised of 50 RAT items. The RAT was included only as a filler task for the incubation period, therefore the results of this test were not analyzed.

Procedure. Participants were tested individually in an experimental session that lasted approximately 45 minutes. All participants first completed Trial 1 of the riddles. This consisted of the three filler riddles and five of the experimental riddles. Participants were instructed that they would have one minute to type a response to each riddle. As in Experiment 1, it was stressed that they try to write a response to each riddle. The incubation group then was given the paper and pencil RAT test that consisted of 50 RAT items. The test was explained to them and an example was given to ensure that the participants understood the procedure. They were given 15 minutes to solve as many of the RAT items as possible. The RAT task was presented as a filler task to ensure that participants were distracted from working on the riddle responses during the incubation period.

The experimenter returned after the 15 minute period and collected the RAT papers. Participants were then presented with the ratings task. As in Experiment 1, they were asked to read each clue statement carefully and rate it for truthfulness on the 1 to 5 scale. A brief filler period followed the ratings task, during which the participants were asked for their student ID cards and their names and student ID numbers were recorded on the attendance sheet. Participants were then presented with Trial 2 of the riddles. They were instructed that they would receive the riddles that they had attempted to solve previously, along with some additional ones. They were told that the sentences that they had rated would help them to solve the riddles. To make this point clear, the experimenter read the "bald" riddle and its corresponding clue sentence aloud.

The procedure for the no-incubation group was identical to that of the incubation group, except that the order of the administration of the RAT test and the first trial of the riddles was reversed. In this way, the no-incubation group first completed the RAT, then Trial 1 of the riddles, then the ratings task, and after the filler period, were presented with Trial 2 of the riddles. Therefore, there was approximately a five-minute interval between the completion of the ratings task and the presentation of Trial 2 riddles for both groups of participants.

Results

Separate analyses were conducted for Trial 1 and Trial 2 riddles. No significant difference was found between the two sets of Trial 1 riddles. Therefore, these data were analyzed together. Means for both trials are shown in Table 5. A independent groups t-test on Trial 1 data revealed no significant difference between the number of riddles solved by the incubation and no-incubation groups, t (30) = .33, p = .73.

A one-way ANOVA on Trial 2 data showed no significant difference between the incubation and no-incubations groups on number of riddles solved, F (1, 30) = 2.50, MSe = 2.03, p = .13. An further analysis of the old/new factor revealed no difference in the number of old and new riddles solved, although this effect did approach significance, F (1, 30) = 3.00, MSe = .75, p = .09. The interaction of group and the old/new factor did not approach significance, F (1, 30) = .33, MSe = .75, p = .57. Simple effects tests showed no difference between the old/new factor for the incubation group, t (15) = .70, p = .5. This analysis was very close to significant for the no-incubation group, t (15) = 2.07, p = .06. In both cases, participants solved more new items.

Discussion

The purpose of Experiment 2 was to determine if providing an incubation period between the first and second exposures to the riddles would increase the percentage of riddles solved on the second trial. While the trends were as expected, the statistical analysis did not find these trends reliable. Perhaps the most striking aspect of this finding is that Trial 2 solution rate to "old" riddles was no better than Trial 2 solution rate to "new" riddles, although the clue sentences were presented *after* the first attempt to solve

Table 5. Mean Solution Percentages for Riddle Trials 1 and 2: Experiment 2

	Trial 1		Trial 2			
			Old		New	
Condition	M	SD	M	SD	M	SD
Incubation	11.2	10.2	58.8	22.5	63.8	23.0
No Incubation	10.0	10.3	45.0	25.8	55.0	22.5

the riddles. This might be conceptualized as proactive interference from the Trial 1 solutions, while previous work has demonstrated retroactive interference effects from initial solution to "old" riddles (e.g., Adams et al., 1988; Perfetto et al., 1983). For example, in the present experiment, participants first attempted to solve riddles such as the "minister" riddle. After doing so, they read the acquisition sentences that provided the solutions to these riddles. If the participants recognized this relationship as they were reading the acquisition sentences, then one might expect the Trial 2 solution rate for "old" riddles to be higher than that for "new" riddles, particularly for the no incubation group, given that these participants read the clue sentences only several minutes after first attempting to solve the problems. However, the no-incubation group solved more "new" problems than "old" problems, although this difference was not significant.

This finding of fixation to self-generated responses on the riddle task differs from previous research using other types of transfer tasks, such as analogical transfer. For example, Duncker (1945) noted that a few of his participants initially produced solutions to the radiation problem that might be considered correct. These included sending the radiation through the esophagus, or using a lead shield to protect the surrounding tissue from the excess radiation. In contrast to the present finding, Duncker and later researchers (e.g., Gick & McGarry, 1992) showed that initial solution failures to these types of problems enhanced subsequent solving of the problems.

In the present experiment, it is possible that participants believed their original solutions to be correct, even in the incubation condition. This possibility is not as likely in the radiation problem, given that the other possible solutions to the radiation problem are clearly flawed. In the riddles experiments, it is certainly possible that some participants believe that polygamy is legal in Utah. Therefore, their solution to the minister problem could seem reasonable to them.

Overall, there seem to be three possibilities for the present finding of no decrease in fixation effects from Trial 1 to Trial 2 solving, following the incubation period. The first is that the participants believed their original solutions to be correct. This possibility is supported by a pilot study in which participants were presented with Trial 1 of the riddles after completing the ratings task. Participants were instructed to write a solution to each riddle, but only if they were certain that the solution was correct. If they were unsure if the solution was correct, they were instructed to leave the riddle unanswered. The participants in this experiment provided solutions to nearly every riddle, although their solution rate was no higher than Experiments 1 and 2 here. This suggests that the participants' confidence for their solutions was very high.

It is also possible that the time allowed for the incubation period was insufficient to facilitate a decline in the activation of the competing response. This could be due to the original response being generated by the participants. Previous work has shown that information that is self-generated is better recalled than information that is simply read (Slamecka & Graf, 1978). Providing a much longer incubation period, such as a 24-hour period, or even longer, might diminish the participants' tendency to experience fixation from their incorrect responses on Trial 1. Previous researchers have shown that an incubation period of this duration resulted in greater improvement in anagram solution rate, versus shorter durations (Goldman et al., 1992).

Finally, the power to find significant differences might not have been sufficient in this experiment. It is possible that a larger sample size would reveal a significant difference between solution rates to "old" riddles for the incubation versus no-incubation groups.

While the solution rate to the initially unsolved riddles was not effectively increased via an incubation period, it has been shown that an incubation period can result in increased solution to other stimulus materials, such as a RAT (Patrick, 1986; Smith & Blankenship, 1991). Experiment 3 made use of the RAT to investigate several questions.

Experiment 3

Experiment 3 was conducted in an effort to answer two questions. The first was whether the suppression task devised by Gernsbacher et al. (1990) would predict performance on the RAT. Such a finding would extend the results of Experiment 1 to show that the suppression task predicts ability on a different problem solving test. The second objective of Experiment 3 was to evaluate whether participants can easily discard extraneous information when solving the RATs. To this end, the RAT items were presented along with additional words that were meant to "block" participants' access to the correct response. This is similar to the procedure that was used by Smith and Blankenship (1991). In accordance with Smith and Blankenship's results, it was expected that these blockers would diminish participants' ability to solve the RATs, in comparison to participants who did not receive the blockers with the RAT items. It was also of interest to determine if the solution rate would increase significantly when participants were provided with a second chance to solve the RAT items after a period of incubation. Results of this endeavor were compared to those of Experiment 2. Perhaps the failure to improve solutions to the "old" riddles in Experiment 2 with an incubation period were particular to the riddles that were used in that experiment. While the riddles seem to elicit firmly entrenched solutions that were not discarded even when participants were told that these solutions were incorrect, it is possible that participants will be better able to disregard initial incorrect responses to the RAT, after being provided an opportunity to solve the RAT items in the absence of the blockers.

Experiment 3 included three levels of incubation. The first was a no-incubation level, in which participants were presented with each RAT item only once, for a total of 60 seconds. The first 30 seconds was considered to be the first solution period (RAT 1), and the final 30 seconds was the second attempt (RAT 2). The short-incubation condition was the second level. In this condition participants attempted all RAT items, then were presented with the same items again. The long-incubation condition was similar to the short-incubation condition, except that a 10-minute incubation period was interpolated between the first and second presentation of the RAT items. During this period, participants were presented with a variation of the Sternberg (1966) letter-search task.

Method

Participants. Participants were 60 University of New Hampshire undergraduates who participated in order to receive credit for Introductory Psychology. Ten participants were assigned each of the six experimental groups in a 3 (level of incubation; no-, short-, or long-incubation) by 2 (fixation; fixation or no-fixation) design.

Materials. Four tasks were presented to each participant. The first was the 18 Remote Associates Test (RAT) items (Mednick, 1962). These are shown in Appendix B. Each item is made up of a set of three words. The task was to produce the fourth word that forms a common phrase with each word on the set. The participants were given this example; WASHER, SHOPPING, PICTURE. Fixation materials included three distractor words that were presented along with each RAT set. The distractors provided for this example RAT were: glass, sidewalk, and pane. The solution to this example problem was "window." Four random orders of presentation of the RAT items were prepared.

The second task was the suppression measure (Gernsbacher et al., 1990) used in

Experiment 1. The third task was a pencil and paper version of the RAT that consisted of 30 items. Finally, participants in the fixation conditions were presented with a recall test. This was composed of 10 of the RAT items, presented one at a time. The task was to recall as many of the three distractors as possible for each presented RAT item.

Procedure. Participants were tested individually in two sessions. The first session was approximately one hour and the second session was approximately 20 minutes. Upon arrival at the first session, the participants were randomly assigned to one of the six experimental groups. Three of the groups were fixation conditions and three were no-fixation conditions.

The were three fixation conditions, which were divided according to the length of the incubation period that was interpolated between the first and second presentation of the RAT items. The first condition was a no-incubation condition, in which each RAT item was presented for 30 seconds with the three distractors. This was followed immediately by a 30-second presentation of the same RAT item without the distractors. The short-incubation group completed all 18 RAT items with distractors. After all 18 items were presented, the same items were presented again, in the same order. On this second presentation the distractors were not presented. Please note that this was the procedure that Smith and Blankenship (1991) referred to as their "no-incubation" condition. The final RAT condition was the long-incubation condition. These participants completed all 18 RATs with distractors. They then worked on an absorbing letter-search task (Sternberg, 1966) for a period of 10 minutes. The second presentation of the RATs, without distractors, followed this incubation period. All experimental RAT items were presented for a total of 60 seconds. For all groups, RAT 1 was the first 30-second presentation of the items and RAT 2 was the second 30-second presentation.

The no-fixation groups were divided in a similar fashion. The no-incubation group was presented with each RAT item for a total of 60 seconds. The first 30 seconds was considered as RAT 1, and the second 30 seconds was recorded as RAT 2. The short-incubation group completed all 18 RAT items. They were then presented with all items again. The long-incubation group completed the 18 RATs, worked on the letter searching task for 10 minutes, then were presented with RAT 2.

The experimental RAT items were presented on a Macintosh SE computer. Each three-word RAT item was presented on a separate page. In the fixation conditions, the RATs were presented along with the three distractor words. Fixation participants were shown this example item: WASHER, SHOPPING, PICTURE, along with the clues: "glass," sidewalk," and "pane" printed beneath their corresponding RAT word (see Appendix). Participants were instructed that their task was to think of a fourth word that formed a common phrase with each of the three words in the set. They were also told that the clue words were provided to make the task easier for them. It was explained to participants that the clues were very similar to the correct answer.

Participants were further instructed that each RAT item would be presented for 30 seconds and that they should type their response as soon as they knew it, in a box provided at the bottom of each page. They were told to spend the entire 30 seconds working on each item. That is, that they were not to press the return key unless they had typed in their response. Incubation participants were not informed that they would be retested. No-incubation participants were told that they would receive each RAT item for a total of 60 seconds, with the first 30 seconds including the "clues," and that the second 30 seconds would contain only the three RAT words.

Participants in the no-fixations conditions were given similar instructions. All were shown the example RAT and its solution to ensure that they understood the task before beginning. The no-incubation group was told that each RAT item would be presented for 60 seconds. Participants in the two incubation conditions were not informed that they would be retested.

Following RATs 1 and 2, the fixation participants were presented with the recall task. This task was comprised of 10 of the RAT items, presented without distractors. Each item was presented individually. Participants were shown the example RAT item (WASHER, SHOPPING, PICTURE) and were reminded of the distractors that had been presented in this example. They were told that they would be presented with some of the sets of RATs that they had just completed and that their task was to recall the three clue words that had been presented along with each RAT on the first presentation. Participants were provided with as much time as necessary to type in as many of the clues as they could recall.

The final test administered in Session 1 was the pencil and paper version of the RAT. Participants were given 15 minutes to solve as many of the 30 RAT items as possible.

Session 2 consisted of a single task. This was the suppression task that was used in Experiment 1. The materials and procedure for this task were identical to those detailed in Experiment 1. This session lasted approximately 20 minutes.

Results

RAT 1 and RAT 2 Solution Rates. Data from RAT 1 and RAT 2 were analyzed separately. A 2 (fixation) x 3 (incubation) ANOVA was conducted on RAT 1 solution rate. This analysis showed a significant main effect of fixation, with higher solution rate for the no-fixation groups, F (1, 54) = 30.5, MSe = 5.35. Neither the main effect of incubation, F (2, 54) = .07, MSe = 5.35, nor the interaction, F (2, 54) = .53, MSe = 5.35, of the two factors approached significance. Mean solution percentages for all groups are given in Table 6.

A 2 (fixation) x 3 (incubation) ANOVA was conducted on RAT 2 solution rate. This also revealed a significantly higher solution rate for the no-fixation groups, F (1, 54) = 9.06, MSe = 7.53. The main effect of incubation did not reach significance, F (2, 54) = 2.35, MSe = 7.53. The interaction of fixation and incubation did not approach significance, F (2, 54) = .39, MSe = 7.53.

Improvement Effects. An analysis of improvement effects was conducted to determine if there were differences in improvements in solution rates between the various conditions. Improvement was defined for each participant as the number of RAT items solved on RAT 2 that were not solved on RAT 1. A 2 (fixation) x 3 (incubation) ANOVA revealed a main effect of fixation, with the fixated groups demonstrating greater improvement, F (1, 54) = 10.5, MSe = 1.95. The main effect of incubation was also significant, with the groups that had an incubation period between presentations of each RAT item showing greater improvement from RAT 1 to RAT 2, F (2, 54) = 10.3, MSe =

Table 6. Mean Solution Percentages for RATs 1 and 2: Experiment 3

Condition	RAT 1		RAT 2		
	M	SD	M	SD	Improvement
No Fixation					
No Inc	38.3	10.9	43.9	10.9	5.6
Short Inc	42.8	19.4	53.9	19.6	11.1
Long Inc	38.9	10.6	50.6	11.2	11.7
Fixation					
No Inc	23.9	7.9	31.1	11.7	7.2
Short Inc	20.0	11.6	38.3	16.0	18.3
Long Inc	21.1	10.8	43.3	15.3	22.2

1.95. The interaction of these two factors did not reach significance, F (2, 54) = 1.68, MSe = 1.95.

One-way ANOVAs were conducted comparing the three incubation durations for both the fixation and no-fixation conditions. For the no-fixation condition, this analysis revealed no significant differences in improvement for the no-, short-, and long-incubation groups, F (2, 28) = 1.90, MSe = 1.95. A significant effect was revealed between the three fixation conditions, F (2, 28) = 10.1, MSe = 1.95. Planned comparisons showed that the no-incubation group had lower improvement than both the short-incubation, t (28) = 3.21, and the long-incubation groups, t (28) = 4.33. The short- and long-incubation groups did not differ in the degree of improvement from RAT 1 to RAT 2, t (28) = 1.12.

Suppression and Problem Solving Ability. Also of interest was the relationship between performance on the inhibition task and solution rate on the RAT task. Participants were defined as high, medium, or low ability problem solvers based on their scores on the pencil and paper rat. High ability participants were those who scored above the median. Medium ability participants scored at the median, and low ability participants scored below the median. This division resulted in 23 high-ability, 14 medium-ability, and 23 low-ability participants. Means for these groups are shown in Table 7.

A 3 (problem solving ability) x 2 (level of ambiguity) ANOVA was conducted. Due to attrition, inhibition data were available for only 52 participants; 21 high-ability, 13 medium-ability, and 18 low-ability participants. Separate analyses were carried out for the 850 ms delay and the 100 ms delay conditions. Results of the 100 ms condition will be reported first.

Table 7. Mean Reaction Times for High- and Low-Ability RAT solvers at 100 and 850 ms Delays: Experiment 3

	Delay Interval					
	100 ms			850 ms		
Ability	Ambig	Unambig	Diff	Ambig	Unambig	Diff
High	768	728	40	682	673	9
Medium	806	783	23	777	768	9
Low	918	831	87	881	784	97

This analysis showed a main effect of group, F (2, 49) = 3.63, MSe = 43,167. The main effect for ambiguity was also significant, with the response times for the unambiguous target words being faster than for the ambiguous targets, F (1, 49) = 35.7, MSe = 1,759. The interaction of these factors was also significant, F (2, 49) = 5.25.

Simple effects tests showed that the high-and low-ability groups had significant differences between the ambiguous and unambiguous conditions at this delay, t (20) = 3.21, and t (17) = 5.34, respectively. There was no difference for the medium-ability group, t (12) = 1.85.

An analysis of the data from the 850 ms condition showed a significant main effect of group, with the F (2, 49) = 5.96, MSe = 39,941. There was a significant main effect of ambiguity, with faster reaction times recorded for the unambiguous condition, F (1, 49) = 21.1, MSe = 1,745. The interaction between ability level and ambiguity was also significant, F (2, 49) = 12.9, MSe = 1, 745.

Simple effects tests showed that only the low-ability group showed a difference in reaction times between the ambiguous and unambiguous conditions at this delay, t (17) = 5.87. The high-ability group showed no difference, t (20) = .71. The medium-ability group also showed no difference, t (12) = .94.

Regression analysis. A multiple regression was performed using score on the paper version of the RAT as the dependent variable. As in Experiment 1, the two predictor variables were the difference scores between the ambiguous and unambiguous conditions and the average of the ambiguous and unambiguous conditions. This analysis was conducted for the data in the 850 ms delay condition. Results showed that the two variables together accounted for 28.6% of the variance (25.7 adjusted). Both variables contributed significantly to the regression, t (49) = 2.77, and t (49) = 2.25 for the average and difference variables, respectively.

Improvement Effects and Problem Solving Ability. To examine the effect of the incubation periods on RAT solution for participants of varying ability levels, scores on the pencil and paper RAT were used to predict improvement from RAT 1 to RAT 2. For this analysis, data from the 40 participants in the two incubation groups were used. This division yielded 16 high-ability, 8 medium-ability, and 16 low-ability participants. A one-way ANOVA revealed a significant difference between the groups, F (2, 37) = 5.26, MSe = 2.63. Pairwise comparisons showed that the only significant difference was that the high-ability solvers showed greater improvement scores than the low-ability group, t (37) = 2.95. No other paired comparison approached significance. Means are given in Table 8.

Distractor Memory. Data from the recall task were analyzed for the fixation groups. A one-way ANOVA revealed a significant difference between the three groups, F (2, 27) = 16.7, MSe = 13.87. Planned comparisons showed that the no-incubation group recalled significantly more of the distractors than the two incubation groups, t (27) = 4.55, t (27) = 5.33, for the difference between the no-incubation group and the short-incubation group, and between no-incubation and long-incubation group, respectively. Means for the three groups are given in Table 9. Thus, these results parallel those comparing improvement effects between the three groups. Here, it is shown that the continuation of the fixation effect in the no-incubation condition, that is; no improvement, is accompanied

Table 8. Mean Improvement for High-, Medium-, and Low-Ability RAT Solvers: Experiment 3.

	Incubation Effect	
Ability Level	M	SD
High	3.56	1.9
Medium	3.57	2.1
Low	1.88	1.0

Table 9. Mean Distractors Recalled in No-, Short-, and Long-Incubation Conditions.

	Distractors Recalled	
Incubation Condition	M	SD
None	18.6	4.8
Short	11.0	3.0
Long	9.7	3.0

by a high availability of the blocking information, compared to that for the two incubation conditions.

Discussion

Results of Experiment 3 extend those of the previous experiments in several important ways. Most importantly, the suppression task proved useful in predicting problem solving ability, as measured by the RAT. This strengthens the finding of a relationship between the suppression task and the riddle solving task in Experiment 1. The finding further supports Gernsbacher et al.'s (1990) claim that their suppression task has value as a tool for predicting general cognitive abilities. It can be concluded that the suppression task is a reliable indicator of both of these problem solving skills. Additionally, the overall speed of response to the ambiguous and unambiguous words predicted success on the RAT.

The present results contrast with those of the first two experiments, with regard to the diminishing of fixation effects. In both Experiments 1 and 2, the fixating effects of the initial incorrect responses was evident at re-testing both immediately (Experiment 1), and after a period of incubation (Experiment 2). In contrast, the distracting information provided in Experiment 3 had a short-lived effect. This can be seen by comparing the improvement on RAT 2 for the no-incubation participants versus the incubation participants. While the no-incubation participants, both fixated and non-fixated, showed virtually no improvement from RAT 1 to RAT 2, all other groups did demonstrate increased solution rate. This increase in solution rate for the incubation conditions is especially important in the non-fixation groups, because it suggests that participants do become "fixated" on some incorrect response, whether this response is experimentally provided, or is generated by the participant. In both the fixation and non-fixation RAT conditions, participants were able to discard this incorrect information during the incubation period, as shown by significantly higher solution rate for RAT 2 versus RAT 1.

Finally, the present experiment confirmed expectations that the high-ability problem solvers would benefit most greatly from the incubation interval. This is contrary to Smith and Blankenship's (1991) findings with the same materials, but does support other incubation research (Patrick, 1986). The present assumption is that high ability participants were better able to make use of the incubation period as a means of discarding incorrect, blocking responses. Upon returning to the problems, these high ability participants did not re-access the responses that they generated, or were provided to them, on the first solution attempt.

It is possible that one reason for the high-ability solvers showing greater incubation effects is that the problems were simply too difficult for the low-ability participants. If incubation is defined as an increase in the solution rate of solvable problems after a period away from the problems, then the problems must be within the domain of knowledge of all participants. Experiment 4 will examine this issue by using a procedure similar to that of Experiment 3, with the most difficult RAT items replaced with easier items.

A further question for Experiment 4 concerns the degree to which the effect of the blockers can be controlled by participants. In Experiment 3, the participants were explicitly instructed to attend to the fixators because they would help them solve the problems. It is likely that some participants realized that the blockers were not helping them to solve the problems. Several participants reported this phenomenon. However, it seems that the participants were not able to avoid attending to the blockers. This is supported by the observation that the participants fared no better in solving the last 9 items than in solving the first 9. If they did decide to ignore the "clues," they did not do so successfully. An alternative possibility is that participants did not actively attempt to avoid the clues.

Experiment 4 examined these possibilities by instructing some participants that the distractor words were meant to be distracting and that they should attend only to the words of interest. This manipulation allowed me to determine the extent to which the instructions that the "distractors" are helpful, and therefore should be attended to, contributed the fixation effect. This "ignore" condition was compared to participants who were told to attend to the information. It was of interest to determine whether the solution rate for the "ignore" participants would be significantly greater than for the "attend" participants.

This inquiry was instigated from the results of the first three experiments. In Experiments 1 and 2, participants were unable to reject previously-generated responses. However, in Experiment 3, participants were able to overcome the fixating effects of the previously-presented distractors, as shown by increased solution rate on Rat 2. This suggests that the fixating effect of the distractors in Experiment 3 might be partially due to the instructions that these "distractors" would be helpful to solution, rather than exclusively to the mere presence of the distractors. In Experiment 3, participants attended to the distractors voluntarily. This is in contrast to the usual way that distracting information reduces retrieval rate. For example, when experiencing a tip-of-the-tongue state (TOT), participants are actively trying to reduce the activation of (i.e., ignore) the interloper (Jones, 1989), but are unable to do so.

A final objective of Experiment 4 was to show that instructions to attend to or ignore extraneous information can result in positive or negative impact on solution rate, dependent upon the usefulness of this extraneous information. Specifically, it will be determined if instructions to ignore the information can actually decrease solution rate, if that information provides a useful clue for solving the RAT item. Such a finding would further support the theory that instructions exert a substantial effect on performance on the RAT task. In this case, strategies to ignore the clues can be effectively implemented by the participants. The method for testing this theory is outlined below.

Experiment 4

This final experiment was designed to investigate three major questions. The first was the degree to which it is possible to exert control over the effects of distractors, (i.e., ignore the distractors) when those distractors are known to be detrimental to solution of the RAT items. This was accomplished by presenting participants with a RAT procedure similar to that used in Experiment 3, with several modifications. The most substantial of these was that some participants were told that the words accompanying the RAT items were meant to be distracting and therefore, that they should ignore those words when solving the RATs.

A second purpose was to determine whether the instructions to ignore the distractors could prove to be detrimental to solution, when the distractors actually provided useful clues. To this end, the final five RAT items, out of a total of 20, were accompanied by clues that were helpful to solution. These items each contained one "distractor" that was very similar to the solution. For example, the RAT item: SKATE, PICK, WATER was accompanied by the words: blade, choose, and bath. The last two of these words are the same distractors that were used in Experiment 3. The first word, blade, was helpful to solution because together, "skate," and "blade" are very similar to the solution word, "ice". If participants were successfully ignoring the accompanying words, then it would not be expected that those who received these helpful clues would perform better than participants who received distracting words on these five RAT items.

The third purpose was similar to the second. In this case, it was of interest to determine how well participants who were instructed to attend to the distractor words would make use of the five helpful clues. The procedure was identical to that described above, except that the participants were instructed to attend to the words accompanying the RAT items because these words would aid them in solving the items. This was the same procedure followed in Experiment 3. As described above, the final five RAT items were accompanied by the helpful clues. It was expected that the participants who received the helpful clues on these items would be able to make use of the clues, and solve more of these items than would the participants who received distracting words on the final five RAT items.

Method

Participants. Participants were 50 University of New Hampshire undergraduates who participated in order to receive credit for Introductory Psychology. Ten participants were assigned to each of the four experimental groups, and ten participants made up the control group.

Materials. Materials were similar to the RAT items used in Experiment 3. The most difficult item was dropped from the set and replaced with an easier item, based on pilot testing. Two additional items of low difficulty were added, for a total of 20 RAT items in this experiment. These materials are included in Appendix C. There were two attend groups: Helpful-Attend (HA) and Distracting-Attend (DA). These participants were instructed to attend to the "clues" because they would help them solve the problems. These were the same instructions given to participants in Experiment 3. In the HA condition, the first 15 RAT items were accompanied by distracting "clues." The last 5 items were accompanied by helpful clues. In the DA condition, all 20 of the accompanying "clues" were distractors. There were two ignore conditions: Helpful-Ignore (HI) and Distracting-Ignore (DI). The ignore participants were told that the words accompanying the RAT items were meant to be distracting and therefore, that they should try to avoid them when solving the RAT items. In the HI condition, the first 15 RATs were accompanied by truly distracting distractors, while the last 5 were accompanied by helpful "distractors." In the DI condition, all 20 of the RAT items were accompanied by distracting words. The control condition was the same as that in Experiment 3, with the participants receiving only the RAT items without distractors on both experimental trials. Thus, there were five groups of participants: HA, DA, HI, DI, and control.

Other materials were similar to those used in Experiment 3. These included the recall test for the participants in the four distractor conditions, and the paper and pencil RAT for all participants.

Procedure. All participants received two trials of the RAT items. Participants in the attend conditions were instructed that the distractor words would help them to solve the RATs and that they should pay attention to these words. The example given was the same "window" example used in Experiment 3. The only difference between the HA and the DA conditions was in the last 5 items. In the HA conditions, the last 5 distractor items were helpful to solving the RATs, while these items were not helpful in the DA condition. This same distinction applied between the HI and DI conditions. In these ignore conditions, participants were told that the accompanying words were intended to distract the participants from solving the RATs and that they should try their best to attend only to the RAT words when solving the items. The control participants received the RAT items without any clues. All participants had 30 seconds to type their response on RAT 1. They were again instructed to spend the entire 30 seconds trying to solve the each item.

On RAT 2, all participants received only the RAT items, without distractors. RAT 2 was presented immediately after the participants completed all items in RAT 1. Because there were no differences found between the short-incubation and long-incubation conditions in Experiment 3, RAT 2 was considered to be an incubation condition.

The recall and pencil and paper RAT procedures were the same as described in Experiment 3.

Results

RAT 1 and RAT 2 Solution Data. Data from RAT 1 and RAT 2 were analyzed separately. Within the RAT 1 analysis, the first 15 RAT items and the final 5 items were analyzed separately. These separate analyses were conducted because the first 15 items were the same for both attend groups and both ignore groups. The final 5 items differed between the groups, in terms of the usefulness of the "distractors."

A one-way ANOVA was conducted on the first 15 items, for the attend, ignore, and control groups. This analysis revealed a significant effect, $F(2, 47) = 7.83$, $MSe = 3.89$. Planned comparisons showed a significant difference between the attend and control groups, $t(47) = 3.60$, with the control group solving significantly more of the RAT 1 items. The analysis between the attend and ignore groups also reached significance, $t(47) = 2.97$, with the ignore group solving more items than the attend group. The analysis revealed no difference between the ignore and control groups, $t(47) = 1.18$. Means are presented in Table 10.

A one-way ANOVA was conducted on the data from the final five items on RAT 1, between the 5 experimental conditions: control, HA, DA, HI, and DI. This analysis revealed a significant effect, F (4, 45) = 4.23, MSe = .74. Pairwise comparisons using the Newman-Keuls procedure showed that this effect was due to the poor performance of the DA group. The solution rate for the DA group was significantly lower than all other groups. For DA vs DI, t (45) = 3.65, for DA vs control, t (45) = 3.13, for DA vs HI, t (45) = 3.13, and for DA vs HA, t (45) = 2.86.

RAT 2 data were also analyzed with a one-way ANOVA that compared solution rates for the five experimental groups. This analysis revealed no significant differences between the groups, F (4, 45) = 1.56, MSe = 6.56, p = .20. Means are given in Table 10.

Improvement Effects. As in Experiment 3, improvement was defined for each participant as the total number of RAT items solved on RAT 2 that were not solved on RAT 1. A one-way ANOVA between the control, attend, and ignore groups revealed a significant effect, F (2, 47) = 6.82, MSe = 1.79. Planned comparisons showed that improvement was greater for the attend group than for the control group, t (47) = 3.67. The difference between the ignore group and the control group did not reach significance, t (47) = 2.12, p = .12. Comparison between the attend and ignore groups did not approach significance, t (47) = 1.34. Means are provided in Table 11.

Distractor Memory. A t-test compared the percentage of distractors recalled by the attend participants and the ignore participants. This revealed a significant difference, with the attend participants recalling more of the distractors, t (38) = 3.88. Means are presented in Table 12.

Table 10. Mean Solution Percentages for RATs 1 and 2: Experiment 4

	RAT 1				RAT 2	
	1st 15		Last 5		Total	
Condition	M	SD	M	SD	M	SD
HA	21.3	14.0	44.0	18.4	47.5	12.5
DA	24.7	10.5	22.0	14.8	44.0	11.5
HI	36.0	11.0	46.0	21.2	56.0	9.1
DI	34.7	14.7	50.0	14.1	54.5	15.1
Control	40.0	16.3	46.0	16.5	53.0	14.8

Improvement Effects and Ability Level. Scores on the pencil and paper RAT were used to classify participants as high-, medium-, or low-ability RAT solvers. High-ability participants were those who scored above the median, medium-ability participants scored at the median, and low-ability participants scored below the median. This resulted in 16 high-ability, 7 medium-ability, and 17 low-ability participants. A one-way ANOVA revealed no differences in the improvement scores for these three groups, $F(2, 47) = 1.90$, $MSe = 2.40$. Means are presented in Table 13.

Discussion

There were two major findings of interest in Experiment 4. The first concerns the performance of the participants in the ignore conditions. These participants exhibited solution rates that were significantly higher than those of the attend group, but not lower than those of the control group. This suggests that the fixation effects demonstrated in Experiment 3 were not due exclusively to the presence of the distracting information. Rather, this study suggests that the distractors, coupled with the instructions to attend to them, served to prevent participants from performing as well as the control group on the RAT task.

This conclusion is supported by the results of the recall task. In this task, attend participants recalled significantly more of the distractors than did the ignore participants. This suggests that participants in the ignore group were somewhat successful in their attempts to ignore the extraneous words, at least as indicated by their explicit memory for these words. This finding raises an interesting question concerning the method by which participants process the distracting stimuli. The knowledge that an extraneous stimulus

Table 11. Mean Improvement from RAT 1 to RAT 2: Experiment 4.

	Improvement	
Group	Mean	SD
Attend	21.0	6.2
Ignore	15.0	8.9
Control	11.5	7.1

Table 12. Mean Recall (Attend and Ignore Conditions): Experiment 4.

	Recall	
Group	M	SD
Attend	38.7	17.2
Ignore	20.9	11.2

Table 13. Mean Improvement for High-, Medium-, and Low-Ability RAT solvers: Experiment 4.

	Improvement	
Ability	M	SD
High	2.96	1.6
Medium	4.33	2.1
Low	3.33	1.5

was not appropriate for solution was sufficient to diminish the effect of that stimulus. That is, participants were able to successfully ignore the information when they were aware that the information would not be helpful to them. Therefore, Smith and Blankenship's (1991) results, as well as the results of Experiment 3 can be said to be partly due to the instructions that participants were given; that is, to exploit the distractors to find solutions to the RAT items.

This finding demonstrates a fundamental difference between Smith and Blankenship's (1991) blocking procedure and what actually takes place when we find ourselves unable to retrieve a known piece of information. For example, when we experience a TOT, the mere knowledge that the interloper that has been accessed is incorrect does not make it possible to reduce the activation level of that interloper (e.g., Jones, 1989; Jones & Langford, 1987).

The present finding can be compared to the results of Experiments 1 and 2. In those experiments, the fixating effects of the incorrect riddle responses continued to exert an effect on later solution attempts, both in the short-term (Experiment 1) and after an incubation period (Experiment 2). In these riddles, the participants themselves generated the incorrect responses. This is in contrast to the RAT example, in which the incorrect responses were provided experimentally.

Also with respect to the topic of incubation, the present experiment found no differences in the degree to which participants of varying ability levels benefited from the incubation period to improve the number of RATs solved on Trial 2. This is in contrast to Experiment 3, in which the high-and medium-ability participants showed an advantage to the low-ability solvers in this regard. This might be accounted for in two ways. First, the task performed in Experiment 4 was generally easier than that in Experiment 3, given that the ignore participants were quite capable of ignoring the distractors. Therefore, these participants solved more RAT items on Trial 1. Subsequently, there was an overall decrease in the amount of improvement on RAT 2 for the ignore participants, compared to those in the attend group. Second, there was a decrease in the difficulty level of the RAT items from Experiment 3 to Experiment 4. This also made the task easier. This is especially important, in light of research in social psychology demonstrating that positive feedback can improve scores on the RAT (e.g., Fodor & Greenier, 1995), particularly for individuals who have already been identified as having high ability for the task. Based on this research, it might be the case that the low-ability participants in Experiment 3 became discouraged by their poor performance on the RAT items, which might have served to further diminish their performance.

CHAPTER V

GENERAL DISCUSSION

The present experiments were conducted to investigate several primary hypotheses. The first of these was the supposition that suppression efficiency is part of a general cognitive mechanism. Previous research by Gernsbacher and colleagues (e.g., Gernsbacher & Faust, 1991; Gernsbacher et al. 1990) has shown that suppression efficiency is predictive of comprehension ability. Further, they have demonstrated that this suppression mechanism operates on nonlinguistic as well as linguistic tasks. Based on their findings, these researchers predicted that suppression skill underlies a variety of cognitive abilities.

In Experiment 1, it was revealed that spontaneous transfer and informed transfer abilities are related to suppression efficiency. This is significant because it extends the previous work of Gernsbacher and associates to the realm of problem solving. Thus, it supports the claim that suppression skill is a part of cognitive abilities as a whole. Further, Experiment 3 showed that ability on another problem solving task, the Remote Associates Test, is also related to suppression skill. That these problem solving tasks are related is not surprising, if both are considered as measures of individuals' ability to draw associations between sources of information that do not seem to be immediately related. For example, in order to solve the riddles in Experiment 1, participants had to recognize the relevance of the previously-presented sentences. This was true in both the informed and uninformed conditions. Similarly, the RAT measures the ability to draw associations between words that are not obviously related to each other. That is, each of the three words in a RAT item is related to the two other words only through its connection to the fourth, unpresented, word. Because three RAT words are not directly related to each other in any way that is useful to solution, participants must disregard any immediate connection that any given pair of the words might share, and instead direct their search to some remote word.

This process is very similar to what is involved in accessing the solution to the riddles. For example, to solve the minister riddle, one must look beyond the obvious meaning of the word, "marry" and instead access the less common meaning of this word. Once this is accomplished, the solution to the riddle is clear. Each of the riddles requires a similar procedure to obtain solution. These results nicely complement Simonton's (1988) conjecture that the ability to draw associations between remotely related concepts is especially high in individuals who generate random permutations of mental associations. Because they randomly shift focus, these individuals do not perseverate on habitual associations between concepts, thus allowing access to atypical connections between words. Such an ability would certainly facilitate access to both the riddle and RAT solutions. These accessing processes can also be compared to those that have previously been shown to be related to suppression skill, such as solving a pun (Gernsbacher & Robertson, 1995), or comprehending riddles (Fowles & Glanz, 1977; Yuill & Oakhill, 1991).

In sum, the suppression task devised by Gernsbacher et al. (1990) proved to be effective in distinguishing between participants who were high- or low- skilled problem solvers. Thus, the present experiments have extended Gernsbacher et al's construct of a general suppression mechanism to the skill of problem solving. Further, this finding adds to previous research in problem solving that has investigated the differences between individuals who vary in the ability to make use of base analogs in studies of analogical transfer (Chen, 1995; Gick & Holyoak, 1980, 1983; Novick, 1988). Specifically, the present findings suggest that skilled suppressors are able to make use of the similarities between the acquisition sentences and the riddles, although there was very little surface overlap between the two sources of information.

A second central theme of the present dissertation was that of the attenuation of fixation effects in problem solving. Results of the riddle and RAT procedures yielded differential results in this regard. While participants easily overcame their fixation to the artificial blockers provided in the RAT procedures (Experiments 3 and 4), there was no such recovery from fixation to the participant-generated solutions to the riddles in Experiments 1 and 2. These findings are interpreted in light of the generation effect (Slamecka & Graf, 1978), which states that information that is generated by a participant is better remembered than information that is experimentally provided to the participant.

This result can be contrasted with work in analogical transfer that has shown that solution failures can actually improve performance on later-presented problems (e.g., Duncker, 1945; Gick & McGarry, 1992; Needham & Begg, 1991; Ross, 1984; Ross & Kennedy, 1990). Needham and Begg (1991) showed that participants' failed attempts to solve a base analog to the radiation problem resulted in higher solution rate to the radiation problem, compared to participants who only read the base problem, but did not attempt to solve it. Perfetto et al. (1987) showed the opposite effect using the insight riddles. Participants who attempted to solve the riddles on an initial uninformed trial performed less well on a subsequent informed trial than participants who simply read the incorrect solutions in the uninformed trial. The present results are consistent with this finding. It seems likely that participants' failure to solve "old" riddles in the informed condition resulted from some combination of having generated the incorrect responses themselves, and a misguided perception that these solutions were the appropriate answers.

While this account effectively explains the results of Experiment 1, the results of Experiment 2 are more elusive. Past research has shown that the introduction of an incubation period can serve to reduce the activation effect of incorrect information and thus, result in increased solution rates on problems such as the RAT (Patrick, 1986; Smith & Blankenship, 1991) and anagrams (Goldman et al., 1992; Peterson, 1974), as well as on reminiscence effects (Smith & Vela, 1991). Unlike initial incorrect responses in these experiments, incorrect responses to the riddles were not alleviated during the incubation period. It is possible that introducing a longer period between successive solution attempts might result in an incubation effect with the riddles. Previous research has demonstrated that incubation effects are more dramatic after a 24-hour interval than after a duration of 20 minutes (e.g., Goldman et al., 1992). Further research might make use of this procedure to determine whether the fixation to self-generated solutions to the riddles would be similarly decreased.

A final issue regarding the riddles is whether the participants "caught on" to the relevance of the clue sentences at some point during the uninformed phase of riddle solution. Previous researchers have adhered to this account (e.g., Lockart et al., 1988; Ross et al., 1989). Alternatively, others have suggested that participants do not "catch on," but rather, they access the necessary information, but are not aware that this transfer has taken place (Landrum, 1990; Maier, 1931; Perfetto et al., 1983). For example, Maier presented participants with the two-string problem. As a clue to solution of the problem, he "accidentally" brushed by the rope, causing it to swing. Although solution rate to the two-string problem increased after this hint, participants did not mention this incident when describing how they came to their solution. To the contrary, participants most often reported that the solution "just came to them." This result, which might be referred to as the "insight" solution, was replicated by Landrum (1990).

In contrast, Ross et al. (1989), found convincing evidence for the "catching on" position. They presented participants with the riddles previously used by Perfetto et al. (1983). A majority of participants reported that they became aware of the relationship between the riddles and the acquisition sentences during uninformed solution of the riddles. In a postexperimental questionnaire, Ross et al. asked participants to specify the riddle that they were working on when they made this realization. An analysis of the response rate on this trial showed that solution rates increased after this connection was reported to have been made. That is, participants solved more riddles in the uninformed condition after the first riddle in which they reported that they noticed the relevance of the sentences to the riddles.

The present set of experiments does not settle this dispute. However, it is likely that the "bald" riddle did serve as a cue as to the relevance of the sentences to the riddles. A simple method of testing this possibility in the future would be to provide only one group of uninformed participants with the bald riddle on Trial 1. If this riddle served the purpose stated above, the participants who receive the bald riddle on Trial 1 will show greater increases in Trial 2 solution rate than participants who are not provided with this cue.

In comparison to the outcome of the riddle experiments, results of Experiments 3 and 4 showed that fixation to experimentally-induced distractors is more easily overcome. In Experiment 3, participants who initially attempted to solve the RAT items with the distractors present experienced difficulty in solving, in comparison to control participants who had no distractors. However, solution rate for fixated participants increased substantially on RAT 2 when no distractors were present, although these participants did not increase to the level of control participants on RAT 2. This result was replicated in Experiment 4 for the "attend" participants.

Experiment 4 more closely examined the process by which the distractors exerted their effects in Experiment 3. Comparison between the attend and ignore participants on RAT 1 revealed that the ignore participants solved significantly more RAT items than did the attend participants. This suggests that the detrimental effects of the distractors in Experiment 3 were due in large part to the instructions that participants attended to the distractors because they thought they would be helpful to solution. When told to ignore these distractors in Experiment 4, participants were able to do so. This draws a distinction between the usual effects of distracting information in everyday problem solving and the somewhat contrived distractors used here. In normal problem solving, such as when a TOT state occurs, fixation to a distracting stimulus is not so easily overcome. Attempting to disregard an incorrect word often serves to strengthen the fixating effect of that word. Nonetheless, it can be concluded that "attend" groups in Experiments 3 and 4 experienced fixation to the distractors, and that this fixation was mitigated by the introduction of an incubation period.

Results of the relative effectiveness of an incubation period for individuals of varying ability levels were inconclusive. Experiment 3 showed greater incubation effects for the high-skilled problem solvers, replicating Patrick's (1986) findings, but contrasting with Smith and Blankenship's (1991) results. Experiment 4 revealed no differences in the incubation effect for participants of varying RAT solution abilities. Although this result is disappointing, it is not out of step with previous incubation research, some of which has shown benefits to high-ability problem solvers (Patrick, 1986; Smith & Blankenship, 1991, Experiment 5), and other work that has shown that poor problem solvers benefit more from incubation periods (Murray & Denny, 1969; Smith & Blankenship, 1991, Experiment 1).

This controversy is only fueled by the present findings. It is possible to conjecture as to the basis for the differential incubation results in Experiments 3 and 4. It is possible that the incubation period did not prove as helpful in Experiment 4 because the participants were able to successfully ignore the distractors on RAT 1. Therefore, solution rates on RAT 1 were not hindered by the presence of the distractors to the degree that RAT 1 solutions were depressed in Experiment 3. Such a process would render the incubation period less useful because participants solved more problems on RAT 1. Comparison of the RAT 1 solution rates between Experiments 3 and 4 supports this possibility.

Conclusions

The present experimental materials examined one of the oldest issues in cognitive research, that of the influence of past experience on problem solving performance. The relative effect of a domain of knowledge has intrigued investigators since Thorndike (1898) placed cats in his puzzle box. The present experiments made use of materials that were certainly within the domain of knowledge of participants, given that all participants are aware of the solutions to the insight riddles, as well as to the common phrases formed in the RAT items. Thus, performance is not dependent solely on possession of such knowledge, but is also greatly affected by diverse factors, such as the ability to access that information when necessary, the ability to ignore irrelevant information, and skill in suppressing inappropriate word meanings.

Further, these experiments showed that fixation effects can be attenuated under certain circumstances, but that these effects can be quite enduring in other instances. These differential findings seem to be resultant of the type of problems that are presented, as well as the method by which blocking is induced. Specifically, it was shown that fixation to superficial distractors can be effectively overcome, in that such distractors were easily ignored. However, distractors that are generated by the participants are more difficult to surmount. In fact, the procedures used in these experiments did not result in attenuation of these fixation effects. Further research might investigate more effective methods to achieve this end.

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APPENDIX A

Riddles and corresponding clue sentences from Experiments 1 and 2

The first three riddles are the filler materials. The fourth is the "bald" riddle that was used to demonstrate the relationship between the sentences and the riddles. Therefore, these four riddles were not included in the analyses reported in this dissertation.

Dan comes home from work and finds Charlie dead on the floor. On the floor is some broken glass and some water. Dan takes one look around and immediately knows how Charlie died. How did he die?

Charlie was a fish.

A criminal took his wife to a movie theater that was showing a shoot-em-up western. During one scene, when many guns were fired, he murdered his wife by shooting her in the head. He then took his wife's body out of the theater, but no one stopped him. How did he manage it?

It was a drive-in movie.

Two train tracks run parallel except for a spot where they go under a tunnel. The tunnel is not wide enough to accommodate both tracks, so they become a single track for the distance of the tunnel. One afternoon a train entered going one direction, and another train entered the same tunnel going the opposite direction. Both trains were going at top speed, yet there was no collision. Explain.

The trains entered at different times.

A man was caught in the rain with no hat or umbrella. There was nothing over his head and his clothes got soaked, but not a hair on his head got wet. How is this possible?

A bald man does not have to dry his hair after taking a shower.

A man who lived in a small town in the U. S. married twenty different women of the same town. All are still living and he has never divorced any of them. Yet he has broken no law. Can you explain?

A minister marries several people each week.

Whenever my aunt comes to visit me at my apartment, she always gets off the elevator five floors beneath my floor. She then walks up the stairway to my apartment. Can you tell me why?

The top buttons on an elevator are too high for a midget to reach.

A wine bottle is half-filled and corked. How can you drink all of the wine without removing the cork from the bottle?

A cork can be opened by pulling it out or pushing it in.

Can you make a tennis ball go a short distance, come to a dead stop, then reverse itself and go in the opposite direction? Note: Bouncing the ball is not permitted, nor can you hit it with anything, nor tie it to anything

If you throw a ball into the air, it comes back down.

The Great Sol Loony announced that on a certain day, at a certain time, he would perform a great miracle. He would walk for twenty minutes on the surface of the Hudson River without sinking into the water. A big crowd gathered to witness the event. The Reverend Sol Loony did exactly what he said he would do. How did he manage to walk on the surface of the river without sinking?

A person walking on frozen water will not fall through.

If you had only one match and you wanted to light a kerosene lamp, an oil heater, or a wood burning stove, which would you light first?

You must first light a match before you can light a fire.

Why are 1987 dollar bills worth more than 1986 dollar bills?

1,850 dollar bills are worth more than 1,849 dollar bills.

One night my uncle was reading an exciting book when his wife turned out the light. Even though the room was pitch dark, he continued to read. How could he do that?

A blind person can read Braille in the dark.

Uriah Fuller, the famous superpsychic, can tell you the score of any baseball game before the game starts. What is his secret?

Before any game is played, there is no score.

This morning, one of my earrings fell into my coffee. Even though my cup was full, the earring didn't get wet. How come?

You add hot water to ground beans to make coffee.

APPENDIX B

RAT items from Experiment 3

RAT test items are in upper case, distractors are in lower case, and solutions are in boldface.

	Problems			Solutions
1.	LICK tongue	SPRINKLE rain	MINES gold	**salt**
2.	WIDOW woman	BITE chew	MONKEY wrench	**spider**
3.	TYPE style	GHOST goblin	STORY tale	**writer**
4.	SURPRISE trick	LINE angle	BIRTHDAY cake	**party**
5.	WHEEL tire	ELECTRIC cord	HIGH low	**chair**
6.	CAT nap	SLEEP might	BOARD wood	**walk**
7.	SHIP ocean	OUTER inner	CRAWL floor	**space**
8.	BALL soccer	STORM tornado	MAN boy	**snow**
9.	FAMILY mother	APPLE pie	HOUSE home	**tree**
10.	ATTORNEY lawyer	SELF me	SPENDING shopping	**defense**
11.	WORM bug	SCOTCH whiskey	RED green	**tape**
12.	WATER bath	PICK choose	SKATE board	**ice**

13. RIVER lake	NOTE music	BLOOD wound	**bank**
14. FOOD eat	CATCHER pitcher	HOT cold	**dog**
15. HEARTED broken	FEET inches	BITTER sweet	**cold**
16. SANDWICH jelly	GOLF course	CANADIAN Montreal	**club**
17. GRAVY potato	SHOW movie	TUG pull	**boat**
18. ARM leg	COAL furnace	PEACH pear	**pit**

APPENDIX C.1

RAT items from Experiment 4, helpful conditions

RAT test items are in upper case, distractors are in lower case, and solutions are in boldface.

	Problems		Solutions
1. LICK	SPRINKLE	MINES	**salt**
tongue	rain	gold	
2. TYPE	GHOST	STORY	**writer**
style	goblin	tale	
3. SURPRISE	LINE	BIRTHDAY	**party**
trick	angle	cake	
4. WHEEL	ELECTRIC	HIGH	**chair**
tire	cord	low	
5. CAT	SLEEP	BOARD	**walk**
nap	might	wood	
6. BALL	STORM	MAN	**snow**
soccer	tornado	boy	
7. WORM	SCOTCH	RED	**tape**
bug	whiskey	green	
8. FOOD	CATCHER	HOT	**dog**
eat	pitcher	cold	
9. HEARTED	FEET	BITTER	**cold**
broken	inches	sweet	
10. SANDWICH	GOLF	CANADIAN	**club**
jelly	course	Montreal	
11. GRAVY	SHOW	TUG	**boat**
potato	movie	pull	
12. ARM	COAL	PEACH	**pit**
leg	furnace	pear	

13. PASTE glue	BUCK deer	FAIRY pixie	**tooth**
14. FINGER hand	OIL olive	BRUSH comb	**paint**
15. FLAG banner	NORTH south	VAULT tomb	**pole**
16. WIDOW black	BITE chew	MONKEY wrench	**spider**
17. CRAWL storage	OUTER floor	SHIP ocean	**space**
18. APPLE branch	HOUSE home	FAMILY mother	**tree**
19 SKATE blade	PICK choose	WATER bath	**ice**
20. RIVER edge	NOTE music	BLOOD wound	**bank**

APPENDIX C.2

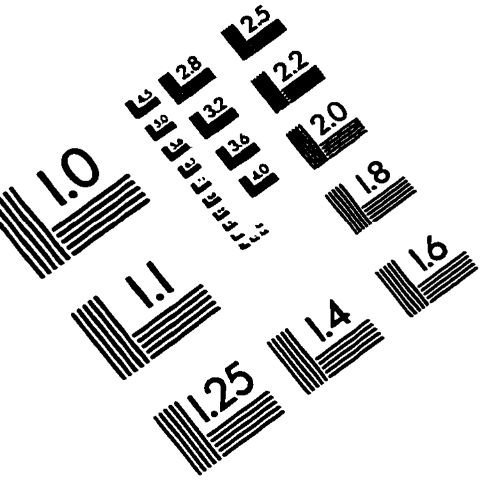
RAT items from Experiment 4, distracting conditions

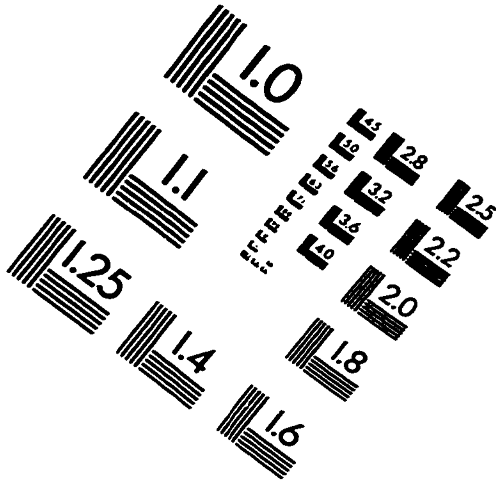
RAT test items are in upper case, distractors are in lower case, and solutions are in boldface.

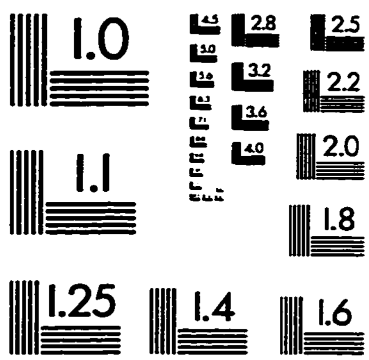
	Problems			Solutions
1.	LICK tongue	SPRINKLE rain	MINES gold	**salt**
2.	TYPE style	GHOST goblin	STORY tale	**writer**
3.	SURPRISE trick	LINE angle	BIRTHDAY cake	**party**
4.	WHEEL tire	ELECTRIC cord	HIGH low	**chair**
5.	CAT nap	SLEEP might	BOARD wood	**walk**
6.	BALL soccer	STORM tornado	MAN boy	**snow**
7.	WORM bug	SCOTCH whiskey	RED green	**tape**
8.	FOOD eat	CATCHER pitcher	HOT cold	**dog**
9.	HEARTED broken	FEET inches	BITTER sweet	**cold**
10.	SANDWICH jelly	GOLF course	CANADIAN Montreal	**club**
11.	GRAVY potato	SHOW movie	TUG pull	**boat**
12.	ARM leg	COAL furnace	PEACH pear	**pit**

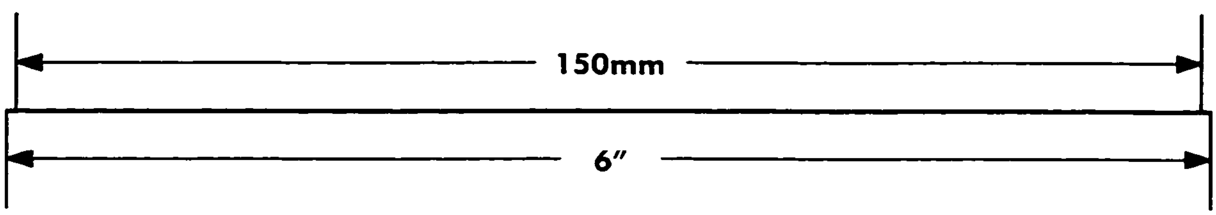
13. PASTE glue	BUCK deer	FAIRY pixie	**tooth**
14. FINGER hand	OIL olive	BRUSH comb	**paint**
15. FLAG banner	NORTH south	VAULT tomb	**pole**
16. WIDOW woman	BITE chew	MONKEY wrench	**spider**
17. CRAWL floor	OUTER floor	SHIP ocean	**space**
18. APPLE pie	HOUSE home	FAMILY mother	**tree**
19 SKATE board	PICK choose	WATER bath	**ice**
20. RIVER lake	NOTE music	BLOOD wound	**bank**

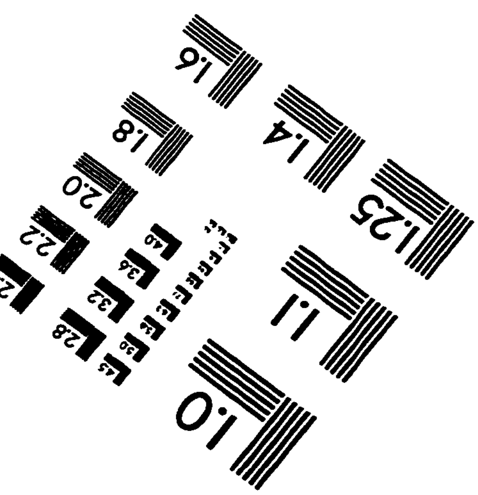
IMAGE EVALUATION TEST TARGET (QA-3)

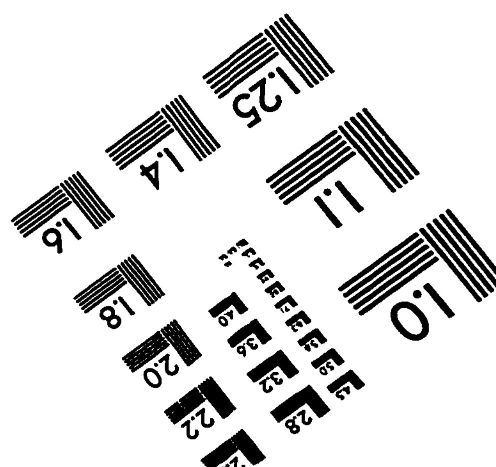












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