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The influence of task similarity, topic interest and incentives on spontaneous and informed transfer

Kaufman, Christopher James, Ph.D.

City University of New York, 1993

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A

THE INFLUENCE OF TASK SIMILARITY, TOPIC INTEREST AND INCENTIVES ON SPONTANEOUS AND INFORMED TRANSFER

By

CHRISTOPHER J. KAUFMAN

A dissertation submitted to the Graduate Faculty in Educational Psychology in partial fulfillment of the degree of Doctor of Philosophy, The City University of New York

1993

APPROVAL PAGE

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Abstract

THE INFLUENCE OF TASK SIMILARITY, TOPIC INTEREST AND INCENTIVES ON SPONTANEOUS AND INFORMED TRANSFER

by

Christopher Kaufman

Advisor: Professor Sigmund Tobias

The purpose of this study was to examine the influence of motivational variables (i.e., topic interest, task interest, extrinsic incentives) and structural variables (task similarity and schema quality) on access to prior learning in a novel problem solving context. In addition to being the first study to investigate the impact of both intrinsic and extrinsic motivational variables in a problem solving context, the study was also the first problem solving experiment to explore the interaction between motivational and structural variables.

The sample was comprised of 165 New York City public high school students enrolled in at least one advanced placement science class. Most participants demonstrated a strong interest in science, as determined by a topic interest survey administered during the experiment.

The basic experimental procedure was to provide subjects with a story analogy, describing a problem and its solution, and then to observe how subjects used the analogy in solving a subsequent (seemingly novel) target problem. The experiment was comprised of three distinct phases: (1)

story analog acquisition; (2) testing for task interest and science interest (topic interest); and, (3) problem solving. The task similarity independent variable was manipulated in the acquisition phase. Subjects either acquired the necessary strategy through an acquisition phase task similar or dissimilar to the subsequent problem solving task. The topic/text-based interest and incentive independent variables were manipulated in the problem solving phase. Subjects attempted to solve either an "interesting" or "dull" version of Duncker's Radiation Problem and were also randomly assigned to "financial incentive" or "no financial incentive" conditions.

Contrary to expectations, the results indicated no main effects for task similarity or any of the motivational variables examined. Significant interaction effects were also not obtained. Successful problem solvers were found to differ significantly from unsuccessful problem solvers with regard to their conceptual understanding (schema quality) of the salient information provided during the acquisition phase.

The comparative importance of structural variables (i.e., schema quality and task similarity) and motivational variables (i.e., topic interest and task interest) to the problem solving process are discussed. Implications for educators and future research are also described.

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I owe a considerable debt of gratitude to Professor Sigmund Tobias, my mentor and friend. The interest he has continually demonstrated in both my research and career has been very beneficial to my professional development, and will never be forgotten. Special thanks are also due Professors Anastasiow, Fish, Saigh, Tittle, and Zimmerman for their support and encouragement.

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CHAPTER I

INTRODUCTION

It is impossible to find behavior arising from affectivity alone without any cognitive elements. It is equally impossible to find behavior composed only of cognitive elements.

Jean Piaget (1981, p. 2)

Piaget's comment regarding the inextricable link between affect and cognition would seem self-evident. Indeed, it would be difficult to argue that any of our actions can be attributed solely to either emotional or cognitive sources. Despite the apparent logic of this position and the attention paid to affective variables by such important early figures as Yerkes and Dodson (1908), Dewey (1913, 1916) and Thorndike (1935), psychologists have a long tradition of constructing purely rational models of human cognition. This narrowly defined perspective has come to be termed by many researchers as the study of "cold cognition," referring to a disregard of the potential energizing influence of affective variables. Recently, however, there has been growing interest in an expanded view of cognition ("hot cognition") that stresses the relationship between affective variables and cognitive processes. As was noted by Hidi and Baird (1988), hot cognition has finally become a "hot issue" for educational researchers.

Paris (1988) and Paris and Cross (1983) emphasize the inextricable link between "skill and will," recognizing that no learning occurs unless both are present. Given the importance of the affect/cognition link, it is regrettable that the increasing calls for the examination of affect/cognition relationships have yet to lead to a significant shift in the manner in which cognitive performance variables are investigated. In her review of the literature, Hidi (1990) concluded that very little empirical progress has been made toward integrating cognitive factors with affective and motivational aspects of thinking. On the basis of the studies that have been conducted, however, several prominent researchers (e.g., Bereiter, 1985; Brown, Collins, & Duguid, 1989; Csikszentmihalyi, 1975, 1988; Hidi & Baird, 1986, 1988; Larson, 1988; Paris & Cross, 1983; van Kijk & Kintsch, 1983) have concluded that purely rational models of human cognition are inadequate to describe the manner in which information is retained, processed, and accessed (Hidi, 1990).

Although many of the specific fields of inquiry within cognitive psychology would benefit if examined from the perspective of hot cognition, topics centered around problem solving would seem particularly in need of research that embraces such an expanded view of cognitive performance. Given the attempts in both education and industry to enhance problem solving via the manipulation of affective variables

(i.e., the offer of extrinsic incentives), the paucity of research on the manner in which motivational variables influence problem solving is both surprising and unfortunate. The small number of studies that have looked at the influence of extrinsic motivational variables on cognitive performance have suggested that the effects obtained are not always consistent with the expectations of most educators and office managers. That is, under certain conditions and task requirements, incentives have been found to actually inhibit performance rather than facilitate it (Eysenck, 1984; McGraw, 1978). Even less is known about the influence of intrinsic motivational variables such as interest on problem solving and other cognitive performance variables. With exception of one recent study, the interaction between intrinsic and extrinsic motivational variables in terms of their influence on cognitive performance variables has been completely disregarded by researchers.

It is apparent that a great deal more must be learned about the influence of motivational variables on problem solving and cognitive performance. Among the more interesting cognitive research paradigms developed in the area of problem solving involves subjects' access to prior learning ("inert knowledge") when asked to solve novel problems. A growing body of research conducted from a purely rationale ('cold cognition') perspective has attempted to

identify the conditions under which subjects can access information acquired in one context when solving novel problems set in another context. The literature review described in Chapter II considers the studies to pursue this line of inquiry before turning to an examination of the few studies that have recently explored the influence of motivational variables on spontaneous and informed transfer. Although, as the review indicates, these fledgling efforts have produced some contradicting results, their findings suggest that affect can impact the transfer process.

A fundamental purpose of the empirical investigation described in Chapter IV (Methods) was to determine the relative importance of structural variables and motivational variables to subjects' access of prior learning in a novel problem solving context. Specifically, the experiment sought to determine whether variables like 'task similarity' (the degree of similarity between initial learning and transfer tasks) and schema quality (the quality of a subject's conceptual understanding of information acquired in initial learning tasks) have a greater influence on spontaneous and informed transfer than motivational variables like individual (topic) interest, task interest, and the offer of extrinsic incentives. The study addressed two of the more glaring gaps in the transfer literature by examining the comparative importance of structural and motivational variables on transfer and by investigating the interaction

of intrinsic and extrinsic motivational variables in a problem solving context.

The findings (described in Chapter IV) suggest that the quality of subjects' conceptual understanding of information acquired during initial learning tasks is the single greatest determinant of transfer of this information to subsequent problem solving tasks. Countering experimental hypotheses, the affective variables examined were found to have little or no influence on the transfer process. Chapter V (Discussion) examines aspects of the experiment's design and procedures that may have limited the chances of obtaining effects for motivational variables, and suggests methods of altering the design of affect/cognition research to increase its generalizability to classroom learning contexts.

CHAPTER II

REVIEW OF THE LITERATURE

Early Explorations of Problem Solving and Inert Knowledge

Transfer is paradoxical. When we want it,
we do not get it. Yet it occurs all of the time...

W.J. McKeachie (1987, p.707)

One orientation towards problem-solving that has a long history in psychology places much importance on the transfer of old associations to new problems. Given this orientation, it becomes important to demonstrate that preestablished associations can indeed be transferred to new problems. Most of the initial research in this area operated out of a two-stage experimental design. In the first stage, potentially relevant associations are established in one group of subjects, while a second group acquires an irrelevant association. Both groups then try to solve some criterion problem, with the expectation that the subjects who earlier acquired the relevant association would solve the problem more quickly (Weisberg, DiCamillo, & Phillips, 1978).

The more recent research into the transfer of previously acquired material has centered around access to stored learning and the degree to which the transfer of relevant associations can be facilitated by cognitive cuing of the previously stored information. Several studies (e.g., Perfetto et al., 1983; Weisberg et al., 1978) have

demonstrated that transfer will occur to a much higher degree in subjects who are informed of the connection between previously acquired material and problems to be solved than in subjects who are not informed of this connection. This section of the literature review will examine both types of research, beginning with those studies that investigated the utility of previously learned material in novel problem solving contexts.

Although it was not their stated purpose, Judson, Cofer, and Gelfand (1956) can be credited with being the first to demonstrate the difficulty of accessing and applying previously learned information in novel problem solving contexts. The actual purpose of their associative learning study was to determine whether the frequency of correct solutions to Maier's (1945) "two-string" and "hat rack" problems could be increased through prior reinforcement of relevant associations (cue words). Briefly, the two-string problem presents the subject with the task of tying two vertically hanging strings together that are too far apart for one to be reached while the other is grasped. The hat rack problem requires the construction of an apparatus that can be used to suspend a hat using only two boards of different lengths and a metal clamp. The subjects in the experimental group were asked to learn the following list of words before working on the two string problem: rope, swing, pendulum, clock, and time. Control group

subjects were exposed to a string of five words unrelated to the problem. Similar procedures were followed for the hat-rack problem. It was hypothesized that the exposure to the string of relevant words would facilitate the experimental subject's ability to correctly solve the problems in that the cue words would trigger the correct pendulum and construction solutions.

The results of this study suggested that the effect of the previously established solutions was not as strong as had been hypothesized. That is, for the two-string problem, the difference between the performance of the experimental and control groups was not found to be significant. Two attempts at replicating the experiment also did not produce a significant difference. A significant difference was found between the two groups on the hat-rack problem; however, this difference was obtained only when the male subjects' (who comprised 50% of each group) responses to the problems were analyzed separately. Based upon these results, Judson et al. concluded that the preestablished associations were not effective at increasing problem-solving. Furthermore, a study adopting virtually identical procedures by Maltzman, Belloni, and Fishbein (1964) failed to replicate even the weak effect reported by Judson et al.

By failing to demonstrate that the memorization of clue words facilitates problem solving, Judson et al. (1956) clearly illustrated that knowledge learned in one context

(i.e., the rote memorization of words) cannot be readily accessed by subjects when a problem related to the stored information is presented. Although the learned material is not forgotten and can in fact be accessed if individuals are requested to reproduce it (e.g., the experimental subjects in the two aforementioned studies all were able to memorize the string of cue words), the information is not utilized when needed in a novel problem-solving context. Thus, in terms of its utility for later problem solving, the information can be considered inert.

Among the earliest educators to address the issue of students' failure to access related, previously stored information in a problem-solving context was Alfred Whitehead (1929), who warned educators of the dangers of what he termed "inert knowledge." Inert knowledge was identified as information which is accessed only in a restricted set of contexts even though it is potentially applicable to a wide variety of domains. Whitehead further posited that most common educational practices tended to create inert knowledge, given the emphasis typically placed upon context bound learning. According to this theory, overly contextualized instructional practices inhibit many students from transferring the knowledge acquired in one context to other contexts since no (or little) attempt is made to demonstrate how information and strategies can facilitate problem solving across a range of situations.

Before considering the research into the conditions which must be present in order for inert knowledge to be accessed in a new problem solving context, it may be helpful to explore the reasons why knowledge often remains inert. Bransford, Vye, Adams, and Perfetto (1989) offered three possible explanations for students' inability to access information apart from the immediate context in which it was learned:

(1) Students, across all grade and skill levels, are frequently encouraged to memorize specific facts rather than be helped to understand the significance of the information. In this rote learning process, even the most able students may employ a highly task-specific mnemonic device to facilitate the retention and recall of the information stored. While such reliance on rote learning and memory enhancement skills often enables the student to store a considerable amount of material and perform well on specific academic tests, these procedures do not aid students in recognizing the significance and/or relevance of the factual material they have learned.

(2) Students may acquire concepts in a restricted context and hence fail to understand their applicability to a wider variety of domains. In illustrating this point, Bransford et al. (1989) cite a description by Bransford (1979) of a student preparing for an exam in statistics. The student could solve all the problems on the study sheets

provided for him and therefore felt prepared for the exam. After a friend cut out each problem from the study sheets and reshuffled them before presenting them to the student, however, the student was unable to solve most of the problems. It soon became apparent that the student had been inadvertently relying on chapter cues in order to choose the formulas and principles that were applicable to each problem. Once the problems were presented in an alternate order, the student was no longer able to recognize the cue and thus was unable to solve the problems.

(3) Students may have acquired knowledge yet be unable to access it in an efficient manner that requires minimal attentional effort. That is, the ability to activate the information may not be automatized to the degree that the information will be accessible in contexts which differ from the original learning situation. In illustrating this phenomenon, Mezynski (1983, cited by Bransford et al., 1989) discussed several studies in which researchers attempted to teach new vocabulary to students in order to improve reading comprehension. While each of the studies was successful in increasing students' scores on vocabulary tests, many of the students were nevertheless unable to utilize their new word knowledge under conditions where the information had to be accessed quickly (e.g., a timed reading comprehension task).

Asch (1969) was among the first to purposefully provide a clear demonstration of a lack of spontaneous access and

use of stored information in new problem solving situations. The methods he employed, in general terms, were as follows: Subjects were first required to learn a standard paired-associate task consisting of several letter-number combinations (i.e., 24-E, 35-L, etc.). Approximately ten minutes later they were asked to learn a similar paired associate list which included one well-learned pair from the first list. The subjects were not informed of the identity of the recurring pair, allowing the researcher to compare the "relearning" of the recurring pair by subjects who did and did not identify it as previously learned. Asch was specifically interested in the number of trials it would take to learn the 'old' pair as compared with the number of trials required to learn the new pairs that only occurred on the second list.

The results of the Asch (1969) study revealed that there was a clear relation between recall of the critical paired-associate item and reports of recognition. That is, those subjects who did not recognize the recurring pair as appearing in list one (63% of the sample) required just as many learning trials to learn the 'old' pair as they did to learn the unfamiliar items. Those subjects who did recognize the recurring pair, however, mastered the familiar item faster than the unfamiliar paired associates. It also merits noting that no difference was found between recognition and nonrecognition subject's ability to learn a new pair,

suggesting that the recognition subjects' more rapid recall of the recurring paired associate can be attributed to the facilitating influence of recognition. On the basis of these findings, Asch concluded that associative recall is a two-step process in which recall must be preceded by recognition.

Asch's study can be considered critical to the formation of much of the research which followed it in that it demonstrated the importance of recognition of previously learned information in the problem solving process. That is, his findings indicated that without recognition of the existence and utility of what had been inert knowledge, this information would have to be "relearned" in a novel problem solving context. This result is crucial to the subsequent research in this area (i.e., Weisberg et al., 1978; Perfetto et al., 1983) because it suggested that the spontaneous transfer of knowledge learned in one context to a second (apparently unrelated) context is highly unlikely since spontaneous recognition of its utility is unlikely. Before examining the later research which illustrated the means by which inert knowledge can be accessed in a novel problem solving context, I will present additional research which expanded upon Asch's findings.

Spontaneous Transfer of Problem Solving Strategies

A number of later studies demonstrated that subjects often fail to utilize relevant, previously learned

information when problem-solving. Given that certain strategies can be used to solve problems across a variety of contexts, researchers endeavored to determine whether a strategy learned in one context could be successfully accessed and applied to solve a problem set in another context. For example, Reed, Ernst, & Banerji (1974) studied the effect of solution transfer between two problems having similar (homomorphic) problem states. In their Experiment I, subjects were presented with either the "Jealous Husbands" or "Missionary-Cannibal" problem before being asked to solve the other problem. While the problems differed in terms of the cast of characters and setting, the solution to each problem was identical. The results of this first experiment indicated that while 68 of the 97 subjects were able to correctly solve both problems within the time limit, transfer of the correct solution from problem to problem did generally not occur. Two additional experiments were conducted in order to determine the conditions under which transfer would occur. Experiment II investigated whether transfer would spontaneously occur between repetition of the same problem and Experiment III was designed to test whether transfer would occur between the Jealous Husbands and Missionary-Cannibal problems if subjects were informed of the relationship between the two problems.

Considered together, the results of the three experiments conducted by Reed et al. revealed that while

transfer did spontaneously occur between repetition of the same problems, transfer occurred between the Jealous Husbands and Missionary-Cannibal problem only when (a) subjects were told the relationship between the two problems and (b) the Jealous Husbands problem was given first. Thus, as in the Asch (1969) study, subjects needed to be directly informed of the connection between stored information and the new problem solving context in order for the information to be accessed and applied.

In a similar experiment, Simon and Hayes (1976) noted that students who learned how to solve the Tower of Hanoi puzzle did not spontaneously realize it was structurally isomorphic to the "tea ceremony" problem and other variants of the "Hanoi" puzzle. These researchers asked subjects to solve a series of problems (all isomorphs of the Tower of Hanoi problem) which could have been readily solved by mapping them into the corresponding Tower of Hanoi puzzle (which had been solved previously). None of their 20 subjects did this, and only three even recognized the solutions to the problems were analogous to the solution of the Tower of Hanoi puzzle.

A third study to demonstrate that subjects are unable to spontaneously access previously stored strategies relevant to a novel problem solving context was conducted by Gick and Holyoak (1980, Experiment IV). They first had college students memorize a story about a military campaign

in which a general is only able to capture a well defended fortress by dividing his army into small units and attacking from all sides. According to the researchers, memorization of this story equipped subjects with an "attack-dispersion" solution to problems analogous to the fortress story. After the students had successfully recalled the military story and its solution, they were given Dunker's (1945) "Radiation Problem" to solve:

> Suppose you are a doctor faced with a patient who had a malignant tumor in his stomach. It is impossible to operate on the patient, but unless the tumor is destroyed the patient will die. There is a kind of ray that may be used to destroy the tumor. If the rays reach the tumor all at once and with sufficient intensity, the tumor will be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumor either. What types of procedure might be used to destroy the tumor with the rays, and at the same time avoid destroying the healthy tissue (Gick & Holyoak, 1980, p. 308).

The radiation problem may be solved by transferring the "attack-dispersion" strategy employed by the general in capturing the fortress to the destruction of the dangerous tumor. That is, the tumor can be safely destroyed by applying low levels (small forces) of the ray to the tumor from numerous directions. As with the fortress problem, only

smaller attacks from all sides will produce the desired result.

As the researchers required subjects to memorize the story about the military campaign, it can be reasonably assumed that the subjects had sufficiently stored the solution to the problem prior to attempting to solve the Radiation Problem. This contention is born out by the finding that over 90% of those subjects who were cued to the relationship between the two problems were able to adapt the campaign strategy to the destruction of the tumor. But, only 20% of those subjects not cued to the usefulness of the campaign strategy were able to spontaneously apply the strategy to the Radiation Problem.

Considered together, the results of the Reed et al. (1974), Simon and Hayes (1976), and Gick & Holyoak (1980) studies suggest that while problem solving strategies can be readily accessed and applied to novel problem solving situations, the relationship between the inert information and the new problem must be directly cued in order for the information to be of use. Thus, the studies described above make a strong case for the contention that retrieval of previously stored information will not spontaneously occur in the absence of direct cuing.

Spontaneous Transfer of Problem Relevant Clues

Distinct from those studies which expose subjects to complete strategies prior to the presentation of the novel

problem solving situation are those which only expose subjects to problem relevant clues. While this research also first presents subjects with potentially relevant information and then attempts to determine the conditions necessary for them to utilize this information in problem solving tasks, the information is not presented within a problem solving context. The potentially useful information is acquired by subjects as they engage in tasks such as learning lists of paired associates (Weisberg, Camillo, & Phillips, 1978) or rating a series of sentences for truthfulness (Adams, Kasserman, Yearwood, Perfetto, Bransford, & Franks, 1988; Bowden, 1985; Perfetto, Bransford, & Franks, 1983).

In a design similar to that first employed by Asch (1969), Weisberg, Camillo, and Phillips (1978) examined the influence of previously established associations on the production of the box solution to the candle problem. Subjects were first required to learn as list of paired associates, one of which was "candle-box." It was hypothesized that the availability of this association would later cue a solution to the "candle problem" (Dunker, 1945). The problem requires subjects to describe how a candle may be attached to a wall so that it will burn properly. The available materials are a box of nails, a book of matches, a hammer, and the candle. It was expected that the low frequency of the box solution in the candle-box problem

would make it possible to examine the influence of experimentally established associations on problem solving. Towards this end, half of the experimental subjects in the study were informed that one of the previously learned pairs could aid them in solving the candle problem (the "informed group"). The other half of the experimental group was not informed of the connection (the "association group"). A control group learned an irrelevant association.

The results of the experiment indicate that the candle box association was effective in cuing the expected solution only when subjects were clearly told of the useful connection between one of the paired associates and the candle problem. On the basis of these results (replicated in two similar experiments by the same authors), Weisberg et al. concluded that transfer of potentially useful material is not a spontaneous or automatic process. Rather, they contend, previously established associations will only be utilized in a problem solving context if an individual recognizes its relevance to the problem at hand.

Perfetto, Bransford, and Franks (1983) speculated that the results consistently obtained in Weisberg et al.'s three experiments could be attributed to two distinct hypotheses:

> First, subjects may have spontaneously retrieved the appropriate cue when working on the candle problem but discarded it as irrelevant (note that the cue "candle-box" does not communicate much specific

> information). Alternately, subjects may have failed to retrieve the appropriate cue... The first hypothesis argues that subjects may have spontaneously retrieved "candle-box," but that this information may have been insufficient to facilitate problem solving because subjects did not perceive the information to be relevant...The second hypothesis noted above suggests that subjects actually fail to retrieve the relevant information in the absence of explicit instructions to do so (Perfetto et al., 1983, p. 24).

In order to test these two hypotheses, Perfetto et al. (1983) designed a series of experiments which presented subjects with obvious clues that were more directly relevant to problem solving. That is, for each problem to be solved, a sentence clue was constructed that more blatantly suggested the solution to the problem. For example, the statement, "Before any game begins, the score is zero to zero" was developed as a clue to the following problem: "Uriah Fuller, the famous Israeli superpsychic, can tell you the score of any baseball game before the game starts. What is his secret?" Another problem was, "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?" The sentence constructed as a clue to this problem's solution was "A minister marries several people

each week."

The subjects in all conditions were first presented with the list of clue statements and required to rate them for their truthfulness. Prior to the presentation of the problems to be solved, some subjects were informed that the sentences they had just rated would help them to answer most of the problems (informed group). A second "uniformed group" was not made aware of the connection between the sentences and problems, while a third group of subjects (serving as the baseline) completed the problems without any exposure to the clue sentences.

The results of the experiments indicated that although the problem-solving of the informed group was excellent, the performance of the uninformed group was comparatively poor. In fact, no significant difference was found between the performance of the uniformed group and that of the baseline subjects. As was noted by Bransford et al. (1989), these findings represent an especially strong demonstration of access failure (i.e., inert knowledge) because the clues were constructed to be obviously relevant to problem solution. Indeed, based on a comparison of the Perfetto et al. clues with those used by Weisberg et al. (1978), it had been expected that even those subjects who were uninformed of the connection between the clue sentences and problems would spontaneously access the solutions given their supposed 'obviousness'.

Task Similarity and Spontaneous Transfer

Adams et al. (1988) speculated that the dramatic difference between the informed and uninformed subjects' problem solving performance in the Perfetto et al. study would not be surprising if viewed from the perspective of transfer-appropriate processing. This perspective emphasizes the importance of similarity between the means by which the target information is initially processed and the processes that are invoked during some later testing situation (Bransford, Franks, Morris, & Stein, 1979, as cited by Adams et al., 1988). These researchers posited that even though the problems and their corresponding clue statements were quite similar in terms of informational content, the processes required during acquisition and the subsequent problem solving task were very different. It will be recalled that in the acquisition task, subjects were only required to read the series of clue statements and rate each one for truthfulness. Thus, no real problem solving was involved in this initial "learning" task. During the problem solving phase of the experiment, subjects were required to do just that - solve a series of challenging problems. As Adams et al. note, the relative dissimilarity between the types of processes evoked in the two phases of the experiment might have limited subjects' spontaneous access to acquisition information during subsequent problem solving.

In order to investigate the relationship between transfer-appropriate processing and access, Adams et al. (1988, Experiment I) varied the cue statements employed by Perfetto et al. while holding the corresponding problems constant. That is, the original cue statements were modified to invoke problem-oriented (task similar) processing during the acquisition phase. For example, recall that the original form of the acquisition sentence corresponding to the minister problem was "A minister marries several people each week." To induce problem-oriented processing, this sentence was changed to the following form: "It is possible to marry several people each week if one is a minister." These researchers maintained that although the two versions of the sentence are highly similar in terms of content, the revised form evokes (at least momentarily) a problem solving orientation, whereas the original version does not. It was hypothesized that the processes evoked by the problem-oriented acquisition clues would resemble those subsequently evoked during problem solving, and this contextual similarity between acquisition and performance would lead to increased access and problem solving.

In order to provide a clearer illustration of the impact of problem-oriented acquisition as compared to 'fact-oriented' acquisition, subjects were divided into the following three groups: the fact-oriented condition (cues presented were identical to those developed by Perfetto et

al.); the problem-oriented pause condition (the form of the cue sentences was changed so that the sentence consisted of two clauses, separated by a 2-second pause), and the problem-oriented no pause condition (no deliberate pause between the two clauses).

The results of the Adams et al. experiment indicated that although no significant difference was indicated between the problem solving performance of the two problem-oriented conditions, the combination of these two conditions produced significantly higher problem solving performance than did the fact oriented condition. Thus, it was concluded that problem-oriented (task similar) processing during acquisition led to greater spontaneous access during problem solving than did fact-oriented processing during acquisition.

In a similar study, Lockhart, Lamon, and Gick (1987) demonstrated importance of processing similarity to transfer. Applying many of the same riddles used in the Perfetto et al. (1983) and Adams et al. (1988) studies (i.e., "How can a man marry several women each week and yet remain single?"), Lockhart et al. assigned subjects to either task similar or task dissimilar acquisition phase conditions. Subjects in the task similar ("aha") group first read a puzzling statement that presented the misconception usually perceived by subjects on the transfer riddle. For example, the puzzling statement corresponding to the riddle

above might be, "A man marries several women each week because it makes him happy." After reading each puzzling phrase, subjects in this group were then presented with a word or phrase that effectively solved the puzzle (i.e., "clergyman"). Subjects in the task dissimilar condition were presented with clue information in the form of straightforward statements containing no puzzle (i.e., "A minister marries several people each week because it makes him happy."). Subjects who acquired the solution information in the task similar (puzzling context) were more likely to apply this information spontaneously when the riddles were presented during the problem solving phase than subjects in the task dissimilar condition.

Stein, Way, Benningfield, & Hedgecough (1986) also found that the spontaneous transfer of clue information to subsequent problem-solving tasks is affected by the contextual relevance and surface-structure similarity of the clue statements to the problems. The transfer task used by these researchers asked subjects to provide plausible explanations to seemingly implausible statements originally developed by Auble, Franks, and Soraci (1979). One such implausible sentence read as follows: "The house was small because the sun came out." The cue concepts clarifying these sentences (i.e., "igloo") were embedded in four types of acquisition statements that varied the degree to which the surface structure and contextual relevance matched the

problem sentences. Subjects were assigned to one of ten condition groups that differed in terms of the surface similarity of the cue sentences and their contextual relevance to the implausible (problem) statements. Cue sentences were said to contain similar-surface structure and contained at least two key words that were also found in the problem statements. The contextually relevant cues were those that prompted subjects to consider properties of the key concepts that were relevant to the solution of the problem. Given the problem sentence regarding the "small home," the similar-surface structure/contextually relevant cue sentence was as follows: "An igloo is a home that can be damaged by the sun."

Stein et al.'s (1986) results provide additional support for the task similarity effect in that the clue sentences containing a similar surface structure and contextual relevance were significantly more likely to elicit spontaneous transfer than dissimilar/contextually irrelevant cues. That these researchers were able to find significant main effects for both surface structure and contextual relevance (in addition to a significant interaction effect) suggests that cues which contain either factor are likely to trigger spontaneous transfer.

The task similarity effect demonstrated by Adams et al. (1988), Lockhart et al. (1987), and Stein et al. (1986) is consistent with the knowledge-based theories of transfer put

forth by several noted researchers (i.e., Anderson, 1987; Newell & Simon, 1972; Simon, 1980). Newell and Simon (1972) suggested that the "problem space" that must be searched by subjects during the act of problem solving contains not only the correct answer to the problem but also numerous incorrect solutions. Given the difficulty of recognizing the correct solution in the presence of an array of confusing choices, it is not surprising that a close match between the problem and stored solution will facilitate problem solving.

Simon (1980) posited that the knowledge which underlies competent performance in any domain is represented as productions rather than as mere facts or propositions. These productions are comprised of "condition-action pairs" and hence provide information about the critical features of problem situations that make particular actions (strategies) relevant. That is, when an individual is presented with a problem solving condition sufficiently similar to the context in which initial learning occurred, the condition will spontaneously trigger the action (information or strategy) enabling effective problem solving. If the condition is not sufficiently similar to the original learning context, a strong memory cue of some type is required in order for the individual to recognize the link between the condition and its corresponding action.

Bowden's 'Day-to-Day Problem Solving' Paradox

In addition to supporting the knowledge-based theories

of problem solving, the research discussed above would appear to suggest that "spontaneous transfer" of previously learned information is an unlikely phenomenon. If either a direct cue or a close match between the original learning context and the new problem to be solved is required in order for a stored "production" to be accessed, then spontaneous transfer will - according to this research - only occur under rather narrowly defined conditions. However, if these restrictions on spontaneous transfer are valid, what are we to make of the myriad of problems solved in "real life" by each of us in which we access inert knowledge as part of the problem solving process. As was first noted by Bowden (1985), in "real life" situations, problem solvers are rarely explicitly informed of the connection between information they have previously learned and the solution to a presented problem. Despite this absence of explicit clues as to where to search in our memories for a problem solution, however, we are able to arrive at the correct solution to an array of problems by accessing information initially learned in a context different (to varying degrees) from that in which a given problem is set. Thus, it would appear that the restrictions placed upon spontaneous transfer of information and strategies reported by the studies discussed above are inconsistent with day-to-day problem solving.

Bowden (1985) hypothesized that spontaneous transfer

can (and frequently does) occur in the absence of an explicit cue; however, additional time is required for the recognition of problem/problem solution connection. Thus, in studies such as that conducted by Weisberg et al. (1978) and Perfetto et al. (1983), those subjects who were not informed of the connection between the "cues" and the problems may have been able to problem solve as effectively as the informed subjects had they been given more time to do so. It will be recalled that it was Perfetto et al. who suggested that the absence of spontaneous transfer in those studies which employed paired associates as the cue to problem solution (i.e., Weisberg et al.) could have been attributed to the vagueness of the cues. While the sentence cues used in their 1983 study were certainly more obvious cues to the problems than the simple word cues or paired associates used in some of the earlier research, however, it can not be assumed that the cues were sufficiently "obvious" to be accessed within the 40 second period allotted for the solving of each of the 15 problems. When one considers that a portion of this time allotment must be devoted to reading the problem and writing the solution, the subjects were only afforded a brief period of time to engage in problem solving. While the 40 second allotment may have been sufficient for those subjects who were informed of the connection between the cues and the problems, it may not have provided uninformed subjects sufficient time to

thoroughly scan their problem space.

In order to test the hypothesis that time spent in problem solving has a significant influence upon spontaneous transfer, Bowden (1985) replicated the Perfetto et al. design, but increased the time allotted to solve each problem from 40 seconds to two minutes. The results of this experiment differed from those reported by Weisberg et al. (1978) and Perfetto et al. (1983) in that subjects who were not informed of the relevance of the clue sentences produced congruent solutions as frequently as did subjects who were informed of the condition. Uninformed subjects, however, required considerably more time to arrive at the correct solutions. Comparisons of the mean problem solving times of both cued and "uncued" (uninformed) subjects indicated that the former tended to produce correct solutions towards the beginning of the two minute period (less than 40 seconds), whereas uninformed subjects produced the majority of their correct solutions later in the period. Thus, while replicating the findings of Perfetto et al. within a 40 second allotment, Bowden found that simply allowing all subjects more time to work on the problem seemed sufficient to compensate for any advantage given to the informed subjects by being told of the clue/problem connection.

Although Bowden's results would appear to contradict the results of the Weisberg et al. and Perfetto et al. studies, the findings are not inconsistent with the

knowledge-based theories of problem solving. By drawing a comparison between a search through a cluttered sock drawer and a subject's search through the "problem space" (Newell & Simon, 1972), Bowden illustrates how extending the problem solving time removes the advantage from the individual who is informed of exactly where to look for a desired item (whether it be a preferred pair of socks in a cluttered drawer or a correct solution in the problem space).

Affect and Cognitive Performance

Bowden's (1985) study illustrates that if allowed to persist at the problem solving task, subjects are eventually able to access the previously learned information to facilitate problem solving. Although no attempts have been made to replicate his results, his findings offer compelling evidence to suggest that the conditions necessary for spontaneous transfer are far less restrictive than has been suggested by much of the earlier research (e.g., Adams et al., 1988; Perfetto et al., 1983). If persistence is sufficient to prompt recognition of previously stored condition-action pairs, then the ability to arrive at the correct solutions to problems such as those employed by Bowden and Perfetto et al. may be a function of time allowed to complete the task and an individual's persistence in completing the task.

In Carroll's school learning model (1963), degree of learning is seen as a function of the learner's time on task

divided by the time needed to accomplish the task. Time on task reflects the interaction process between opportunity to learn (the time allotted to the individual to attain proficiency in a learning task) and perseverance (the amount of time/effort the learner is willing to spend on a learning task). Clearly, then, Carroll attributes an important role to perseverance in his theory of learning and performance. If, as is reasonable to assume, affective variables influence perseverance on problem solving tasks, then it would follow that factors such as motivation and mood can influence the occurrence of spontaneous transfer.

A considerable body of research suggests that affective factors such as mood have significant effects on the speed and ease of access to previously learned information. For example, Bower (1981) and Weingartner, Miller, and Murphy (1977) found that if someone is in a sad or unpleasant mood, it can be difficult to access information that was acquired while in a more positive affective state. Similarly, Bransford, Vye, Adams, and Perfetto (1989) suggested that students who are typically in a negative state during a certain type of learning task (e.g., solving math word problems) due to a history of failure may have difficulty accessing relevant knowledge that was acquired under more positive affective conditions.

While the research on the restraints of transfer should be credited for documenting the difficulty of accessing

previously learned information when confronted by a novel problem solving context, the literature did not address the impact of motivational and other affective variables on subjects' access to and use of previously stored associations. This disregard of affective factors in the problem-solving literature is surprising, given the growing number of studies within the larger metacognition literature which link reading comprehension strategy transfer and task performance with motivational variables such as locus of control (Weed, 1984), task-specific attributions (Borkowski, Estrada, Milstead, & Hale, 1989; Kurtz & Borkowski, 1984; Paris & Oka, 1986; Weed, 1985), and achievement motivation (Mealy, 1990). Indeed, comprehensive theoretical papers have examined in detail the extent to which motivational variables impact upon cognitive processes and problem-solving (Boekaerts, 1986; Hidi, 1990). It would appear, then, that research which assumes that learning processes are inextricably bound up in emotional/motivational issues ("hot cognition") is gaining prominence in research areas long dominated by lines of inquiry which disregarded affective factors. Surely, if motivational factors can be linked to reading strategy transfer, then it is reasonable to suggest that access to previously stored information can also be impacted by motivation.

If an extended perception of cognition that embraces

the influence of affective variables is applied to the studies conducted by Adams et al. (1988), Perfetto et al. (1983), and Weisberg et al. (1978), the absence of spontaneous transfer displayed by the "uninformed" subject groups may be explained by affective as well as purely cognitive variables. That is, the uninformed subjects' failure to utilize available knowledge in the problem solving situation may, at least partially, be attributable to insufficient motivation to engage in rapid searches of the problem space (long term and working memory) required for problem solving. Indeed, novel or difficult problems such as those employed in much of the prior research probably require subjects to repeatedly scan their long-term and working memory before the appropriate solution to a given problem is found. In the absence of activating cues to facilitate the retrieval of prior learning, relevant information can probably be recovered only by iteratively scanning through memory for the required material. Thus, as is consistent with Bowden's (1985) findings, subjects who are neither informed of where to search in the problem space nor provided sufficient time or incentive to continue scanning through long-term memory will not solve problems as effectively as those who are directly cued to a problem's solution. Viewed along these lines, the hypothesis may be advanced that in the absence of explicit cuing, spontaneous transfer and problem solving should be facilitated by

offering incentives to students for successful performance.

In order to test this hypothesis, Tobias and Kaufman (1991) conducted a series of experiments to determine the conditions under which motivation can influence subjects spontaneous access and application of inert knowledge in a novel problem solving context. More specifically, the experiments sought to determine whether subjects who were given extrinsic incentives to successfully solve a series of problems (yet were uninformed of the connection between stored information and a problem solving task) would be able to retrieve and apply previously stored information at least as effectively as subjects who were informed of the connection.

It merits noting that much of the earlier research involving inert knowledge used university undergraduates as subjects. Most frequently, the only incentive available to undergraduates participating in problem solving studies is that they satisfy course requirements for research participation. Therefore, they have little inducement to solve problems correctly. In each of the four experiments which comprised the Tobias and Kaufman study, a monetary incentive was offered to subjects uninformed of the connection between the cue material and the problems to be solved.

Experiment I was designed to replicate the basic design employed by Perfetto et al. (1983) with the following

change: A third group of subjects was added who were not informed of the connection between the "cue sentences" and the problem solving task yet were told they would receive a monetary award for each of the problems solved correctly. It was hypothesized that no significant difference would be found between the problem solving performance of this "incentive group" and the "informed group." It was also posited that the performance of the two experimental conditions would be superior to the uninformed control condition.

The materials employed for this and the other three experiments which comprised the study were generally identical to those developed by Perfetto et al. (1983). The problems selected were 12 "insight" problems described previously which were adapted by Perfetto et al. from Gardner (1978). For each problem, a sentence clue was constructed that implicitly suggested the solution to the problem. Consistent with the paradigm devised by Perfetto et al., subjects in this experiment were first asked to rate the truthfulness of 14 statements using the following rating scale: "never true," "sometimes true," and "always true." Twelve of the 14 statements contained clues for the solutions of the experimental problems. Subjects were allowed 20 seconds to read and rate each statement. The rating constituted an incidental task acquisition for the subsequent problem solving task.

Following the incidental task, a delay of approximately three minutes was inserted between the two phases of the experiment by the collecting of the rating sheets and attendance forms. Subjects in the informed condition were told that the sentences they had just rated would help them answer most of the "riddles" in the problem packet. Subjects in the incentive condition were not informed of the connection between the cue sentences and the problems; however, they were told that they would be paid $1. for each problem solved correctly. Subjects in the control condition were also not made aware of the cue sentence/problems connection or offered any sort of incentive for problem solving. Prior to the 12 experimental problems, all of the problem booklets included three additional filler problems also adapted from Gardner (1978). As per Perfetto et al. (1983), these three initial filler problems were included to reinforce the separation of the acquisition task and the first clue-related problem. Subjects were allowed 40 seconds to read each problem and write a solution in the space provided.

The results of the first experiment indicated that there were significant differences among the groups ($F=1.425$, $p < .001$). However, subsequent comparisons indicated that the cue group solved more riddles than the other two condition groups. While these results replicated Perfetto et al.'s (1983) findings in terms of the utility of

cuing, they failed to support the hypothesis for this study. Inspection of the means indicated that the cue group solved about 40% of the riddles, while the other two groups solved only a fifth of the problems.

Although the informed group solved a greater number of problems than the subjects in the other groups, the relatively poor performance of subjects across groups (Cue Group mean = 6.8, Incentive Group mean = 3.1, and the Control Group mean = 3.1) suggested that the conditions of the experiment may have made it inordinately difficult to retrieve relevant cues. The set of riddles was preceded by two problems for which no relevant cues were presented, possibly obscuring the relationship between the cue sentences and the riddles. In an effort to replicate Perfetto et al.'s (1983) design, the time limit employed in Experiment I allowed subjects only 40 seconds to solve each riddle, which included the time needed to read the problems and write solutions to them by hand. It seemed likely that allowing so little time also reduced the probability of solving the riddles, whether or not students were motivated to do so. As was discussed above, Bowden (1985) found that when subjects were provided with two full minutes to solve each riddle, the difference between students who were informed of cues/problems relationship and those who were not disappeared. It seemed likely, therefore, that extending the time limits and removing the filler problems would

create more opportunity for motivational factors to affect the rate of student problem solving.

In Experiment II, the conditions were altered to make it easier for subjects to utilize the cues presented to them in the sentence rating task. That is, the three "filler" problems were removed from the problem packets in order to heighten the connection between the rating and problem solving tasks, and the time limit for solving each problem was doubled to 20 minutes (80 seconds per problem from 40 seconds per problem).

Although the results of this experiment were consistent with our expectations in that no difference was found between the cue and incentive conditions (suggesting that the changes had the desired effect of reducing the advantage of direct cuing), again no difference was found between the control group and the subjects in the two experimental conditions. Thus, while the increase in the time limit and removal of the three extraneous problems seemingly increased 'uninformed' subjects' access to the cue material, the strong performance of the control group vis a vis the experimental subjects suggests that the incentive did not play a significant role in problem solving.

Further analysis of the procedures indicated that there was a contrived component to the task. The instructions used (asking students to rate the truthfulness of the cue sentences) were misleading with respect to the actual

purposes of the cue sentences. Consistent with the methods originally developed by Perfetto et al. (1983), students in our first experiment were only asked to rate the truthfulness of the cue sentences as a means of acquiring the information needed to solve the problems presented in the problem solving phase. Superficially, it would appear that this subterfuge was similar to other problem solving situations in daily life, in that people often do not know in advance what information may be useful in solving problems encountered later. However, a question arises about whether rating sentences leads to any type of meaningful learning. That is, when people solve problems in daily life, they retrieve prior learning to solve novel unanticipated problems arising in the future. In the experimental task used in this study, and previously by Perfetto et al. (1983), it was never clear whether the material was stored effectively and available for retrieval. The low rates of riddle solution in the first two experiments, and in the prior research reemphasizes the uncertainty about whether the cues were ever acquired satisfactorily.

A third experiment was conducted to assure that the problem cues were actually available for retrieval. Subjects in all groups were asked to learn the cue sentences, rather than merely to rate their truthfulness. It seemed that such a manipulation was more similar to problem solving in daily life, and to the role an incentive could play in

facilitating retrieval and problem solving. It was reasoned that in such a situation, motivated students (and those informed of the relationship between the cues and riddles) ought to perform more effectively than the controls. The procedures employed in this study were also identical to those used in the first two experiments; however, the directions included one significant exception: All subjects were asked to memorize the cue sentences, and informed that they would have to recall them at the end of the experiment. After subjects completed solving the riddles, they were presented with a sheet of ruled paper and asked to write down all of the sentences they remembered.

Contrary to our expectations (and consistent with the results of the first two experiments), the results indicated that the incentive did not significantly influence the number of solutions. It merits noting, however, that a high correlation between recall and solutions (r = .71) was obtained, suggesting that availability of cues was substantially related to the probability that the cues would be used to solve relevant problems. This finding suggested the cues that were retained were likely to be retrieved during problem solving. These results would also appear to suggest that, even though they had not increased subjects' retrieval of relevant knowledge directly, incentives may be more effective in improving acquisition, which in turn may be expected to raise problem solving.

The fourth and final experiment in this study sought to determine more about the relationship between cue acquisition and the manner in which it impacts upon problem solving. Experiment IV was also designed to expand upon Bowden's (1985) findings concerning the amount of time cued and uncued subjects require in order to successfully problem-solve. It will be recalled that Bowden's results indicated that uncued subjects were often able to solve problems as effectively as cued ("informed") subjects when provided sufficient time in which to do so. Employing similar procedures, our fourth experiment was designed to demonstrate the extent to which extrinsic incentives influenced the amount of time subjects were willing to invest in problem solving and studying tasks. It was anticipated that those subjects provided with an incentive to correctly solve problems would invest more time in problem solving than subjects not provided with an incentive, and solve at least as many problems as subjects directly cued to the problems' solutions. It was also predicted that subjects provided with an incentive to retain cue sentences would recall more cues and solve problems more effectively (given their retention of useful material) than those not provided with any incentive.

Consistent with the results of the previous three experiments, the findings of Experiment IV were not supportive of the hypothesis that the provision of extrinsic

incentives facilitates the spontaneous transfer of previously learned information during a novel problem solving task. Similar to Experiments II and III, no difference was found between the number of problems solved by the four condition groups ($F=2.24$, $p=.086$) suggesting that neither the provision of a cue nor an incentive significantly aided problem solving. No difference was also found between the groups in terms of the number of cue sentences recalled ($F=2.09$, $p=.104$) or the amount of time devoted to problem solving ($F=2.1$, $p=.098$). The correlation between solutions and sentence recall was also similar to that obtained in Experiment III ($r=.67$, $p < .001$).

The results of Experiment IV indicated that while retention of cue sentences and correct solutions were strongly related, the provision of incentives at either the acquisition or problem solving phases of the experiment did not lead to significant differences among the condition groups in terms of time on-task or performance. Although an examination of group means indicated that subjects provided with an incentive to either recall the cue sentences or solve the problems were more successful at these tasks than subjects in the other conditions, the effect obtained was very small. Interestingly, despite the seeming incentive to devote a greater amount of time to the given tasks than subjects not provided with an incentive, subjects in the two incentive conditions did not devote more time to their

respective tasks than did the subjects in Groups C and D.

The findings must be considered particularly significant in that they would appear to contradict - to some degree - the results obtained by Bowden (1985). It will be recalled that Bowden found subjects not cued to the relationship between previously learned material and related problems required more time to solve problems as effectively as subjects directly cued to the relationship. Given this finding, it was anticipated that subjects in our 'uninformed' conditions would invest greater amounts of time to problem solving than the Direct Cues Condition (Group C). This was not the case, however, as no significant difference was found between the four condition groups in terms of time devoted to problem solving.

One explanation for the absence of a significant difference between the condition groups in terms of the number of problems solved may be provided by the findings of Frase (1971). Frase found that introducing motivation prior to learning improved students' posttest performance, whereas promising incentives prior to posttest had comparatively little effect. Thus, when motivation was not aroused during initial learning, its activation at retrieval had little effect on performance. In Tobias and Kaufman's Experiments III and IV, subjects were only offered an incentive prior to initial learning or prior to problem solving. No subjects were motivated during both phases of the experiment. If the

phenomenon noted by Frase is accurate, then the results of Experiments III and IV would not be surprising since incentive subjects were not sufficiently motivated at both the acquisition and problem solving phases.

Considered together, the results of Tobias and Kaufman's four experiments would appear to offer only minimal support to the position that incentives facilitate problem solving. Overall, the findings suggest that rather than facilitating problem solving (by energizing the information search within the problem space), the offer of extrinsic incentives does not significantly improve performance to the extent hypothesized by the researchers. While the results of Experiments II, III, and IV were consistent with the hypothesis in that no significant difference was found between direct cuing and incentive groups, the equally strong performance of the control groups in each of these experiments is inconsistent with the contention that rewarded subjects would solve more problems than unrewarded subjects. That no significant difference was found between the cued, incentive, and control conditions suggests that neither the provision of direct cuing or extrinsic incentives is effective in increasing subjects' problem solving. These results contradict Perfetto et al.'s (1983) findings and suggest that the effect of direct cuing is not as strong as previously contended.

The performance of the control group in each of the

four experiments (particularly Experiments II and III) was particularly interesting. Rather than performing in an inferior manner due to the absence of direct cuing or an incentive (as had been predicted), the control group solved problems about as effectively as the direct cue and 'motivated' conditions. Moreover, the fact that the control group invested more time in problem solving than the other three condition groups in Experiment IV indicates that the absence of an extrinsic incentive to continue problem solving did not have the expected effect of limiting these subjects' willingness to continue to engage in the task.

Perhaps the explanation for the unanticipated performance of the control group vis a vis the incentive groups can be found in Deci's (1975) cognitive evaluation theory. Deci argued that when offered an extrinsic incentive to accurately complete an intrinsically interesting cognitive task, subjects' intrinsic interest in engaging in the task is diminished. Thus, a task in which subjects may have engaged with some interest (if not enthusiasm) in the absence of extrinsic incentives may lose its intrinsic appeal in the presence of an extrinsic incentive. Lepper, Greene, and Nisbett (1973) referred to this phenomenon as the "overjustification effect" since extrinsic incentives often constitute overjustification for performing intrinsically interesting activities. Deci (1975) also contended that adding external incentives to intrinsically

motivated behavior may decrease individual's feelings of competence and self-determination. The control subjects in each of our four experiments were not provided with an extrinsic incentive for accurate problem solving and therefore may have retained greater intrinsic interest in the cognitive task and greater self-efficacy expectations than subjects in the incentive conditions. The following section examines the research on the influence of extrinsic incentives on cognitive performance variables in greater detail.

Extrinsic Incentives and Cognitive Performance

Given the strong investment that many behavioral psychologists, educators, and business managers place in achieving desired behavior via the offer of incentives, it is not surprising that Deci's cognitive evaluation theory has been highly controversial since its inception. Although a considerable amount of research has been conducted which supports the contention that extrinsic incentives inhibit intrinsic motivation (Deci and Ryan, 1985), an equally large body of research has been compiled which suggests that the opposite is true. In his review of the research for and against cognitive evaluation theory, Zimmerman (1985) concluded that adverse effects of rewards on intrinsic motivation are a limited phenomenon. The effect tends to be evident only when rewards are given to subjects simply for participating in a task and convey the sense that

participation is being controlled by the rewards. Extrinsic incentives, according to Zimmerman, tend not to inhibit intrinsic motivation if the rewards convey performance efficacy information. In their meta-analytic review of the literature, Rummel and Feinberg (1988) generally agree with this conclusion, noting that the phenomenon tends to be exhibited only within strictly specified parameters defined by Deci. That is, the inhibiting effect will only occur if the extrinsic reward conveys obvious controlling information to the subject.

The controversy which has surrounded Deci's theory is a logical extension of the debate which has long raged in the fields of psychology and education regarding the influence of incentives on cognitive performance. Those advocating purely behavioral explanations of skills and abilities have endeavored to discredit more cognitive theories which link cognition with affective factors such as motivation and anxiety. Perhaps the best known of these theories, summarized in the "Yerkes-Dodson law," posits a U-shaped function in which increasing the intensity or level of motivation (by any means) will enhance performance up to a point; after that, further motivation will result in poorer performance (Yerkes & Dodson, 1908). Thus, as was noted by McCullers (1978), the Yerkes-Dodson law implied that detrimental effects were due to a disruption of behavior beyond some optimal level of motivation. The Hull-Spence

theory also predicted conditions under which incentives will inhibit performance (Spence, 1956). Applying their equation E = H x K, the theory predicts an enhancing effect of reward (K) on performance in simple tasks but a detrimental effect in more complex tasks (since K multiplies indiscriminately with all available habits or response tendencies of the organism).

Standing strongly opposed to the notion that extrinsic reinforcers can actually inhibit the performance of a desired behavior is B. F. Skinner's (1938; 1953) theory of operant conditioning. According to Skinner, the prediction and control of behavior rests entirely on reinforcement and the manner in which it is delivered. While the Yerkes-Dodson law and the Hull-Spence theory each were the center of considerable attention in its day, the enormous popularity of Skinner's model led to the wide-spread acceptance of the idea that extrinsic incentives increase performance and motivation (although Skinner, himself, continued to eschew any discussion of the concept "motivation"). His central premise, however, clearly stipulates that extrinsic rewards serve to enhance the performance of a desired behavior. One is left to wonder, as was suggested by McCullers (1978), whether recent theories regarding the variable influence of incentives on both performance and motivation (i.e., Deci's cognitive evaluation theory) would have generated such controversy had Skinner's theory of

operant conditioning not so completely overshadowed the Yerkes-Dodson law.

While less research has been conducted than many educators might assume that indicates incentives facilitate performance on cognitive tasks, a small number of studies have successfully demonstrated this effect. Frase, Patrick, and Schumer (1970) studied the effects of different placement and spacing of adjunct questions on student learning from reading. Motivation to succeed at the task was manipulated via the offer of a small financial reward (no money, three cents, or tens cents) for each correct response. In addition to indicating that the "motivated" subjects performed significantly better than those not offered an incentive (and spent more time on-task), Frase et al.'s (1970) results suggested that the incentive was more powerful in stimulating learning and maintaining students' attention than any other variable studied.

In a follow-up experiment discussed earlier, Frase (1971) found that introducing incentives prior to initial learning improved students' performance on both adjunct and posttest questions. It was also determined that the offer of incentives prior to the posttest (without any attempt to stimulate motivation during the initial learning phase) had relatively little effect on performance. Presumably, as Tobias (1989) notes in his review of the literature, when motivation was not aroused during initial learning, its

activation at retrieval had little effect on posttest performance.

One of the more contemporary theories of the effects of reward on performance was developed by McGraw (1978), who differentiated problem solving tasks along two dimensions: how aversive or attractive they are to the individual performing them, and the manner in which the task is solved, heuristically or algorithmically. In reviewing the literature relating to the first point, McGraw indicates that individuals are generally unlikely to be motivated to perform such mundane operations as lever pulling or button pushing without extrinsic motivators. In the presence of these incentives, however, subjects will often persist at unappealing tasks in order to obtain a desired reward. Tasks requiring insight and/or the production of creative solutions, however, such as determining the solutions to amusing riddles, are assumed to be inherently interesting, leading people to perform them without extrinsic incentives. Thus, tasks such as discrimination learning, concept attainment, insight learning, creativity problems, and incidental recall are the types of attractive tasks used in research that have produced evidence of reward having a detrimental effect. In elaborating upon the algorithmic/heuristic distinction, McGraw (1978) demonstrates how those studies that did find a detrimental effect of reward on performance tended to use heuristic

problem solving tasks that required a creative solution. Studies finding that extrinsic incentives tended to enhance performance typically employed tasks requiring algorithmic solutions (i.e., mental multiplication, verbal learning, and perceptual-recognition tasks).

As was noted by Arkes and Garske (1982), McGraw's theory regarding the manner in which incentives impact problems requiring straightforward (algorithmic) and creative (heuristic) solutions is consistent with the Hull/Spence explanation of the Yerkes/Dodson law.

When the dominant response is correct, as is the case with simple tasks, increasing either drive (D) or incentive (K) will make the dominant response even more dominant. When the dominant response is incorrect, as is the case when the nonobvious solution must be "discovered," increasing D or K will make the task even more difficult (Arkes & Garske, 1982, p. 338).

One of the earliest studies to examine the influence of incentives on cognitive performance provides perhaps the clearest illustration of McGraw's theory regarding the manner in which incentives influence performance on algorithmic and heuristic tasks. Glucksberg (1962) made use of a candle-box problem originally devised by Dunker (1945) involving the mounting of a candle on a vertical screen using only a box and a few nails. In order to correctly solve the problem, subjects needed to recognize that the box

must be used as a platform secured to the wall with the nails. People often experience difficulty with this puzzle task since the box in which the nails were contained is normally regarded as a container. Subjects must overcome their "functional fixedness" in order to perceive the container as both a platform and a container. Glucksberg found that there was no effect of monetary incentive when an easier version of the problem was used, but incentive significantly increased problem solving time when the more difficult version of the puzzle was presented. Thus, consistent with McGraw's theory, the incentive only inhibited performance when the puzzle was presented in a heuristic form.

In support of his theory, McGraw (1978) cites a considerable body of literature examining the effects of incentives across a broad range of cognitive tasks. The evidence he presents is both detailed and compelling, and need not be repeated here. As Eysenck (1984) cautions, however, there are research findings that contradict both of the major points of his theory. For example, incentive typically has no effect on intelligence-test performance, in spite of the heuristic and interesting nature of many of the verbal and perceptual-motor tasks which comprise contemporary scales of intellectual functioning. A further difficulty with McGraw's theoretical stance cited by Eysenck is that very strong incentives sometimes harm performance on

tasks that are neither intrinsically interesting or heuristic. Eysenck goes on to contend that one of the fundamental weaknesses of McGraw's theory is its failure to address the fact that there may be a curvilinear relationship between the amount of incentive and level of performance on many cognitive tasks, as is predicted by the Yerkes-Dodson law.

In reviewing the literature both supporting and contradicting the contention that extrinsic rewards inhibit cognitive performance, Eysenck (1984) constructed what may be considered a more detailed explanation of the phenomena described by McGraw and others. He suggested that while the offer of rewards may increase attentional selectivity, increase performance speed, and increase short-term storage capacity, they may also decrease the accuracy of subject's performance and contribute to some cognitive inflexibility. In addition, Eysenck (1984) suggested that since incentives are arousers, they may interfere with the information processing needed to develop creative solutions by affecting memory storage and/or retrieval.

As evidence for his contention that incentives may limit cognitive flexibility, Eysenck cites a study conducted by McGraw and McCullers (1979). These researchers used a series of water-jar problems in which subjects had to arrive at the correct solution to the problems using as many as three jars of different sizes. As is typical for water-jar

problems, the subjects were asked to described how the liquid may be poured from jar to jar in order to obtain a specified quantity in one of the three jars. McGraw and McCuller presented their subjects with a series of ten problems, the first nine of which required a three jar solution. The final problem required the use of only two of the three jars, requiring subjects to alter their problem solving approach in order to correctly solve the problem. Performance on this last item was intended to reflect the ease or difficulty of breaking the problem solving set established by the previous problems. The results of the study indicated that while solution speed on the first nine problems was unaffected by financial incentive, subjects who were to receive an incentive took approximately 60% longer to solve the final problem than those subjects not offered a reward. These findings, according to Eysenck, demonstrate that "cognitive inflexibility" is brought about by subject's persistence with previously established ways of thinking in the presence of an incentive - even when counter-productive.

Evidence for what Eysenck (1984) referred to as a "speed or accuracy trade-off" (1984, p. 345) was provided by Feldman (1964), who found that high-incentive subjects (those seeking a desired apprenticeship) worked faster than low-incentive subjects (those previously accepted into the apprenticeship program) on a digit-cancellation task. Feldman also found, however, that the high-incentive

subjects made considerably more errors and were also less likely to notice errors when checking the accuracy of their work. Also cited was a study conducted by Bavelas and Lee (1978), who observed the effects of incentive in the form of goal level (i.e., the number of objects they were asked to list), on the performance of an object-listing task (i.e., listing objects that were "hard, white, and edible"). The results of this study indicated that the number of objects written down was positively related to incentive or goal level, but the quality of performance, in terms of the extent to which the objects matched up to the three criteria, was inversely related to goal level.

In terms of the influence of extrinsic incentives on incidental learning, both McGraw (1978) and Eysenck (1982; 1984) cite a range of studies which indicate that while incentives tend to improve performance (or have no effect) on the intentional task (the task presented to subjects as the task to be solved), they generally diminish the quality of performance on the incidental learning task.

The study which established the research paradigm for the many which followed it was conducted by Bahrick, Fitts, and Rankin (1952). While these researchers engaged their college-aged subjects in a tracking task for which half were promised a reward and half were not, an array of three or four colored lights arranged at the periphery of the visual field were unexpectedly turned on and off for 5-second

durations. Subjects were then scored on whether they noticed the lights and, if so, whether they recalled the particular sequence they had been exposed to. Those subjects who had been offered a reward based upon their tracking performance experienced significantly more difficulty recalling the light sequence than did the subjects in the no reward condition. Furthermore, 17 of the 50 subjects in the reward group failed to notice the lights at all, compared to only four of the 50 in the no reward condition. A number of studies pursuing similar lines of inquiry conducted since this seminal work have generally supported the findings of Bahrick et al. (1952).

It would appear, as noted by Eysenck (1984), that the offer of an extrinsic incentive acts as a kind of implicit instruction directing subjects to focus their attention exclusively on the stimuli associated with the incentive. In effect, then, the incentive contributes to a 'tunnel vision' phenomena in which subjects attend only to selected stimuli. Although Eysenck has yet to make the connection between his interpretation of the incidental learning research findings and his contention that incentives engender cognitive inflexibility, the results of the incidental learning studies would seem to support his theory.

Incentives and the Use of Inert Knowledge in Problem Solving

Although a range of studies have investigated the

influence of incentives on learning and cognitive performance variables, only Tobias and Kaufman (1991) and McNeil and Kimmel (1989) have addressed the impact of rewards on the spontaneous transfer of inert knowledge. Unlike Tobias and Kaufman, who tested the hypothesis that incentives would facilitate subjects access to inert knowledge, McNeil and Kimmel designed their study to determine if - as McGraw's (1978) theory would predict - the offer of monetary incentives would inhibit the transfer of previously learned material on a heuristic problem solving task. These researchers also sought to determine whether the provision of incentives would decrease subjects intrinsic motivation to engage in problem solving tasks again on an unrewarded basis, as Deci's cognitive evaluation theory would predict.

Similar to the method first employed by Perfetto et al. (1983), McNeill and Kimmel asked their college-age subjects to solve a series of ten problems that required plausible explanations to seemingly implausible events. Key concepts for clarifying the implausible statements were embedded in 15 acquisition/clue statements (ten plausible, 5 dummy) which subjects were asked to rate in terms of clarity. As in the Perfetto et al. (1983) study, participants had to spontaneously retrieve, transfer, and apply the previously stored information (clues) to each of the problems in 40 seconds. In addition to manipulating some subjects

motivation via the offer of incentives, McNeill and Kimmel also measured all subjects' initial intrinsic motivation to engage in the type of problem solving task asking participants to complete an 'Interest Questionnaire' prior to assignment to groups. This instrument provided a sample problem to be solved and asked subjects to rate their interest in solving problems of this type. These researchers assigned their 120 subjects to one of 12 groups based on incentives, gender, and interest level. The comparatively small cell size (10) brought about by this procedure must be considered a significant weakness of the study given the limited power of their statistical analysis.

The results of the study were consistent with McGraw's (1978) theory in that the incentive groups solved fewer problems than control groups not offered an incentive for problem solving. No difference was found between the incentive and no-incentive conditions in terms of time spent problem solving. As would be predicted by the overjustification effect (Lepper, Greene, & Nisbett, 1973), the offer of an incentive resulted in a significant difference between the incentive and no-incentive conditions in terms of minutes volunteered to participate in future problem solving studies on a no-reward basis. Interestingly, McNeill and Kimmel's prediction that high initial interest incentive group subjects would volunteer for less time than low initial interest subjects was not

supported by their results.

The superior performance of the unrewarded subjects vis a vis the rewarded subjects suggests that, rather than facilitating subject's access to inert knowledge, incentives inhibit the retrieval of previously learned material during heuristic problem solving tasks. It must be recalled, however, that Tobias and Kaufman's (1991) findings directly contradicted those of McNeill and Kimmel since no difference was found between the problem solving performance of rewarded and unrewarded subjects across four experiments. One possible explanation for the contradictory results produced by the two studies relates to the different manner in which subjects acquired cue information. Unlike McNeill and Kimmel, who asked subjects to simply rate the clarity of the cue sentences, Tobias and Kaufman instructed subjects to attempt to memorize the cue sentences for later recall. It is tenable that the greater knowledge of cue material brought about by memorization facilitated motivated subjects access to the needed information resulting in greater performance.

Noting that nearly all of our knowledge regarding the effects of motivation on cognition is based solely upon extrinsic motivational factors, Eysenck (1984) strongly urges more research into the relative importance of both intrinsic and extrinsic motivation as well as on the interaction between these variables. Despite their

difficulties in objectively defining subjects intrinsic motivation, McNeill and Kimmel can be credited with having conducted the only cognitive study to measure the influence of both extrinsic and intrinsic motivational variables on problem solving. Given the complex interaction between intrinsic and extrinsic variables during problem solving, it is apparent that a great deal more research needs to be conducted in this area. In view of the emphasis placed upon extrinsic motivation in the problem solving literature (and the relative disregard for intrinsic factors), it is equally evident that more research is needed which examines the influence of variables such as task interest and topic interest on cognitive performance. The following section will examine some of the more important studies which have pursued such lines of inquiry.

Interest and its Influence on Cognitive Performance

Renninger and Wozniak (1985) noted that although the effect of interest on memory has been well documented since the middle of the last century, the concept of interest virtually disappeared for several decades and has only begun to reemerge as a legitimate area of research. Krapp and Schiefele (1986), in their review of basic educational psychology textbooks, found that interest was rarely mentioned in chapters on cognitive processes and was generally considered a topic of only passing importance. This is not surprising, however, when one recalls that

affective variables in general - and interest in particular - have been neglected by the majority of investigators who have studied cognitive processes (Hidi & Baird, 1988).

In a literature review which attempts to link the early research on the influence of interest on cognition to the new range of studies conducted over the last decade, Hidi (1990) demonstrates how, prior to the dominance of Behaviorism, many of the 'founding fathers' of American educational psychology stressed the importance of affective variables such as interest in formulating their theories of learning. Both Dewey (1913, 1916) and Thorndike (1935), for example, acknowledged that learning is impacted not only by personal interest but also by the interestingness of the objects and tasks presented to students. Bartlett (1932) also emphasized the critical role played by individual interest in human remembering, serving as a forerunner for the more recent body of research into the relationship between various affective states (i.e., mood) and memory. The emergence of cognitive psychology over the past two decades has led to an expanded view of cognition and renewed interest in both the affective variables and individual differences that can influence performance (Hidi, 1990).

The manner in which individual interest has been defined in the literature has generally emphasized the roles of topic knowledge and prior experience. For example, Estes and Vaughan (1972) delineated interest as a research

variable in the following manner: "...as previous knowledge of the topic, need for information, previous reading of the author's work, attraction to the kind of writing being used, background experience, and to some degree, perception of the ease or difficulty with which the selection may be read." (p. 151). In a more recent definition, Renninger (1989, 1990) also stressed that individual interest is centered around stored knowledge and values related to particular topics: "Building on the work of Vygotsky (1967) and Piaget (1940, 1981), the knowledge and value components of interest derive from what the individual brings to present action from prior experience with both objects and others" (Renninger, 1992, p. 362). "Knowledge," for Renninger, refers to cognitive representations stored from past experience, while "value" refers to related affective responses, such as feelings of competence. Thus, as Hidi (1990) summarizes this view, individual interest and related knowledge are interdependent factors that develop hand in hand and influence the manner in which the individual engages in tasks.

Perhaps the most useful definition of interest from a cognitive perspective was offered by Hidi and Baird (1986), who described the role played by this affective variable in the cognitive process:

"We suggest that the two types of interest ("cognitive" and "emotional") may involve the same evaluative response.

Both involve an increase in cognitive effort - information search, inferencing, and so on - to augment one's knowledge and understanding of some circumstances or text... What is central to the response of interest is that a person is compelled to increase intellectual activity to cope with the greater significance of incoming information (p. 154). What is suggested by this definition is that interest serves to facilitate cognitive performance by energizing task involvement and/or increasing persistence. Much of the research pertaining to individual interest and cognitive performance has embraced this view of interest as facilitating cognition, attempting to demonstrate, for example, that subjects will demonstrate greater comprehension of interesting passages than neutral or disinteresting passages.

It is necessary at this point to note a distinction identified by Hidi and Baird (1986, 1988) between two different methods of examining the role of interest on cognition. The first, commonly referred to in the literature as investigations of "personal interest" or "individual interest," centers around the manner in which intrinsic interests influence performance on a range of cognitive tasks. Studies which pursue this line of inquiry typically examine the extent to which subjects focus on, engage in, or persist with tasks of varying personal interest. Other researchers working from the perspective of individual

interests have varied the topic or content of a research task ("topic interest") in order to be more or less attractive to individuals of different interests. The second method, which has come to be known as "situational interest" or "text-based interest," refers to the interesting properties of varying situations or contexts irrespective of individual interests (across subjects). As Hidi (1990) notes, "In this type of investigation, the focus is on interest that has been elicited, for example, by seeing something in the environment, hearing a conversation, or reading a text" (pp. 550-551). Since it is a purpose of this study to examine the effects of individual interests on spontaneous transfer and problem solving, the following review will concern itself primarily with the research pertaining to individual interests and their influence on cognitive performance variables. The existent research pertaining to situational and "text-based" interest is discussed in detail in Hidi's (1990) comprehensive review of this literature.

Topic Interest and Reading Comprehension

A significant portion of the research that has addressed the influence of topic interest on cognitive performance has centered around reading comprehension. As early as the mid-1950's, educational researchers have endeavored to demonstrate that topics of high interest to students are associated with superior comprehension compared

to those of low interest. The research paradigm employed in much of the earlier research (i.e., Bernstein, 1955; Schnayer, 1967) involved the assessment of subjects' interest after they had read and recalled a passage. While this research paradigm was generally successful in displaying greater comprehension of interesting rather than neutral or less interesting passages, the methodology employed in these studies has been subject to considerable criticism. Asher (1980), in his review of the methodological and theoretical issues relating to topic interest and children's reading comprehension, noted a significant flaw in those studies that gauged interest after the passages had been read.

"This procedure confounds the assessment of interest with reading comprehension because children report more interest in a passage they have understood than one with which they have had difficulty" (Asher, 1980, p. 256) Therefore, as Asher indicates, those studies that measured interest subsequent to the presentation of reading passages may have been assessing subjects' perceptions of the difficulty level of each passage rather than their interest in each passage.

In one of the earliest studies to avoid the pitfall noted by Asher, Estes and Vaughan (1973) assessed subject interest by administering an inventory of six interest areas prior to passage readings. Each of the 46 fourth graders

included in their study were given one high interest and one low interest passage to read based on the interest inventory scores. A ten-item multiple choice task followed, designed to measure comprehension of facts, inferences, main ideas, and vocabulary. The results indicated a significant difference in comprehension scores between high and low interest passages. That is, participating students received higher comprehension scores for the high interest passage than they did for the low interest passage. The authors interpreted these results to reveal that interest is a critical factor in comprehension.

A similar study conducted by Asher and Markell (1974) assessed children's interests by having them rate on a seven point scale 25 color photographs representing a wide array of subjects. One week later, children received six passages (three high interest, three low-interest) related to the photographs they had rated for interest previously. Passages came from standardized reading material and were presented using a cloze procedure format. Results indicated that students comprehended more of high- than low- interest material. In a follow-up study, Asher, Hymel, and Wigfield (1978) also found that students performed better on high- than low-interest passages.

Belloni and Jongsma (1978) examined the relationship between topic interest and reading comprehension on low-achieving adolescents. In their first meeting with the

experimenters, subjects were presented with 12 passage titles and corresponding story abstracts and asked to choose one story they would most like to read and one story they would least like to read. One week later, students were asked to read the stories they had selected prior to completing a cloze comprehension tests for each of the passages. Order effects were controlled by having half the students read the high interest passage during session two and the low interest passage during session three. Consistent with the results of the earlier research with normal achieving students, the results indicated superior comprehension scores for the high interest passage compared to the low interest passage. Stevens (1980) attempted to determine whether the topic interest effect on reading comprehension would hold consistent for students of high-, middle-, and low-ability reading levels. The procedures employed in this study were similar to those used in the earlier research with a one notable exception. A 25-item interest rating questionnaire was used which presented topics in both verbal and picture form in order to limit the extent to which reading ability influenced interest ratings. Interest level was rated on a scale from one to seven was used to assess topic interest. Topics rated consistently high or consistently low on both inventories were identified as high and low interest passages for each student. In a subsequent session, students were given two

passages of higher interest and two passages of lower interest to read. Reading comprehension was measured via a multiple-choice exam administered immediately following the completion of each passage.

The results of the study can be considered contradictory to the findings of previous research in that an effect of interest was found only for the high ability students. No difference was found between the high and low interest comprehension scores for the middle- and low-ability students. It merits noting, however, that those earlier studies which found an interest effect for lower ability students (i.e., Schnayer, 1967) tended to measure interest in the topic subsequent to reading the target passages, committing the methodological error noted by Asher (1980).

In a more recent study, Renninger (1991) examined how fifth and sixth grade students' reading comprehension and mathematical word problem solving was affected by the 'interestingness' of the contexts in which the tasks were embedded. Unlike its predecessors, which defined interest by asking subjects to rate their level of interest in a range of topics, this study determined subject interest through the use of a Likert-type questionnaire that assessed the frequency of their activity with, feelings toward, and knowledge of each of 40 items (e.g., soccer, swimming, listening to the radio, etc.). Interest(s) were identified

as those activities with which the student did engage, and for which he/she had both more stored knowledge and value relative to the other activities listed. 'Noninterests' were identified as those activities with which the student engaged, and for which he/she had knowledge but low value relative to other activities listed. By only presenting subjects with contexts that met these criteria for 'interesting' and 'noninteresting', the potential confounds of 'topic knowledge' and 'topic familiarity' were controlled.

The results indicated that students tended to be more competent in both their reading and mathematical performance when the problems they were solving were embedded in an interesting context. In explaining this finding, Renninger noted that students appeared to have an easier time engaging in contexts of interest than 'noninterest'. She goes on to conclude that interest may have actually served to enable students to adjust the level of the problem by chunking information in the passage such that it actually becomes easier to solve.

One final study that merits consideration here was by R. C. Anderson, Shirey, Wilson, and Fielding (1987), who examined (among several variables) the motivational properties of sentences studied for later recall. These researchers defined a sentence's motivational property by asking subjects to rate the extent to which each sentence

interested them. It was anticipated that the sentences of interest to their older adolescent population would be those which stated themes and topics with which the subjects could identify or reflected a high activity level. The results of the four experiments which comprised their study indicated that rated interest accounted for an average of 30 times as much variance in sentence recall as readability. That interest produced a substantially larger effect than readability is significant, as these researchers indicated, given that readability remains "the criterion used throughout the country for grading the appropriateness of reading materials" (p. 287).

Topic Interest and Other Cognitive Performance Tasks

Renninger's (1988) study noted above is one of very few to address the influence of individual or topic interest on a cognitive performance variable other than reading comprehension. In an earlier study, Renninger and Wozniak (1985) investigated the individual interests of pre-school children (ages 2.9 - 4.2 years) in a series of freeplay sessions. They found that although the individual interests of the young children varied widely, these interests tended to be accurate predictors of attention, recognition, and recall. Based upon these findings, the authors concluded that the way in which young children engage in tasks is consistently influenced by their levels of interest (value) in and knowledge of the play object.

The few other studies which attempted to link individual interest with cognitive performance variables other than reading also found that heightened interest tends to lead to heightened performance. For example, Schiefele and Krapp (1988, as cited by Hidi, 1990) reported that topic interest resulted in a higher degree of cognitive organization in college students' knowledge structures. This finding led the authors to conclude that interest-based learning might manifest itself more in qualitative than quantitative changes. Hidi (1990) also cites the unpublished work of Nenniger (1987) who focused on two dimensions of content orientation: interest in a particular subject matter and readiness to work on a specific content area. The results of this study suggested that individual interest in subject matter had the greater influence on mathematics performance and is therefore a significant variable affecting the outcome of learning. Although not directly centered around cognitive performance, Prentzel (1988, as cited by Hidi, 1990) found that college students who develop interest in a subject (computers) will reengage and persevere in subject-related activities than their less interested peers. Subject interest was also associated in this study with significantly higher degrees of "absorption" of subject-related information.

Although only a comparatively small number of studies have investigated the influence of individual interests on

cognitive performance variables other than reading comprehension, its is reasonable to conclude that individual interest can play an important role in cognitive processing across a range of tasks. Unlike the contradictory findings regarding the influence of extrinsic incentives on cognitive performance variables, the research on the influence of topic interest has consistently demonstrated a facilitating effect on performance. What most of the topic interest research discussed above did not address, however, is the degree to which subjects' prior knowledge of topics they found personally interesting contributed to the results obtained. The next section will examine the handful of studies to investigate the importance of prior knowledge in regard to the influence of topic interest on cognitive processing.

Topic Interest and Prior Knowledge

A significant limitation of much of the research discussed above relates to the lack of attention to subjects' prior knowledge of the topics they identify as interesting or noninteresting (Beck & Carpenter, 1986; Sacks, 1989). Without attempts to measure and/or manipulate the influence of knowledge, the alternative hypothesis that it is subjects' knowledge of the high interest activities (rather than interest in these topics) that leads to the greater cognitive performance scores remains tenable.

Beck and Carpenter (1986) argued that previous

knowledge can provide a structure that helps the reader organize information in text, determine which information is important, and draw inferences about unstated relations (p. 1104). As Sacks (1989) has indicated, research has consistently shown that those with high prior knowledge recall more information than those students with lower knowledge. She goes on to conclude that those students with more information in pre-existing knowledge structures perform better on recall tasks than students with less pre-existing knowledge structures.

A range of studies support this conclusion regarding the influence of prior knowledge on cognitive performance tasks. For example, Bransford and Johnson (1972, Experiment I) found that subjects exposed to related pictures prior to listening to a recorded passage were able to recall a greater amount of information about the passage then were students in other experimental and control conditions. Anderson, Reynolds, Schallert, and Goetz (1977) investigated the extent to which subjects of different backgrounds (classical music versus amateur wrestling) would be able to recall information from written passages having both a wrestling and classical music theme. Their results indicated a significant interaction between passage type and subjects' background posttest recall performance. That is, those students with a music background recalled considerably more about a music passage (and with greater accuracy) than did

students with a physical education background. Conversely, the physical education students were significantly more successful with a physical education passage than were the music students.

Callahan and Drum (1984) investigated the effects of prior knowledge, text structure, and verbal ability on reading comprehension for textbook passages. Prior knowledge was assessed through a 20-item vocabulary test including 12 words critical to the understanding of each text passage. The results of their regression analyses indicated that prior knowledge was a better predictor for recall and cloze task performance than text structure and verbal ability.

Asher (1975) used a "controlled vocabulary" format to measure the influence of topic interest on reading comprehension while also controlling for the influence of prior knowledge. Topic interest was determined through the use of a interest inventory which asked subjects to rate a series of 25 topic pictures on a seven point interest scale. One week later, students were presented with six text passages corresponding to their highest rated and lowest rated pictures during the interest assessment phase. In order to limit the impact of prior knowledge, passages were written in a format which allowed for the insertion of the three highest and lowest interest topics associated with each child's rating. For example, if a child rated "cats" as a high interest topic, the story was labeled "Cats" and

concerned a story about cats. A cloze comprehension task was administered immediately after each passage was completed.

Although the results of the experiment did not indicate a significant differences in comprehension scores of high and low interest passages, further data analysis did reveal a weak (non-significant) effect for the interest manipulation. Based on these results, Asher concluded that when knowledge is strictly controlled, the enhanced performance associated with topic interest is diminished. This finding would appear to suggest that it is the cognitive variable "prior knowledge," not the affective variable "individual interest," which leads to the documented effect of topic interest on reading comprehension. Asher's findings and conclusions regarding the relative influence of prior knowledge and interest must be considered suspect, however, due to the contrived nature of passages developed for the study. It seems unlikely that text passages that can be readily adapted to suit a broad range of topics will sufficiently trigger individual interests. For example, a passage about "flowers" that is structured and written in virtually the same way as a passage about "cats" is unlikely to be reacted to by subjects (regardless of their individual interests) in a significantly different manner.

Baldwin, Peleg-Bruckner, and McClintock (1985) also examined the relationship between topic interest and prior

knowledge on reading comprehension. Unlike the Asher study, however, a controlled vocabulary procedure was not employed to limit the influence of prior knowledge. Baldwin et al. first administered a 10-item interest inventory to their junior high school aged subjects that asked them to rate their interest for each topic on a scale from one to ten. In a subsequent session, students were administered a 100-item prior knowledge test containing 10 multiple-choice questions pertaining to each of the ten written passages to be read later in the experiment. Several weeks after the initial testing, students were assigned to one of four experimental conditions: (1) high prior knowledge/high topic interest; (2) high prior knowledge/low topic interest; (3) low prior knowledge/low topic interest; and, (4) low prior knowledge/high topic interest. All students read and were tested on their own unique interest/knowledge combinations so that each read four passages corresponding to the four experimental conditions. Immediately after reading each passage, subjects completed a cloze comprehension test and were asked to rate from one to ten how interesting they found each passage.

The results of the Baldwin et al. study indicated significant main effects for both topic knowledge and topic interest; however, no significant interaction effects were obtained. Based on these findings, the authors concluded that topic interest and prior knowledge are independent

factors in terms of their influence on children's' reading comprehension.

Considered together, the results of those studies that have examined the influence of prior knowledge on comprehension and problem solving provide sufficient evidence exists to conclude that background knowledge does significantly influence subject's recall and problem solving. Although the extent to which topic interest and prior knowledge are related in impacting cognitive performance remains in doubt, empirical evidence indicating prior knowledge can be disregarded when studying topic interest has yet to be obtained. The available literature pertaining to recall and comprehension of information from texts indicates that those subjects with high prior knowledge perform more effectively than those students with lower knowledge. It seems reasonable to conclude, as was suggested by Sacks (1989), that students with more information in pre-existing knowledge structures possess topic-specific schemata which enable them to perform better on recall and performance tests than students with less pre-existing knowledge structures. Regardless of the manner in which prior knowledge facilitates performance, however, it is apparent that research which endeavors to gauge the impact of individual interests on cognitive performance variables must also measure subjects' knowledge of all topics/activities presented.

General Summary and Rationale for Experiment

The literature review has examined research in three specific areas: (1) the constraints on spontaneous transfer of information and strategies in novel problem solving contexts; (2) the influence of extrinsic incentives and other motivational factors on cognitive performance variables; and, (3) the influence of personal (or "topic") interest on cognitive performance variables. The findings of this review can be summarized as follows:

1. Numerous studies have indicated that spontaneous access and application of previously learned information in novel problem solving situations is unlikely when subjects are given only a brief period of time to arrive at solutions. Not surprisingly, other studies (i.e., Adams et al., 1988; Stein et al., 1986) have suggested that likelihood of spontaneous transfer increases as the similarity between the initial learning task and the novel problem solving task is increased. Other researchers (i.e., Gick and Holyoak, 1983) have demonstrated the likelihood of analogous transfer can be significantly increased if subjects are exposed to cue information in two analogous forms (i.e., two analogous stories) prior to presentation of a seemingly unrelated problem. The presentation of the cue information in more than one form or context facilitates the development of schemas that can subsequently be applied to problems in other contexts. To date, no research has

directly compared the efficacy of task similarity and schema induction methods of increasing spontaneous transfer.

Considered together, the results of the lines of inquiry discussed above would appear to suggest that the spontaneous transfer of information to seemingly unrelated problem solving contexts will only occur under very restricted conditions. Building upon the work of Bowden (1985), who demonstrated that with persistence subjects can spontaneously transfer seemingly unrelated knowledge to the solving of novel problems, Tobias and Kaufman (1991) examined the whether the offer of financial incentives would facilitate spontaneous transfer. Their results were inconsistent, but clearly warranted the execution of additional research.

2. Despite the mounting evidence suggesting affective variables significantly influence cognitive performance, the research on the impact of extrinsic incentives on cognitive performance variables is inconclusive. While McGraw (1978) cites a considerable body of evidence in support of his contention that incentives inhibit performance on heuristic problem solving tasks (and facilitate performance on algorithmic tasks), several studies have not found this inhibiting effect (Eysenck, 1984; Frase et al., 1970; Frase, 1971; Tobias & Kaufman, 1991). The two studies to directly measure the influence of monetary incentives on the spontaneous transfer of inert knowledge in a novel problem

solving context produced contradictory results. McNeill and Kimmel (1989) found the inhibiting effect predicted by McGraw, whereas Tobias and Kaufman (1991) found no difference between the problem solving of rewarded and unrewarded subjects. Frase's (1971) findings suggest that in order to have a facilitating influence on problem solving, the incentive must also be offered during the initial learning task. Given the apparent contradictions in the findings of these studies, additional research must be conducted to demonstrate the specific conditions under which extrinsic rewards facilitate and inhibit cognitive performance. Research which addresses Eysenck's (1984) theory regarding the "cognitive inflexibility" brought about by the offer of incentives may be particularly valuable in this endeavor.

3. There appears to be little doubt that individual interest has a significant influence on the performance of cognitive tasks. Simply stated, subjects tend to perform better on tasks embedded in a context they find interesting than in contexts that are neutral or less interesting. Research into the contributions of prior knowledge in facilitating the recall and comprehension of interesting material suggests that while an interaction effect between the two variables (interest and prior knowledge) is difficult to obtain, prior knowledge has a powerful impact on performance as an independent variable (Baldwin et al.,

1985; Sacks, 1988). Indeed, based upon their review of the literature pertaining to domain knowledge and strategy use, Alexander and Judy (1988) concluded that individuals possessing high degrees of domain specific knowledge are generally more effective strategy users (when presented with problems set in the domain) than individuals possessing lesser degrees of domain specific knowledge. Clearly, any study of cognitive problem solving that examines strategy use or transfer must attempt to either regulate (or at least control for) this pontentially confounding variable.

Eysenck (1984), upon reviewing the literature pertaining to the influence of affective factors on cognitive processing, strongly encouraged researchers to examine the combined influence of intrinsic and extrinsic variables on cognitive performance variables. To date, researchers, with the notable exception of McNeill and Kimmel (1988), have disregarded this advice. This is unfortunate when one considers that in many classroom learning situations it is unlikely that intrinsic and extrinsic motivational have separate influences on cognitive performance. Indeed, the sequence of steps completed by an individual solving a problem solving in either an academic or industrial context is apt to be influenced by the combined influence of intrinsic and extrinsic motivational factors. In addition to whatever separate impact these two affective variables can have on problem solving, it is

certainly tenable that the interaction of the two forms of motivation will influence performance. Viewed from this perspective, research which measures the independent influence of intrinsic motivational variables and extrinsic motivational variables (in addition to their interaction effects) on problem solving would seem of particular importance to the problem solving literature.

General Description of Experiment

The purpose of the dissertation experiment was threefold: (1) to examine the influence of intrinsic motivational variables (i.e., topic interest/text-based interest and task interest) on spontaneous transfer of prior learning; (2) to more directly investigate the interaction of intrinsic and extrinsic motivational variables on the problem solving process; and, (3) to examine the influence of intrinsic and extrinsic motivational variables on the task similarity effect documented in earlier spontaneous transfer research.

The experiment employed the general research paradigm commonly used in most studies of cognitive transfer. That is, subjects were first provided with salient information (a convergence strategy) during an initial "acquisition phase" by studying two story analogies developed by Gick and Holyoak (1983) for Duncker's (1945) Radiation Problem. A brief survey was administered following the acquisition task to obtain task interest and topic interest scores for each

subject and to enhance the separation between the acquisition and problem solving phases. The third phase of the experiment (problem solving) was composed of both uninformed and informed problem solving trials. During Trial 1, subjects wrote to solutions to the Radiation Problem without being told of the connection between the problem and story analogies. During Trial 2, subjects were informed of the relationship between the stories and the problem and were given another attempt to solve the problem.

The "interestingness" of the problem solving materials was varied in that the Radiation Problem was embedded in either an 'interesting' or 'dull' context (according to principles of topic and text-based interest). In order to examine the combined influence of intrinsic and extrinsic motivational variables on the problem solving process, half the sample were offered an extrinsic incentive (money) for correct problem solving immediately prior to the problem solving phase. If McGraw's (1978) theory regarding the influence of extrinsic incentives on problem solving is correct, intrinsically motivated subjects offered an incentive for correct problem solving should have been less successful on the problem solving task than intrinsically motivated subjects not offered the extrinsic incentive.

In addition to varying the motivating characteristics of the problem solving materials, the experiment also varied the similarity between the acquisition and problem solving

tasks. It will be recalled that the similarity of the initial learning and subsequent transfer tasks can significantly influence the transfer process (Adams et al., 1988; Gick & Holyoak, 1987; Lund & Dominowski, 1985; Lockhart et al., 1987). The more similar the initial learning task is to the transfer task, the greater the likelihood of spontaneous transfer (Bransford et al., 1989). The proposed study examined the influence of motivational variables on the spontaneous transfer process across 'similar task' and 'dissimilar task' conditions.

Research Questions and Hypotheses

Figure 1 illustrates the design of the proposed experiment in a 2 X 2 X 2 contingency table.

Figure 1

2 X 2 X 2 Factorial Design

	Interesting Version of Prob		Dull Version of Problem	
	No Incen.	Incen.	No Incen.	Incen.
Similar Task Acq. Material	Group 1	Group 2	Group 3	Group 4
Dissimilar Task Acq. Material	Group 5	Group 6	Group 7	Group 8

"Similar Task Acq. Material" = Acquisition materials have a problem solving orientation

"Dissimilar Task Acq. Material" = Acquisition materials include no problem solving orientation (story summarization only)

"Incen" = Subjects offered a monetary incentive for accurate problem solving

"No incen" = Subjects offered no incentive for problem solving

It was anticipated that if the combined influence of topic interest, extrinsic incentive, and task similarity on problem solving is additive, the greatest rate (frequency) of correct solutions would be exhibited by Group 2 (the group administered similar task acquisition materials, offered an incentive for problem solving, and administered the "interesting" version of the Radiation Problem). If, however, McGraw's (1978) theories regarding the adverse influence of extrinsic incentives on cognitive performance are correct, however, it was expected that the highest frequency of correct solutions would be exhibited by Group 1 (administered the similar task acquisition materials, "interesting" version of the problem, but not offered an incentive for problem solving).

Other hypotheses tested by the experiment included the following:

- A significantly greater frequency of correct solutions would be produced by subjects solving the interesting version of the Radiation Problem than the neutral/dull version of the problem (main effect for topic interest).
- A significantly greater frequency of correct solutions would be produced by subjects administered 'task

similar' acquisition materials than subjects presented administered 'task dissimilar' acquisition materials (main effect for task similarity).

- A significantly greater frequency of correct solutions would be produced by subjects exhibiting a high degree of task interest (as measured by a "Task Interest/Science Interest Survey") than by those demonstrating lower degrees of task interest.
- Subjects administered the "interesting" version of the problem would rate the problem more interesting than subjects (on a post-experiment interest survey) than subjects administered the "dull" version of the problem.

CHAPTER III

METHOD

As noted earlier, the basic experimental procedure was to provide subjects with a story analogy, describing a problem and its solution, and then to observe how subjects used the analogy in solving a subsequent target problem. Expanding upon materials and procedures developed by Gick and Holyoak (1980; 1983), the experiment was comprised of three distinct phases: (1) story analog acquisition; (2) testings for task interest and science interest (topic interest); and, (3) problem solving. The task similarity independent variable was manipulated in the acquisition phase. The topic/text-based interest and incentive independent variables were manipulated in the problem solving phase.

Subjects

The sample was composed of 165 students (76 males, 89 females) recruited from two New York City public high schools renowned for attracting students with an interest in the sciences: Brooklyn Technical High School and Midwood High School. Approximately 50% of the attendees of both schools are caucasian, 30% are Asian-American, 10% are African-American, and 10% are Latino. (Note: In accordance with New York City Board of Education regulations, the participants in the experiment were not required to indicate their ethnicity on experimental materials.) All

participants were in the eleventh grade (either 16 or 17 years of age) and were enrolled in at least one advanced placement science course. These courses are even more demanding than the standard science courses offered at the participating high schools, and are traditionally attended by students with a strong interest in the natural sciences.

A task interest/science interest survey was administered to subjects immediately following the acquisition phase to determine each subject's interest in solving the type of heuristic puzzle used in the experiment and interest in science as a topic area (a more detailed description of this instrument is provided below). The mean science interest score for each of the eight groups in the experiment was significantly higher than the average science interest score computed for an average achieving population of students attending another New York City public high school.

Acquisition Phase Materials

In the experiment's first phase (story acquisition), subjects were asked to memorize either one or two short stories (of approximately 200 words). Subjects assigned to 'similar task' conditions were instructed to memorize only one story (*The Brilliant General*), while subjects assigned to 'dissimilar task' conditions were asked to memorize two analogous stories (The *Brilliant General* and *Red Addair*). Both stories were developed by Gick and Holyoak (1980, 1983)

to serve as analogies for Duncker's (1945) *Radiation Problem*. The stories are analogous in that the protagonist is only able to conquer an obstacle (a fortress in the case of the *Brilliant General* and a raging oil fire in the case of *Red Addair*) by applying an "attack-dispersion" strategy (also commonly referred to as a "convergence" strategy). That is, each protagonist is prevented from attacking the objective with full force from one direction, but is eventually able to accomplish his goal by directing low concentrations of force from all directions so that it combines at full force at the target (Appendix B contains the two story analogs). The convergence strategy was explicitly stated in the last paragraph of the Brilliant General Story as follows:

> ***The general attributed his success to an important principle: If you need a large force to accomplish some purpose, but are prevented from applying such a force directly, many smaller forces applied simultaneously from different directions may work just as well***

The Radiation Problem can be easily solved through the application of the convergence strategy (Note: For a more detailed discussion of Duncker's radiation problem and its analogies, the reader should consult Gick and Holyoak, 1980).

In the second part of the acquisition phase, subjects assigned to dissimilar task conditions were instructed to

summarize the plots of the two stories (*Brilliant General* and *Red Addair*) placing particular emphasis upon the solutions developed by the protagonists (to increase the likelihood that subjects would mention the convergence solution in their summaries).. Subjects in the similar task conditions were presented with the first two paragraphs of the *Red Addair* story (the third paragraph describing the protagonist's solution to the oil fire was omitted) and instructed to apply the "attack dispersion" strategy used by the *Brilliant General* to predict the method by which *Red Addair* would extinguish the oil fire. *By applying the acquisition phase material (the strategy) in a problem solving context, subjects in the similar task conditions acquired the attack-dispersion (convergence) schema by completing a similar task to the problem they were asked to solve during the experiment's problem solving phase.* To paraphrase Bransford et al. (1989), the similar task acquisition phase procedures required subjects to process the convergence strategy in a similar manner to the problem solving processing required to solve the Radiation Problem. Subjects in dissimilar task conditions acquired the attack-dispersion schema through a summarization task largely dissimilar to the problem solving phase task.

Problem Solving Phase Materials

Each subject was presented with either an "interesting" or "dull" version of Duncker's Radiation Problem during the

problem solving phase. The purpose of this manipulation was to determine the impact of "problem interestingness" on subjects ability to access the attack-dispersion (convergence) strategy when attempting to solve the problem. As noted earlier, previous research has indicated that interest can have a facilitating impact upon certain types of cognitive problem solving (i.e., text comprehension). Given this trend in the literature, it was predicted that subjects presented with an "interesting" version of the radiation problem would be more successful solving the problem than subjects presented with a less interesting ("neutral/dull") version. The original version of Duncker's Radiation Problem is as follows:

> *Suppose you are a doctor faced with a patient who has a malignant tumor in his stomach. Due to the tumor's location, it is impossible to remove through an operation of any kind. Unless the tumor is destroyed, however, the patient will die. There is a kind of ray (radiation beam) that can be used to destroy the tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed, severely injuring the patient. At a lower intensities the rays are harmless to healthy tissue, but will also not affect the tumor. Can you think of a procedure (using the rays) that might be used to destroy the tumor, and at the same time avoid destroying the healthy tissue?*

In order to vary the "interestingness" of Radiation Problem, two modified versions of the problem were developed for the experiment - an "interesting" version and a "dull" version. To increase the "interestingness" of the problem to high school students with a demonstrated interest in science

(the population from which the sample was recruited), the 'interesting' version of the problem was embedded in a scientific context by introducing the problem with the following statements:

> *You were asked to participate in this experiment due to your academic skills and interest in science. Below is a version of puzzle that many scientists (and students of science) have found both fun and challenging. The original version was developed by Dr. Stephen Hawking for "MENSA" (the society for individuals with high IQ's) and has been published in complex riddle books and intelligence tests. Your task is to solve the puzzle. You have 10 minutes to do so. Please read the puzzle twice before attempting to solve it. Enjoy!*

It was anticipated that subjects with a strong interest in science would be more interested in solving the Radiation Problem as a result of reading these introductory statements because the statements frame the problem as being of interest to scientists. The inaccurate statement attributing authorship of the Radiation Problem to Stephen Hawking, a famous scientist whose name frequently appears in the popular media, was included in the instructions in an attempt to heighten subjects interest in the problem.

As a way of further increasing its "interestingness," the "interesting" version of the problem was modified to include topics and themes that have been shown to be universally interesting. Shank (1979) demonstrated that certain kinds of topics are inherently interesting to most people. These include death, danger, chaos, destruction, disease, power, and sex. The death of a young person or a

young person placed in mortal peril were found to be topics that most people find particularly interesting. Anderson, Shirey, Wilson, and Fielding (1984) identified other factors that enhance the interestingness of text passages, most important among these being character identification. Simply put, these researchers found that people are likely to be interested in characters with whom they can identify in terms of sex, age, lifestyle, and values. Based upon the Shank (1979) and Anderson et al. (1984) findings, the "interesting" version of the Radiation Problem was adapted to include more interesting topics and themes:

> *The year is 2006. After completing college and medical school you have become a nationally renowned medical scientist specializing in the diagnosis and treatment of malignant tumors. You are frequently consulted by physicians throughout the world and have aided in the treatment of several prominent individuals.*
>
> *Late one night you receive a call from the Chief White House Physician. The ten year old son of the President of the United States has been stricken with a potentially deadly form of stomach cancer. The boy is in considerable pain and his mother, the president, is inconsolable. Tests indicate the child may die in less than a week unless the malignant tumor is destroyed. Due to the tumor's location it is impossible to operate on the patient. <u>No incisions of any kind can be made in the body and no device can be directed at the tumor through the mouth or other body openings</u>. You know of a new experimental ray (radiation beam) that can be used to destroy the tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed, severely injuring the patient. At lower intensities the rays are harmless to healthy tissue, but they will also not affect the tumor. Can you think of a procedure (using the ray) that might be used to destroy the tumor, and at the same time avoid destroying the healthy tissue?*

It will be noted that while the essence of the radiation problem remains unchanged, the context in which the interesting version is embedded has been "punched up" (based upon the tenets of text-based interest) to make it more interesting to the reader. Whereas the victim in the original version of the problem is some unidentified patient, the victim in the interesting version is the young son of the first female president of the United States. This adaptation was intended to enhance the 'life or death' aspect of the problem, since the victim was young, in mortal peril, and the child of a powerful figure. Rather than present the tumor as a treatment challenge for an unspecified physician, the interesting version of the problem asked subjects to imagine themselves as a medical scientist charged with the task of developing an effective treatment.

Unlike the interesting version of the problem, which was preceded by instructions designed to attract subjects' interest, the instructions to the 'dull' version of the problem were written to convey that it was excerpted from a standard high school science text (and therefore somewhat tedious and routine).

> *Below is a problem to solve. It was excerpted from a 10th grade textbook commonly used in neighboring school districts. It is not necessary that you be familiar with the technical terms in the problem to solve it. Please read through the problem below at least twice before writing solutions. You have <u>ten</u> minutes arrive at correct solutions. If you have any questions about the problem, please raise your hand to signal the*

proctor.

In order to further diminish the 'interestingness' of the neutral/dull version, the problem was preceded by a brief, purposefully dull passage about tumors containing numerous technical terms. Recent text-based interest research (i.e., Wade & Adams, 1990; Wade, Buxton, & Kelly, 1993) has demonstrated that readers tend to judge sentences containing several technical expressions to be among the least interesting/important parts of text passages. The introductory paragraph to the dull version of the problem read as follows:

> *Tumors, also known as "neoplasms," can develop in all regions of the body. Medical dictionaries define neoplasms as a mass of new tissue that persists and grows independently of its surrounding structures, and which has no physiologic use. Many types of neoplasms have been identified. They include the following: cellular tumors (tumors made up chiefly of cells in a homogeneous stroma); connective-tissue (any tumor developed from some structure of the connective tissue); desmoid (a hard, fibrous tumor); heterologous tumors (made up of tissue which differs from that in which it grows); malignant (those that are likely to reoccur and that may terminate life); and sebaceous tumors (cysts formed by the retention of the secretions of a sebaceous gland).*

The object of this preceding paragraph was to make the topic "tumors" seem so dull to the reader that interest in solving the *Radiation Problem* was diminished.

Applying the principles of text-based interest discussed above (Anderson et al., 1984; Hidi & Baird, 1986; Schank, 1979; Wade, 1992), certain nonessential phrases in the radiation problem were also altered to diminish the

problem's "interestingness." For example, the tumor in the neutral/dull version was also described as a "malignant," but no mention was made of the life expectancy of the patient to minimize the 'life or death' nature of the problem. The remainder of neutral/dull version of the problem was read as follows:

> *Suppose a doctor has a patient with a malignant tumor in his abdominal cavity (epigastric region). Due to the tumor's location, it is impossible to operate on the patient. No incisions of any kind can be made in the body and no device can be directed at the tumor through the esophagus or intestines. There is a kind of ray (radiation beam) that can be used to destroy this type of tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed, injuring the patient. At lower intensities the rays are harmless to healthy tissue, but will also not affect the tumor. Can you think of a procedure (using the ray) that might be used to destroy the tumor, and at the same time avoid destroying the healthy tissue?*

Pilot testing of the two versions of the problem indicated that their readability levels were virtually identical. Page 107 presents a more detailed discussion of the pilot test findings. Appendix C contains all problem solving materials used in the experiment.

Instrumentation and Procedures

Subjects were randomly assigned to one of the eight condition groups described earlier. Proctors assigned to each group received approximately 10 minutes of training (by the experimenter) prior to the data collection process. Minimal training of proctors was required, as these

individuals were only required to disseminate and collect experiment materials and to ensure that silence was maintained throughout the experiment. At each of the two participating schools, subjects were addressed in one large group by the experimenter before being divided into the eight condition groups. Subjects were told at this point that the purpose of the experiment was to gather normative data for future research studies involving memory and problem solving. Subjects were also instructed to maintain strict silence throughout the experiment and to raise their hand to signal the proctor (who would then summon the experimenter) if they had a question pertaining to the experiment materials. Proctors were instructed to closely monitor the work of subjects in their groups to ensure that each subject completed tasks without the assistance of other subjects.

Acquisition Phase Tasks

Once subjects were assigned to groups, proctors handed each subject a large manilla envelope containing five documents (clearly labeled "Document 1," Document 2," etc.). Prior to the initiation of the acquisition phase, subjects were told that their envelopes contained five documents and that they should only remove a given document from the envelope when instructed to do so by the proctor.

"Document 1" contained the story memorization part of the acquisition phase materials. Proctors first instructed

subjects to remove only Document 1 from their envelopes and to carefully read the instructions to the document. As discussed above, subjects assigned to similar task groups completed different acquisition phase tasks than subjects assigned to dissimilar task groups. Document 1 administered to subjects in Groups 1 through 4 (similar task groups) contained only the *Brilliant General* story followed by the explicitly stated attack-dispersion principle developed by Gick and Holyoak (1983).

The instructions to the document stated they had 10 minutes to memorize the story's plot and that they were not required to memorize the story word for word. The version of Document 1 administered to subjects in Groups 5 - 8 (dissimilar task groups) contained both the *Brilliant General* story (followed by the attack-dispersion principle) and the *Red Addair* Story. The instructions to this version of Document 1 also indicated that subjects had 10 minutes to memorize the plots of the stories and that the stories need not be memorized verbatim.

At the conclusion of the first 10 minute phase of the experiment, proctors instructed subjects to return Document 1 to the envelope and to remove only Document 2. For subjects in the similar task groups, this second document contained the *Red Addair* story minus the solution developed by the protagonist. The instructions directed subjects to "write a brief ending" to the story using the *Brilliant*

General story as "inspiration." Subjects were given 10 additional minutes to complete this task. For subjects assigned to dissimilar task groups, Document 2 contained two blank pages headed by directions to discuss the similarities between the *Brilliant General* and *Red Addair* stories. In order to ensure that the attack-dispersion principle would be discussed to some extent by each subject, the instructions emphasized that the similarity between the solutions developed by the protagonist of each story should be addressed in the brief essay.

Administration of Task Interest/Science Interest Survey

Document 3 contained the Task Interest/Science Interest Survey administered to subjects in all groups. The purpose of this two-page survey was to determine each subject's interest in the topic "science" (topic interest measure) and interest in solving problems of the type used in the problem solving phase (task interest measure). The first page of the survey was a task interest questionnaire centered around Maier's (1945) "Two-String Problem". Since "task interest" can be said to differ from "topic interest," it was necessary to obtain a task interest score for all subjects in order examine the influence this variable may have had on the results. Although the Two-String Problem is more well-defined than Duncker's Radiation Problem in that it has only one appropriate solution, both problems require a creative solution to an unfamiliar problem solving task. The

directions to the second page of the survey simply asked subjects to read through the problem and to indicate their interest in solving problems like it on a 10-point likert-type scale.

The second page of the survey contained a six-item likert-type questionnaire designed to determine subjects' interest in science as a general topic area. A total "science interest" score (ranging from 6 - 60) was computed for each subject based upon his/her responses to the questionnaire. The Task Interest/Science Interest Survey may be found in Appendix D. Before subjects were instructed to begin the survey, proctors informed them its purpose was to determine participants' interest in science as well as their interest in solving a certain type of riddle. Subjects who asked for additional information regarding the purpose of the survey or other experimental material were told their questions would be answered in full after all subjects in the group had completed all tasks. The proctor of each group initiated the next phase of the experiment when all subjects had returned Document 3 to their envelopes.

Problem Solving Trials and Post-Experiment Interest Ratings

As noted earlier, the problem solving phase consisted of two distinct trials - uninformed problem solving (Trial 1) followed by informed problem solving (Trial 2). During the uninformed trial, subjects were given 10 minutes to

write solutions to the Radiation Problem without being told of the connection between the acquisition phase material and the problem. During the informed trial, subjects were provided an additional five minutes to write solutions to the problem, but were first told of the acquisition phase/problem solving phase relationship. Again, the purpose of the second (informed) problem solving trial was to examine the increase of correct solutions to the radiation problem across groups under informed problem solving conditions.

After all subjects in a group had completed the Task Interest/Science Interest Survey, the proctor directed subjects to return Document 3 to the envelope and to remove Document 4. For all groups, Document 4 contained the uniformed problem solving materials. As was described earlier, the specific version of the radiation problem ('interesting' versus 'dull') included in each packet was determined by the condition group to which subjects were assigned. The problem was presented on the first page only. The second page was blank to provide subjects with sufficient room to write solutions to the problem during the uninformed problem solving phase. Subjects in the incentive conditions were also informed immediately prior to beginning problem solving that they would receive $5 following the experiment if they were able to correctly solve the radiation problem. In order to heighten the effect of the

financial incentive, proctors for the incentive groups displayed the $5 bills just before telling subjects to begin problem solving.

At the conclusion of the first ten minute problem solving trial, subjects were told by proctors to stop working on Document 4 and return it to their envelopes. Subjects were then told to remove only Document 5 and carefully read through the instructions atop the first page. The first and second pages of Document 5 were identical to those of Document 4. However, the instructions also included the following statements:

> ***In this phase of the experiment you will be given 5 more minutes to write solutions to the problem. AN IMPORTANT HINT NOT GIVEN TO YOU BEFORE: ONE OF THE STORIES YOU READ EARLIER MAY ASSIST YOU IN SOLVING THE PUZZLE.***

Document 5 also included a third page containing a brief survey designed to measure subjects' interest in the version of the radiation problem administered to them and motivation to solve the problem correctly (a more complete description of this post-experiment survey is provided below). The instructions to Document 5 directed subjects not to look at the last page (Page 3) until instructed to do so by the proctor. The instructions provided to subjects in the incentive groups (Groups 2, 4, 6, and 8) also included a reminder about the financial incentive for accurate problem

solving:

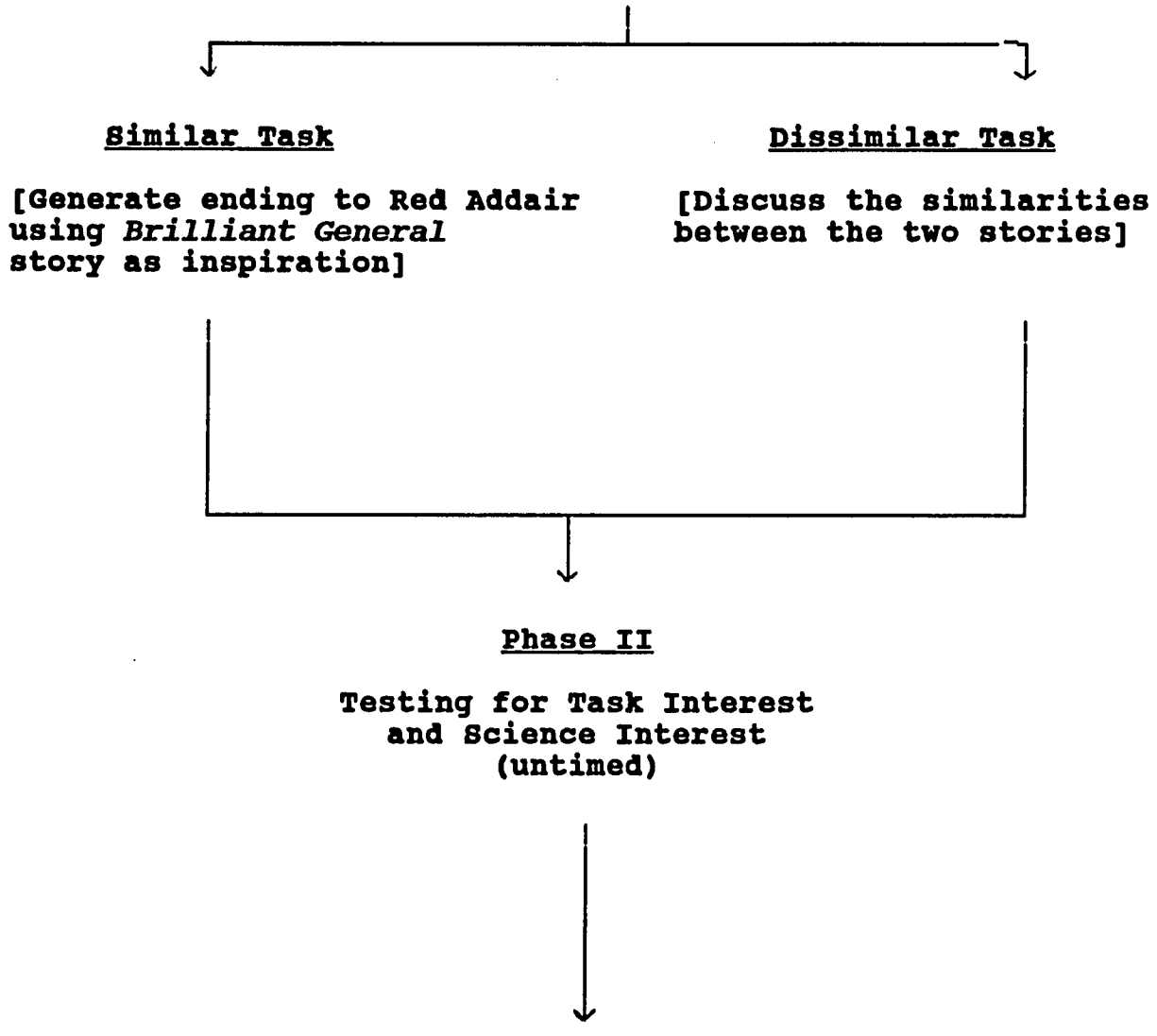
Don't forget - you'll be given $5 following the experiment if you solve the puzzle correctly.

At the conclusion of the second problem solving trial, proctors directed subjects to stop writing and to turn to the four-item post-experiment survey on the last page of Document 5 (the complete survey may be found in Appendix E). The first item asked subjects to rate, on a scale from one to ten, how interesting the found the radiation problem. It was anticipated that subjects presented with the 'interesting' version of the problem would be more likely to rate the problem "interesting" or "very interesting" than subjects presented with the 'dull' version of the problem. The second item asked them to approximate on a scale from one to ten how motivated they were to solve the problem. It was expected that subjects offered a financial incentive for accurate problem solving would be more likely to rate themselves as "very motivated" to solve the problem correctly than subjects not offered the incentive. The third item asked subjects to indicate whether either of the acquisition phase stories aided them in solving the problem during the uninformed problem solving trial (Trial 1). The third item also asked subjects to specify which of the two stories aided them in solving the problem. In order to control for any prior knowledge that subjects may have had about medicine or radiation therapy, the fourth item asked

subjects to indicate whether they possessed any prior knowledge (knowledge not provided to them in the experiment) that made it easier for them to solve the radiation problem. Subjects were given as much time as they required to respond to the post-experiment survey. Figure 2 (Page 106) illustrates the phases of the experiment and indicates the amount of time allocated for each phase.

Figure 2

PHASES OF THE EXPERIMENT



Pilot Testing

Pilot research for this investigation had two goals:

1. Determine if the two versions of the problem were comparable in terms of readability (difficulty level).
2. Establish the utility of the pre-experiment survey as a measure of "science interest" among high school students.

A "reading ease" score and other measures of readability were generated for the "interesting" and "neutral/dull" versions of the radiation problem of by the grammar checking software package *Grammatik IV*. The results obtained are listed in Table 1 below:

Table 1

Reading Ease Scores for Interesting and Dull Versions of the Radiation Problem

READING EASE CRITERIA	INTERESTING VERSION	DULL VERSION
Grade Level	10	10
Reading Ease Score	58 (Flesch)	53 (Flesch)
Mean Sentence Length	19.3 words	17.7 words
Mean Paragraph Length	6.5 sentences	7.5 sentences

The results of the readability scan indicate that the two versions of the problem are virtually identical in terms of reading ease. Both versions are written at the 10th grade level and are comparable in terms of word, sentence, and paragraph length. Given that the sample was comprised of high functioning 11th and 12th grade students, it can be

reasonably concluded that the readability level of the two versions can not have had a significant affect on problem solving results.

Given the importance the topic interest effect to the experiment, it was necessary to demonstrate that the level of interest in science possessed by the subjects in the study was significantly greater than that of a second population of high school students. To accomplish this end, the pre-experiment survey was administered to 30 average achieving juniors and seniors attending another New York City public high school. It will be recalled that the second page of the pre-experiment survey contains a six-item scale that asks students to rate their interest in science and science-related careers. Each item required the student to circle a number on a 10-point likert type scale ("1" reflecting the least interest and "10" reflecting the greatest interest). The lowest interest score obtainable was six and the highest score was sixty. The average interest score for the class of average achieving students was 29.8, whereas the average interest score for all subjects in the experiment was 47.79. The marked difference between the mean scores for the two groups was anticipated given that the subjects chose to attend a high school specializing in science instruction.

CHAPTER IV

RESULTS

The results pertaining to the study's two primary dependent variables (uninformed and informed problem solving) did not support the experimental hypotheses. That is, no significant main effects or interaction effects were indicated with regard to the task similarity, problem "interestingness," and incentive/no incentive variables across the two problem solving trials.

Frequencies of correct solutions after the uninformed and informed problem solving trials for the eight condition groups are listed in Table 2 (page 110). Simple chi square statistics were used to compute between group differences in terms of the dependent variables, unless otherwise indicated. Although between groups differences are suggested for the uninformed problem solving dependent variable, these differences were not predicted by experimental hypotheses and were not significant (Chi Square = 7.0538, $p = .42365$). The highest frequency of correct solutions was demonstrated by Groups 4 and 5 - two groups differing with respect to each of three manipulated independent variables. Given the absence of predicted differences among the condition groups, it was not surprising that the three main effects were found to be insignificant across uninformed and informed problem solving conditions.

Table 2

Frequency of 'Attack-Dispersion' Solutions By Group

		Group	Uninformed (Trial 1)	Informed (Trial 2)
SIMILAR TASK GROUPS	Interesting Version of Problem	No Incen. (*Group 1*, n = 20)	11 (55%)	17 (85%)
		Incentive (*Group 2*, n = 20)	12 (60%)	17 (85%)
	Dull Version of Problem	No Incen. (*Group 3*, n = 20)	8 (40%)	17 (85%)
		Incentive (*Group 4*, n = 21)	14 (66%)	17 (81%)
DISSIMILAR TASK GROUPS	Interesting Version of Problem	No Incen. (*Group 5*, n = 21)	14 (66%)	21 (100%)
		Incentive (*Group 6*, n = 21)	10 (48%)	20 (95%)
	Dull Version of Problem	No Incen. (*Group 7*, n = 21)	11 (52%)	20 (95%)
		Incentive (*Group 8*, n = 21)	8 (38%)	16 (76%)

Main Effects

No difference was found between the frequency of correct solutions generated by subjects in Groups 1 - 4 (Similar Task Groups) and Groups 5 - 8 (Dissimilar Task Groups) during the uninformed problem solving trial (Chi Square = .16466, p = .6849) and informed problem solving trial (Chi Square = 1.63738, p =.2007). This finding held when the uninformed and informed problem solving results were analyzed together as a single dependent variable. That is, in addition to examining the uninformed and informed problem solving data separately (with an incorrect response coded "0" and a correct response coded "1"), the dependent variable data were organized into one variable in the following manner: Subjects who failed to solve the problem correctly across both the uninformed and informed problem solving trials were assigned a "0", subjects who solved the problem during the first (uninformed) trial were assigned a "1", subjects who solved the problem correctly only during the second (informed) trial were assigned a "2". With the data organized in this manner, the results still indicated the absence of a main effect for task similarity (Chi Square = 3.91501, p = .1412). *This finding is important, in that it demonstrates that a dissimilar task can be as effective as a similar task in producing spontaneous analogical transfer.*

No difference was found between groups administered the 'interesting' version of the radiation problem (Groups 1, 2,

5, & 6) and groups administered the 'dull' version (Groups 3, 4, 7, & 8) with regard to the frequency of correct solutions generated during the uninformed problem solving trial (Chi Square = .74559, p = .3879) or informed problem solving trial (Chi Square = 1.35433, p = .2445). No main effect for this variable was indicated with the uninformed and informed problem solving dependent variables combined into one dependent variable as described above (Chi Square = 2.2206, p = .3295).

As with the other two manipulated independent variables, no significant difference was indicated between groups offered the financial incentive for accurate problem solving across uninformed problem solving (Chi Square = .00693, p = .9337) and informed problem solving trials (Chi Square = 1.35433, p = .2445). No effect for 'problem interestingness' was indicated with the two dependent variables combined into one dependent variable (Chi Square = 2.23262, p = .3275).

Interaction Effects

Applying a hierarchical log linear model to analyze the data, no interaction effects were indicated between the task similarity, topic interest/text-based interest, and extrinsic incentive variables in terms of frequency of correct solutions during the uninformed problem solving trial (Likelihood Ratio Chi Square = 7.15636, p = .786). Similar results were obtained for the informed problem

solving (Likelihood Ratio Chi Square = 11.59512, p = .395) and combined uninformed/informed problem solving dependent variables (Likelihood Ratio Chi Square = 19.73933, p = .348). Based upon this findings, it can be concluded that no relationship existed between the three manipulated independent variables (task similarity, topic interest/text-based interest, and extrinsic incentive) and the frequency of correct solutions generated to the radiation problem during the uninformed and informed problem solving trials.

Influence of the Continuous Subject Variables

In order to determine whether subjects who possessed higher levels of task interest were more successful in solving the radiation problem than subjects possessing lower levels of task interest, the sample was divided into two groups based upon task interest score. It will be recalled that the first page of the task interest/science interest survey asked subjects to rate their interest in solving a problem like the radiation problem (The Two String Problem) on a 10-point likert scale. After an examination of the frequency distribution for this variable, the data were recoded applying a median split. No difference was found between the frequency of correct solutions developed by the two groups during the first (uninformed) problem solving trial (Chi Square = 1.507, p = .21953). A difference approaching significance was found between the frequency of correct solutions developed during the second (informed)

problem solving trial (Chi Square = 3.477, p = .06220). Subjects with higher task interest were more likely to eventually arrive at the correct solution to the radiation problem than subjects with low task interest. The comparatively small effect is lost, however, when the two dependent variables are combined into one dependent variable as described on page 111 (Chi Square = 3.756, p = .15261). The influence of science interest (topic interest) on problem solving was determined by dividing the sample into two groups based upon their science interest score. The science interest survey used to determine each subject's science interest scores was comprised of six 10-point likert type items. Each subject's score was determined by summing the responses to the six items. The lowest possible score was six and the highest possible score was 60. Based upon a median split, subjects were divided into low and high interest groups. No difference was found between the frequency of correct solutions developed by the two groups during the uninformed problem solving trial (Chi Square = .08523, p = .77033) or informed problem solving trial (Chi Square = .10160, p = .74992). Combining the two dependent variables into one variable also did not yield a significant result (Chi Square = .30951, p = .85663).

The problem solving of subjects exhibiting both high task interest and high science interest was compared with that of subjects exhibiting lower scores on these variables

across the two problem solving stages. No difference was found between the high task interest/high science interest group and low task interest/lower science interest group during the uninformed trial (Chi Square = .03430, p = .8531) and informed problem solving trial (Chi Square = .58452, p = .6743). Again, combining the dependent variables into one variable had no significant effect on the results (Chi Square = 1.0323, p = .5958).

Subjects were also divided by high and low scores on the continuous variables measured after the experiment: post-experiment interest and post-experiment motivation. A difference approaching significance was found between subjects who rated the radiation problem "very interesting" and those who rated the problem less interesting in terms of frequency of correct solutions during the uninformed problem solving trial (Chi Square = 2.9290, p = .0800). That is, subjects who rated the problem as "very interesting" (8 to 10 on the 10-point likert scale) were more likely to correctly solve the problem during the uninformed problem solving trial than subjects who rated the problem less interesting. No difference was found when the number of correct solutions were counted after the informed problem solving trial (Chi Square = .14216, p = .70615). The difference was also insignificant with the two dependent variables combined into one dependent variable (Chi Square = .42516, p = .11918).

Scores on the post-experiment motivation rating were also found to be unrelated to solutions to the radiation problem across the two problem solving trials. For the uninformed problem solving trial, no difference was found between the frequency of correct solutions generated by subjects who expressed a high level of motivation to solve the problem and those who expressed lower motivation to solve the problem (Chi Square = 2.1710, p = .14063). The difference between the groups was also not significant for the informed problem solving trial (Chi Square = .54474, p = .46462) or when with the two dependent variables combined (Chi Square = .42274, p = .12076).

Subjects were instructed to note their grade point averages (GPA) in order to check the percentage of high achieving students in each group. As discussed in greater detail below, the randomly formed groups ended up being evenly balanced in terms of grade point average. It was anticipated that when grade point average was examined apart from the other factors in the experiment, it would be found to have a significant impact on the frequency of correct solutions across the two problem stages. This prediction was not supported by the findings. No difference was found between subjects with an "A" average (90 - 100) and those with GPA's below 90 in terms of frequency of correct solutions during the uninformed trial (Chi Square = 1.89134, p = .16905) and informed trial (Chi Square = 1.37525, p =

.24091). The between groups difference with the two dependent variables considered together was also not significant (Chi Square = 2.35757, p = .30765).

Finally, it also merits noting that no effect was indicated for gender across the uninformed, informed, and combined problem solving dependent variables. The gender effects and significance levels for the three dependent variables are listed in Table 3 below:

Table 3

Gender Effects Across Problem Solving Trials

PROBLEM SOLVING TRIAL	CHI SQUARE	SIGNIFICANCE
Uninformed Problem Solving (Trial One)	.21083	.6461
Informed Problem Solving (Trial Two)	.01030	.9191
Combined into One Dependent Variable	.210858	.8965

Between Group Differences: Continuous Variables

Analysis of variance statistics were applied to determine whether significant between group differences could be determined for any of the five continuous variables measured over the course of the experiment (grade point average, task interest, science interest, post-experiment interest, and post-experiment motivation. Given that the sample was comprised largely of high achieving students and that groups were formed randomly, the absence of difference (F = .7665, p = .6170) between the mean GPA scores of the

groups was not surprising. Table 4 (page 119) lists the mean task interest and science interest score for each group as well as the standard deviation score for these variables. No difference was found between the eight groups with regard to task interest (F = .4834, p = .8456) or science interest (F = .9564, p = .4651).

Table 5 (page 120) lists the mean post-experiment interest and post-experiment motivation score for the eight groups. Counter to predictions, no difference was found between the groups with regard to post-experiment interest (F = .5542, p = .7920) or post-experiment motivation (F = .4989, p = .8343). It was hypothesized that subjects administered the "interesting" version of the radiation problem would be more likely to rate the problem "very interesting" than subjects administered the "dull" version. It was also predicted that subjects offered a financial incentive for accurate problem solving would rate themselves as more motivated to solve the problem than subjects offered no incentive for problem solving. The findings support neither of these hypotheses. Indeed, a review of the mean scores for the two variables indicates only a small amount of between group variance, suggesting that the manipulated interest and incentive variables had no real influence on subjects' interest in the problem or motivation to solve the problem.

Table 4

Task Interest and Science Interest Ratings by Group

			Task Interest		Sci. Interest	
		Group Number	Mean	Std. Dev.	Mean	Std. Dev.
SIMILAR TASK GROUPS	Interesting Version of Problem	No Incen. (*Group 1*, n = 20)	7.75	1.88	48.35	6.65
		Incentive (*Group 2*, n = 20)	7.95	1.73	48.75	7.13
	Dull Version of Problem	No Incen. (*Group 3*, n = 20)	7.25	1.92	49.05	5.44
		Incentive (*Group 4*, n = 21)	7.14	2.61	49.33	8.00
DISSIM. TASK GROUPS	Interesting Version of Problem	No Incen. (*Group 5*, n = 21)	7.04	1.93	46.71	8.87
		Incentive (*Group 6*, n = 21)	7.71	2.10	45.81	9.78
	Dull Version of Problem	No Incen. (*Group 7*, n = 21)	7.38	1.95	49.28	7.24
		Incentive (*Group 8*, n = 21)	7.38	2.42	45.00	9.32

Table 5

Post-Experiment Interest and Motivation by Group

			Post-Exper. Interest		Post-Exper. Motivation	
		Group Number	Mean	Std. Dev.	Mean	Std. Dev.
SIMILAR TASK GROUPS	Interesting Version of Problem	No Incen. (*Group 1*, n = 20)	6.80	1.79	7.70	2.05
		Incentive (*Group 2*, n = 20)	7.45	2.26	7.80	1.98
	Dull Version of Problem	No Incen. (*Group 3*, n = 20)	7.25	1.86	7.35	1.63
		Incentive (*Group 4*, n = 21)	7.57	1.94	7.95	1.77
DISSIM. TASK GROUPS	Interesting Version of Problem	No Incen. (*Group 5*, n = 21)	7.14	1.99	7.43	1.28
		Incentive (*Group 6*, n = 21)	7.47	1.66	7.09	2.25
	Dull Version of Problem	No Incen. (*Group 7*, n = 21)	7.76	1.75	7.76	1.89
		Incentive (*Group 8*, n = 21)	7.57	1.36	7.76	1.32

Recoding of the data into two groups along the "Topic Interest/Text-Based Interest" dimension (subjects administered the 'interesting' version of the problem were compared to those who received the 'dull' version) offered further evidence of the lack of impact of this variable on subject's post-experiment interest and motivation ratings. The mean interest score for subjects administered the 'dull' version of the radiation problem (7.54) was actually slightly higher than that of students administered the 'interesting' version. This difference, however, was not significant (F = 1.2947, p = .2569). The mean post-experiment motivation score of students administered the dull version was also slightly higher than that of subjects receiving the 'interesting' version. Again, however, the difference was not significant (F = .3941, p = .5310). Based upon these findings, it can be concluded that the 'interesting' and 'dull' versions of the problem were equally motivating and were perceived to be equally interesting. This finding is inconsistent with pilot test results which indicated that the "interesting" version was more likely to be rated interesting than the "dull" version. It merits noting, however, that the pilot study data were conducted with a sample of average achieving students whose interest in the two versions of the problem may have been more easily influenced by situational variables.

With the data recoded into two groups along the

financial incentive dimension (subjects offered a financial incentive compared to those not offered the incentive), no difference was found between the groups with regard to post-experiment interest (F = .9327, p = .3356) or post-experiment motivation (F = .0369, p = .8480). The tiny F ratio reflecting the post-experiment motivation relationship is particularly striking in that it suggests that the financial incentive had no impact (positive or negative) on subjects' motivation to solve the problem.

Data Summary

The data analyses reported to this point can be summarized as follows: There was no relationship between any of the three manipulated independent variables and the two dependent variables (considered separately or as one combined dependent variable). Significant interaction effects were also not obtained. The difference between subjects expressing high task interest and lower levels of task interest approached significance with respect to frequency of correct solutions generated during the uninformed problem solving phase. Subjects expressing higher levels of post-experiment interest in the problem were more likely than those expressing lower levels of interest to eventually solve the problem; however, this difference also did not meet the criteria for statistical significance. All other analyses which examined the influence of subject variables on the dependent variables were far from

significant. The eight condition groups were found not to differ with regard to grade point average, task interest, science interest, post-experiment interest, and post-experiment motivation. Subjects administered the "interesting" version of the problem rated it no more interesting than subjects administered the "dull" version. The offer of a financial incentive was found to have no influence on subject's reported motivation to solve the problem.

How Did Successful Problem Solvers Differ From Unsuccessful Problem Solvers?

Since the manipulated independent variables were found to have no influence on frequency of solutions to the radiation problem, attempts were made to determine how subjects who successfully solved the problem differed from those who were unable to solve the problem with respect to the continuous subject variables. That is, attempts were made to distinguish successful problem solvers from the unsuccessful problem solvers in terms of the continuous variables measured by the task interest/science survey and the post-experiment survey. Questions to be addressed included the following: Did subjects who solved the problem during the uninformed problem solving trial demonstrate higher levels of task interest or science interest? Did successful problem solvers differ from the unsuccessful problem solvers in terms of post-experiment interest, post-

experiment motivation, or grade point average?

The most direct method of determining how subjects who solved the problem differed from those who did not would have been to conduct a discriminant analysis. Unfortunately, the appropriate use of this statistical technique requires that all continuous variables included in the analysis be normally distributed. As was discussed earlier, the distributions for task interest, science interest, post-experiment interest, and post-experiment motivation were all skewed towards the higher end of the distribution, preventing the application of discriminant analysis. Consequently, more robust methods (t-test and ANOVA) were used to examine the difference between successful and unsuccessful problem solvers for each continuous subject variable.

Table 6 (page 126) presents the mean and standard deviation scores for the continuous subject variables when the data were divided into two groups: subjects who solved the problem correctly during the uninformed problem solving stage (successful group) and those who did not (unsuccessful group). The t values and significance levels reflecting the difference between the two groups for each subject variable are also listed. It will be noted that the only subject variable for which there is a significant difference between successful and unsuccessful problem solvers is 'post experiment interest.' Surprisingly, subjects who were unable

to arrive at the correct solution during the uninformed problem solving trial demonstrated a higher level of post-experiment interest in the radiation problem than subjects who successfully solved the problem. The difference between the groups becomes more dramatic when task interest, science interest, and grade point average are used as covariates ($F = 8.278$, $p = .005$). One logical explanation for greater post-experiment interest exhibited by unsuccessful problem solvers is that subjects who were unable to solve the problem during the first problem solving trial were more intrigued by the problem than subjects who solved it correctly (without being explicitly told of its connection to the story analogies). Subjects who solved the problem during the uninformed trial may have subsequently viewed the problem as "easy" and therefore less interesting than subjects stumped by the problem during Trial 1.

The use of task interest, science interest, and grade point average as covariates also increased the difference between successful and unsuccessful problem solvers with regard to post-experiment motivation. Without controlling for these variables, the between groups difference, as reflected in Table 6, is quite small ($t = 1.47$, $p = .144$). With the three variables included in the analysis as covariates, however, the difference between successful and unsuccessful problem solvers becomes significant ($F = 4.401$, $p = .037$). Thus, when adjustments are made for between

Table 6

Continuous Subject Variable Ratings for Successful and Unsuccessful Problem Solvers During the Uninformed Problem Solving Trial

	Successful Group (n = 88)		Unsuccessful Group (n = 77)			
SUBJECT VARIABLE	MEAN	STD. DEV.	MEAN	STD. DEV.	t value	p value
Task Interest	7.6250	1.828	7.2388	2.311	-1.21	.227
Science Interest	48.2273	7.853	47.2468	8.071	- .79	.431
Post Exper Interest	7.0682	1.940	7.7403	1.617	2.40	.018
Post Exper Motivation	7.3977	1.823	7.8052	1.725	1.47	.144
G.P.A.	90.7841	4.159	89.5974	4.250	-1.81	.068

subject differences on the aforementioned subject variables, unsuccessful problem solvers also described themselves as more motivated to solve the radiation problem than successful problem solvers.

Table 7 (page 128) presents the differences between subjects who were able to solve the problem by the end of the second (informed) problem solving trial and those who were not (unsuccessful group) in terms of the continuous subject variables. Although, as the table illustrates, no significant between group differences were indicated, the difference between the groups with regard to task interest approached significance ($p = .068$). Subjects who were eventually able to solve the problem (either during the uninformed or informed problem solving trial) demonstrated higher levels of task interest (as measured by the Task Interest/Science Interest Survey) than subjects who never solved the radiation problem.

Table 8 (page 128) displays the between group differences with the two dependent variables combined into one dependent variable. The between group differences with regard to task interest ($F = 1.826$, $p = .1643$), science interest ($F = .3436$, $p = .7098$), grade point average ($F = 1.7872$, $p = .1707$), and post-experiment motivation ($F = 1.479$, $p = .2318$) were all well below significance. A significant between groups difference ($F = 3.014$, $p = .0502$) was indicated, however, with regard to post-experiment

Table 7

Continuous Subject Variable Ratings for Successful and Unsuccessful Problem Solvers During the Informed Problem Solving Trial

	Successful Group (n = 145)		Unsuccessful Group (n = 20)			
SUBJECT VARIABLE	MEAN	STD. DEV.	MEAN	STD. DEV.	t value	p value
Task Interest	7.5517	1.993	6.6500	2.477	-1.84	.068
Science Interest	47.8966	7.942	46.8500	8.119	- .55	.582
Post-Exper Interest	7.3586	1.855	7.5500	1.605	.44	.661
Post-Exper Motivation	7.6000	1.808	7.5000	1.638	- .23	.815
G. P. A.	90.2552	4.236	90.0500	4.298	- .20	.840

Table 8

Continuous Subject Variable Ratings for Successful and Unsuccessful Problem Solvers (Combined Dependent Variable)

	No Solution (n = 20)		Informed Solution (n = 57)		Uninformed Solution (n = 88)	
SUBJECT VARIABLE	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.
Task Interest	6.650	2.476	7.438	2.236	7.625	1.827
Science Interest	46.850	8.119	47.386	8.121	48.227	7.853
Post-Exper. Interest	7.550	1.695	7.807	1.630	7.068	1.940
Post-Exper. Motivation	7.500	1.638	7.912	1.755	7.397	1.822
Grade Point Average	90.050	4.297	89.438	4.327	90.784	4.159

interest.

Post hoc analysis of the group means (Tukey-HSD Procedure) indicated that the significant difference was found between subjects who solved the problem only during Trial 2 and subjects who solved the problem during the Trial 1. This finding supports the contention that failure to solve the problem during the uninformed problem solving trial led to increased interest in the problem. Subjects who solved the problem during Trial 1 actually rated the problem less interesting than subjects who never solved the problem, suggesting that quick solution of the problem diminished its "interestingness." With task interest, science interest, and grade point average used as covariates, the difference between the three groups in terms of post-experiment interest becomes even more striking ($F = 4.115$, $p = .018$).

Schema Quality and Correct Solutions

The analyses discussed above suggest that subjects unsuccessful at solving the problem during the uninformed problem solving stage expressed significantly greater interest in the radiation problem after the experiment than successful problem solvers. Although this finding is intriguing in that it suggests that initial failure can increase interest in a problem solving task, the results discussed to this point have yet to adequately explain the differences between successful and unsuccessful problem solvers. A difference approaching significance ($p = .068$)

was indicated between the task interest of subjects who solved the problem by the conclusion of the informed problem solving phase and those who did not; however, this finding sheds no light on how subjects who solved the problem during the first (uninformed) problem solving trial differed from those who did not. At this point in the analyses, then, an adequate profile of the successful problem solver has yet to be established.

A well-replicated finding in the spontaneous transfer literature is that transfer is more like likely to occur when subjects possess a strong conceptual understanding of the strategy to be transferred (Bromage & Mayer, 1981; Case & McKeough, 1990; Means & Gott, 1988; Tenney & Kurland, 1988; Gagne, Yekovich, & Yekovich, 1992). Gick & Holyoak (1983) offered perhaps the most concrete example of the importance of conceptual understanding to the transfer process by demonstrating that subjects who acquire a high quality schema of the strategy during the acquisition phase are most likely to apply that strategy when presented with a novel problem set in another context. Given the absence of significant effects for the motivational variables used in this experiment, Gick and Holyoak's methods of analyzing the schema's induced by subjects were applied to determine if "schema quality" had a significant effect on the production of correct solutions during the different problem solving phases of the experiment.

It will be recalled that subjects in the dissimilar task conditions were instructed to memorize the two story analogs (*Brilliant General* and *Red Addair*) and to then summarize the similarities between the stories placing particular emphasis upon the solutions developed by the protagonists. Subjects in the similar task conditions were asked to memorize only the first story analog (*Brilliant General*) and were then instructed to write an ending to the second analog (*Red Addair*). The purpose of these acquisition phase tasks was to enable subjects to induce the "attack-dispersion" strategy (schema). For this analysis, subjects' acquisition phase writings (both task similar and task dissimilar) were divided into three levels of schema quality using the following criteria developed by Gick and Holyoak (1983):

> In order for a description to qualify as a "good" schema, the basic idea of having forces converge from different directions had to be present either explicitly or as an inference. (The idea of using different directions was inferred if the subject mentioned the simultaneous use of multiple forces). In addition, at least one other major aspect of the analogy had to be expressed: either the use of multiple small forces or the parallels in the initial problem situations (e.g., centrally located targets). An "intermediate" schema contained only one of these major

> features. "Poor" schemas contained none of the basic aspects of the convergence principle. They usually alluded to a similarity between the solutions that was abstract to the point of vacuity (e.g., "In both stories a problem was solved using logical means") or did not focus on the problem solving aspects of the story at all (Gick & Holyoak, 1983, p. 23).

Table 9 (133) displays the percentage of subjects producing the 'attack-dispersion solution across both problem solving phases as a function of schema quality. The marked discrepancy between subjects who induced good schemas and those who induced schema's in terms of frequency of correct solutions is readily apparent. The impact of schema quality on spontaneous transfer (Trial 1) is perhaps most dramatic. Over 63% of subjects who produced a good schema were able to solve the radiation problem without any type of hint, as compared to only 33.3% of subjects who produced intermediate quality schemas and 14.% of subjects who produced schemas of poor quality. Not surprisingly, the difference between the three groups (good, intermediate, poor) with regard to frequency of correct solutions during the uninformed problem solving trial was significant (Chi Square = 15.17468, p = .00010).

Table 9

Percentage of Subjects Producing the Convergence Solution During Each Problem Solving Trial as a Function of Schema Quality

SCHEMA QUALITY	UNINFORMED PROB SOLV (Trial 1)	INFORMED PROB SOLV (Trial 2)	NEVER SOLVED	N
Good	63.4 (71)	93.8 (105)	6.2 (7)	112
Intermediate	33.3 (15)	75.6 (34)	24.4 (11)	45
Poor	14.1 (1)	71.4 (5)	28.6 (2)	7

Note: Frequencies are given in parentheses.

The difference between three schema quality groups with regard to frequency of correct solutions during the informed problem solving trial (Trial 2) is also significant (Chi Square = 11.65937, p = .00064), which suggests that schema quality was a determining factor in whether subjects were able to produce the 'attack-dispersion' solution with a hint. Although the between group differences reflected in Table 9 are clearly significant, the findings are less dramatic than those of Gick and Holyoak (1983, Experiment 4) who found that 100% of subjects inducing good quality schemas were able to produce the correct solution during their informed problem solving phase.

The schema quality effect also carried over to the informed problem solving phase. That is, 72.9% of subjects who produced a "good" quality schema were able to solve the problem by the informed problem solving trial, whereas only

27.1% of subjects who produced schemas of less than "good" quality were able to do so. With the two dependent variables (Trial 1 and Trial 2) combined into one dependent variable, schema quality was found to have an even more powerful influence on problem solving (Chi Square = 19.32885, p = .00006). These findings appear to leave little doubt that the variable that most clearly distinguished successful from unsuccessful problem solvers was schema quality.

Interestingly, the task similarity variable had no significant impact upon the quality of the schemas produced by subjects (Chi Square = 1.345, p = .4423). Specifically, 73.9% of subjects in the similar task conditions produced "good" quality schemas as compared to 69% of subjects in the dissimilar task conditions. The absence of a schema quality difference between subjects presented with similar task acquisition phase materials and those administered dissimilar task materials may shed light on the reportedly small task similarity effect (Chi Square = .16466, p = .6849). A task similarity effect would only have been produced if a significant difference was indicated between the quality of schemas produced by the different acquisition phase tasks.

Another interesting finding related to the schema variable is its influence on post-experiment interest ratings. Subjects who produced a "good" quality schema were less likely than those who produced lesser quality schema's

to describe the radiation problem as interesting on the post-experiment survey (F = 8.3123, p = .0045). This finding offers further support for the contention that subjects who had a fairly easy time understanding the attack-dispersion strategy and applying it to the radiation problem described the problem as less interesting than subjects who found the whole process more challenging.

Inter-Rater Reliability

Each subjects's solutions to the radiation problem were scored by two trained judges. An inter-rater reliability coefficient of .96 was computed, indicating the ratings of the judges were in strong agreement. As noted earlier, the internal consistency reliability of the science interest portion of the Task Interest/Science Interest Survey was established using both Cronbach's Alpha and Guttman's Split Half Reliability. Alpha was equal to .8522 and the split half coefficient equal to .8475.

CHAPTER V

DISCUSSION

A primary purpose of this study was to examine the influence of intrinsic and extrinsic motivational variables on subjects' access to previously learned information ('inert knowledge') when presented with a seemingly novel problem solving task. It was predicted that interest variables (i.e., topic interest, task interest, text-based interest) would have a facilitating effect on analogical transfer and that the offer of a financial incentive for accurate problem solving would also increase the frequency of correct solutions to the radiation problem.

The results offer little support for the contention that the motivational variables examined in this experiment have any significant bearing on spontaneous transfer. Neither the "interestingness" of the problem presented during the problem solving trials or the presence/absence of a monetary incentive was found to have an impact on the production of 'attack-dispersion' solutions. Task interest and topic interest (science interest) were also found to be of little importance to the problem solving process. Although subjects with high task interest were more likely to eventually solve the radiation problem (by the end of Trial 2) than those with lower task interest, this difference only approached significance. This task interest effect was produced by a comparison of groups of markedly

divergent size (145 of the 165 subjects in the sample solved the problem by the end of Trial 2), diminishing its importance.

The only significant finding with regard to the motivational variables was that subjects who failed to solve the problem during Trial 1 demonstrated higher post-experiment interest in the radiation problem than subjects who solved the problem during Trial 1. This finding is important in that it offers some of the first empirical support for Deci's (1992) contention that people will rate as most interesting tasks that presented them with an optimal level of challenge (page 159 presents a more detailed discussion of this issue). This finding has little significance, however, to the basic hypothesis tested by this experiment: greater interest/motivation facilitates problem solving.

In examining the reasons for the discrepancy between the findings of this experiment and the numerous studies which found a significant influence of interest on cognitive performance variables, the most logical place to start is with the types of cognitive tasks used in the different studies. With a few notable exceptions (i.e., Renninger, 1984, 1989, 1990, 1991; Tobias, 1992), most studies to examine the influence of interest on cognitive performance have used some aspect of text comprehension as the cognitive performance variable. Generally, these studies have examined

the impact of individual or text-based interest on the number of words correctly recognized or remembered, and/or the type and quality of answers given to content-related questions (Krapp, Hidi, & Renninger, 1992). Varying from this pattern, the present investigation considered the impact of interest variables on a heuristic problem solving task - a task that required subjects to recognize the analogies between acquisition and problem solving materials in order to solve the problem. Recent research regarding the manner in which interest influences text comprehension suggests that greater selective attention is directed towards material perceived to be interesting (Shirey, 1992; Wade, 1992, 1993). Other interest research has indicated that subjects experience pleasant emotions and are more likely to develop vivid visual images when reading interesting passages (Anderson & Kulhavey, 1972; Levin, 1981; Saks, 1988). It can be hypothesized, then, that text comprehension tasks are sensitive to interest effects because interest has a strong impact on selective attention and the use of imagery (two factors strongly associated with good comprehension).

Although selective attention and imagery may play a role in the solving of heuristic puzzles in that the successful problem solver must become mindful of all details of the problem, the difficulty of heuristic puzzles compel the reader to closely attend to all details regardless of

the "interestingness" of the details. That is, if individuals makes a genuine effort to solve a problem like the radiation problem, they are likely to pay close attention to all aspects of the problem, even if it has been adapted to be experienced as dull. The other aspects of the problem solving process (i.e., iterations required to search the problem space for potential solutions) can theoretically be influenced by intrinsic motivation; however, empirical evidence has yet to be obtained which demonstrates that intrinsic motivational variables can impact variables like effort, concentration, and searches through the problem space (Hidi, 1990). In summary, while interest variables consistently influence text comprehension probably as a result of their effect on attention, selective attention seems to play a smaller role in the solving of complex riddles like the radiation problem, making these problems less 'sensitive' to interest effects.

Unlike performance on reading comprehension tasks, which may be contingent upon processing variables like selective attention and working memory, performance on more complex problem solving tasks may rely on deeper cognitive processes (i.e., iterative searches of the problem space) that may not be influenced by motivation in experiments of short duration. As discussed by Tobias (1993), intrinsic motivational variables may exert an influence on problem solving by affecting the degree of sustained effort and

sustained concentration applied to searches for solutions. In order for variance in sustained effort to have a significant effect on the problem solving process, the duration of the problem solving phase of experiments must be long enough to allow the motivational variables to influence effort and thereby influence the quality and accuracy of cognitive performance.

Like virtually all its predecessors, the present investigation was quite limited in duration. Indeed, subjects were only exposed to the problem solving phase materials (the materials in which the interest variables were manipulated) for a total of 15 minutes. Although, as was noted above, brief exposure to interesting materials may exert a significant influence on processing variables like selective attention, it is unlikely that the 15 minute problem solving period was long enough to allow variables like sustained effort and concentration to significantly influence the results. Consequently, only schema quality, a structural variables demonstrated to have a rapid influence on spontaneous transfer (Gick & Holyoak, 1983), was found by this experiment to have an impact on problem solving performance.

Roe's (1951) seminal studies on the distinction between experts and novices support the supposition that the experiment's short duration contributed to the absence of significant effect for motivational variables. Briefly, Roe

Roe conducted detailed psychological studies of eminent physical scientists in an attempt to determine the manner in which these experts differed from graduate students in the same field with regard to a range of personal variables. Roe found no difference between the experts and novices in terms of cognitive variables like intelligence and creativity; however, the scientists were found to expend considerably more effort when solving problems within their domain of interest than the students. In other words, the primary characteristic which distinguished the experts from the 'garden variety' graduate student was the amount (and duration) of labor directed towards domain-specific problem solving. These findings suggest that problem solving research conducted over longer periods of time (i.e., weeks or months) may be more likely to find significant effects for intrinsic motivational variables, given that individuals with a great interest in a topic or task may devote more sustained effort than less interested individuals.

Other variables that may have diminished the likelihood of achieving effects for interest in this experiment relate to the subject population. The sample was made up entirely of secondary school students enrolled in at least one "advanced placement" science class. Despite taking challenging courses, most subjects had a grade point averages in the "B+" to "A+" range and could be accurately labeled 'high achieving.' Such students may have invested

considerable effort to solve the radiation problem regardless of personal or text-based interest factors because it is their custom to apply effort to all tasks. The high achieving students may also have been less likely than average or low achieving students to have been 'put off' by the tedious technical descriptions included in the "dull" version of the radiation problem (Wade et al., 1993). The absence of between group differences in terms grade point average and interest ratings suggests that high achieving subjects like those used in this study tend to vary little with regard to interest in heuristic problem solving tasks. The finding of no difference between the "interesting" and "dull" versions of the problem on the post-experiment interest ratings offers support for this supposition. That significant inter-correlations were found between task interest, science interest, post-experiment interest, and post-experiment motivation only further suggests that participants tended to view most cognitive tasks as interesting and motivating (Table 10, found in Appendix A, lists all correlations among the continuous variables). The inclusion of lower ability subjects in the study would have resulted in greater between group variance with regard to interest variables, which may produced significant interest effects.

It is also possible that the manner in which interest was defined in this study limited the prospect of

significant interest effects. Researchers distinguish between three types of interest that may have bearing on the manner in which individuals engage in tasks: (1) individual interest as a disposition; (2) 'interestingness' of the learning environment (situational interest); and, (3) actualized interest within the person (Krapp, Hidi, & Renninger, 1992). The distinction between the first two types of interest has been addressed in earlier sections of this document (see page 64). The third type of interest, commonly referred to in the interest literature as "actualized interest," can be distinguished from dispositional interest in that it refers to heightened interest as a transient psychological state. According to Hidi and Baird (1988), process-oriented theories of interest propose that actualized interest arises out of an interaction between internal conditions (i.e., dispositional interest) and specific external factors (i.e., the presentation of materials which trigger dispositional interest). Actualized interest, then, may be best characterized as manifestations of dispositional interest that have been prompted, even if momentarily, by particular environmental conditions. This construct has been operationally defined in the interest literature as focused, prolonged attention to tasks and as reported feelings of pleasure and concentration (Krapp, Hidi, & Renninger, 1992).

The topic interest (science interest) survey employed

in this study was found to be a reliable measure of the construct "science interest." Using this instrument, the vast majority of subjects demonstrated comparatively high levels of dispositional interest in science. At no point, however, was subjects' actualized interest in the radiation problem measured. The post-experiment interest measure did ask subjects to rate how interesting they found the problem, but could not gauge the effort, concentration, or attention devoted to problem solving. It is possible that subjects who rated themselves as very interested in science and very interested in the radiation problem (based upon the post-experiment rating) may not have invested as much effort/concentration to solving the problem as subjects with lower science interest and post-experiment scores. More objective measures of effort expended (perhaps defined as timed devoted to problem solving) and concentration may have found a significant relationship between effort and problem solving accuracy.

Small Incentives and Cognitive Performance

The findings with regard to the influence of a monetary incentive on problem solving offer no support for McGraw's (1978) theory that incentives have a negative influence on cognitive performance. McGraw, building upon self-determination theories of motivation (Deci, 1975), postulated that the offer of an extrinsic incentive on an intrinsically interesting task (such a heuristic puzzles)

decreases feelings of self-determination, leading to diminished performance. Similar to the results of earlier studies by Tobias and Kaufman (Experiments I - IV, 1991), the results of the present investigation indicated no difference in the problem solving between subjects offered a financial incentive and those not offered an incentive. Of the six experiments to examine the influence of extrinsic incentives on the solving of heuristic puzzles (present investigation; McNeill and Kimmel, 1988; Tobias & Kaufman, 1991, Experiments I - IV), only the study conducted by McNeill and Kimmel found a dramatic difference favoring unrewarded subjects over those receiving no reward.

Considered together, the findings of the present investigation and those obtained by Tobias and Kaufman suggest that performance on heuristic puzzle tasks is not inhibited by the offer of incentives, failing to support McGraw's theory regarding the impact of incentives on intrinsically interesting tasks. Although, as Deci (1992) cites, empirical studies have demonstrated that people demonstrate greater cognitive flexibility (Benware & Deci, 1984) and creativity (Amabile, 1983) when experiencing self-determination, empirical research has yet to replicate McGraw's (1978) findings that the offer of small incentives has a detrimental effect on cognitive performance. The influence of larger, more dramatic incentives on cognitive performance remains to be indicated. It is possible, for

example, the offer of $50 for correct solutions would have exerted a more dramatic influence on problem solving than the $5 incentive used in this study.

Just as the 'high achieving' status of subjects in this study may have diminished the likelihood of obtaining significant effects for interest variables, it is tenable that the sample may have been less susceptible to the influence of a small monetary incentive than subjects of lower academic/cognitive ability. There is empirical basis for this speculation. Pollack (1989), for example, reported that children with Low Average IQ's were generally more responsive to small rewards for performance on academic tasks than children of greater cognitive ability. As noted earlier, replication of the present investigation using subjects of lower cognitive ability and/or socio economic status may produce more significant effects for both extrinsic and intrinsic motivational variables.

Task Similarity Versus Schema Quality

The finding of no difference between similar and dissimilar task condition groups in terms of frequency of correct solutions to the radiation problem casts new light on prevailing theories in the problem solving and transfer literatures. A range of studies demonstrated that spontaneous transfer is more likely to be obtained when the learner processes the acquisition (training) and transfer tasks in a similar manner, producing compatible responses to

both tasks (Adams et al., 1986; Bransford & Franks, 1976; Lockhart et al., 1987; Lund & Dominowski, 1985; Sherwood et al., 1987). Specifically, this research illustrated that information acquired in a 'problem-oriented' context is more likely to be spontaneously applied to novel problems than material acquired in 'fact-oriented' training settings. These findings are consistent with empirical generalizations developed decades earlier by Bruce (1933) and Wylie (1919), now commonly referred to in the transfer literature as the "Bruce-Wylie" law. Summarized, this law holds that the amount of transfer between two situations depends primarily upon the degree of similarity between the two situations (Gick & Holyoak, 1987). The "Bruce-Wylie law is consistent with an even earlier transfer theory of E. L. Thorndike (Thorndike & Woodworth, 1901), who proposed that transfer depends upon the presence of identical elements in the original task and the transfer task it facilitates (Bower & Hilgard, 1981). Although the findings of the present investigation do not contradict the Bruce-Wylie law or Thorndike's law of identical elements, the results obtained with respect to the task similarity and schema quality suggest that schema quality is clearly an important variable in strategy transfer. In some situations, the determining factor in whether prior knowledge is applied to a novel problem solving context may be the quality of subjects' conceptual understanding of information acquired during the

original learning task - not the degree of similarity between the original and transfer tasks.

A key factor in this study's failure to find the task similarity effect obtained by its predecessors may be the different tasks administered to "dissimilar task" groups. Unlike the investigations of the task similarity effect cited above, the present investigation did not compare a 'problem-oriented' training condition to a 'fact-oriented' training condition (i.e., the memorization of facts or strategies). Rather, subjects in the "dissimilar task" conditions were asked to summarize the similarities between two story analogies, placing emphasis upon the analogous solutions developed by the protagonists. Viewed along these lines, the present investigation can be considered the first to draw a fair comparison of similar task and dissimilar task conditions, because performance of subjects in the "similar task" (problem-oriented) conditions was compared to that of subjects exposed to a dissimilar training task involving more than rote memorization of salient information. Since no difference was found between the frequency of correct solutions generated by subjects in the task similar and dissimilar task conditions, it can be concluded that the task similarity effect will only be obtained when subjects in comparison groups are processing information in a rote memory ('fact-oriented') context. When comparison subjects are engaged in a task that is equally

efficient in inducing good quality schemas, the superiority of problem-oriented (structurally similar) acquisition tasks is eliminated.

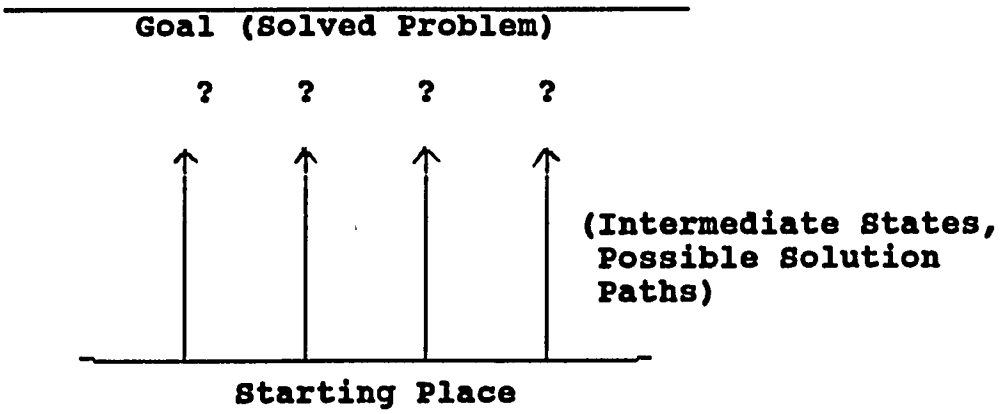
The findings with regard to the relative importance of schema quality and task similarity on transfer would seem to be of considerable importance, given the significance attributed to the task similarity effect in instructional models developed in recent years by authors of the earlier spontaneous transfer research (Bransford, Franks, Vye, & Sherwood, 1989; Cognition and Technology Group at Vanderbilt, 1992). Although information acquired via a problem-oriented training task is clearly more likely to be applied to novel problem solving contexts than material acquired through a fact-oriented presentation, the results of the present investigation suggest that the most effective forms of instruction are those which provide learners with a strong conceptual understanding of salient information.

How does the quality conceptual understanding of information influence searches of the problem space when individuals are asked to solve novel problems? In answering this question, it is first necessary to define what information processing theorists mean when they refer to a "problem space." According to Gagne, Yekovich, and Yekovich (1993), the standard information processing framework for defining problems consists of: (1) a goal or end state, (2) an initial or starting state which is given description of

the problem, and (3) a number of intermediate states, which describe all possible solution paths to the problem. Each solution path is comprised of a number of individual steps that move one away from the starting state toward the goal state. Together, the initial, intermediate, and goal states comprise what Newell and Simon (1972) first identified as the "problem space." Inspired by graphic illustrations developed by Gagne et al. (1993), Figure 3 presents the type of problem space developed when individuals are asked to solve novel heuristic problems.

Figure 3

Problem Space for Novel Heuristic Problem



There are some starting points and a defined goal as an e|d state, but no known path to arrive at the goal state. The individual can identify some possible pathways to the solution, but has no assurance that the paths attempted will lead to the solution.

When presented with heuristic problems like Duncker's radiation problem, the solver first forms a representation of the problem which consists of information active in

working memory (the 'givens' of the problem) as well as all relevant knowledge that can be activated from long-term memory. The activation of relevant information, strategies, approaches in long-term memory that is commonly referred to as "searching the problem space." That is, solvers probe their working and long-term memories for material that will aid them in solving the problem, continually selecting and evaluating each new bit of information to see if it brings them closer to the goal state (solution of the problem). These iterations or cycles of selection and testing of stored information continue until a problem is solved or the solver abandons the task (Gagne et al., 1993; Gray & Orasanu, 1987; Tobias & Kaufman, 1991).

Research has yet to examine the manner in which schema quality facilitates access to information in working or long-term memory. It would seem that individuals possessing a strong conceptual understanding of a strategy would be more apt to recognize the strategy as a likely path to the solution of problem (and therefore quickly select and evaluate the strategies effectiveness) than persons whose understanding of the strategy is less complete. Strategies of which individuals possess clear understanding and which have applied to more than one context would be encoded in memory as 'a useful strategy for solving a certain type of problem.' It might be best, then, to characterize good quality schema's as solution pathways that become

illuminated (activated) in the problem space when a certain type of problem is presented. Strategies that are less well understood are less likely to be stored in memory as useful for a given purpose, and are therefore less likely to be activated during iterative searches of the problem space.

Implications for Future Research

A fundamental limitation of the present investigation, and virtually all studies which have examined access to prior knowledge in a novel problem solving context, is the brief period of time separating the acquisition and problem solving tasks. Conclusions are drawn regarding the transfer of information/strategies stored in long-term memory when in fact the research designs employed require subjects merely to use information that may become inaccessible (or much less accessible) soon after the experiment. The basic research paradigm employed in such seminal studies as Weisberg et al. (1978), Perfetto et al. (1983) and Gick and Holyoak (1980, 1983) requires subjects to solve seemingly novel problems using information provided to them only a short time earlier (often less than 20 minutes earlier). Although this body of research (the present investigation included) strongly indicates that variables like schema quality and task similarity can significantly influence the problem solving process, these conclusions have been drawn from a contrived research context (artificially short-term) that may have only little to do with the type of problem

solving that occurs in school and training settings.

A key question that must be addressed before valid recommendations can be made to educators regarding the importance of structural or motivational variables for the transfer process is whether effects for these variables can be obtained when the distance between acquisition and problem solving tasks is expanded to several days and several weeks. The present investigation, for example, found that approximately 53% of the sample were able to solve the radiation problem during Trial 1 (without a hint). This is consistent with Gick and Holyoak's (1983, Experiment 4) finding that approximately 51% of their sample were able to solve the radiation problem during the uninformed problem solving trial. It is likely that had a period of several days separated the acquisition phase and problem solving phase tasks, the frequency of spontaneous solutions would have dropped considerably. Lengthening the separation between acquisition and problem solving phase tasks may also have diminished the significance of the task similarity effect found by the several studies to examine the problem-oriented/fact-oriented learning distinction.

Finally, it is also likely that such a larger interval between original and transfer tasks would have made it possible for motivational variables to have a greater effect on learning. Intervals of several days (or weeks) rather than a few hours would necessitate changes in research

designs/methodologies that would increase the external validity of the findings with regard to classroom learning. That is, in order for variables like task similarity and schema induction to have the same effect on spontaneous transfer they have had in short-term studies, the initial learning tasks should place considerable emphasis upon the manner in which key information can be used to solve similar problems. For example, in addition to asking secondary school or college subjects to describe the similarities between analogous stories like *The Brilliant General* and *Red Addair*, the problem oriented acquisition phase task could ask subjects to develop (either individually or as a group) other analogous situations in which an attack-dispersion solution could be used to solve a problem. By creating other situations in which the information could be useful for problem solving, subjects may be more likely to access and apply this information to novel problem solving contexts presented days or weeks later. Structural variables could also be manipulated immediately prior to problem solving phases to determine their influence on the transfer of material acquired days earlier. For example, immediately prior to the administration of a heuristic problem like the radiation problem, researchers could instruct subjects to attempt to solve the problem by using strategies they may have learned in other problem solving contexts (without direct reference to the acquisition phase tasks). Such

design and methodology changes would address the significance of task similarity and schema quality effects when the proximity of initial learning and problem solving tasks is greatly increased.

Despite the present investigation's failure to find significant effects for either topic interest or task interest, further research regarding the potential influence of these variables on problem solving in general and spontaneous transfer in particular is clearly merited. Of particular importance would be experiments that involve problem solving tasks that require several days or even weeks to complete. As noted above, performance on such tasks would be more contingent upon sustained effort, which greatly increases the likelihood of finding significant effects for intrinsic motivation.

Given the added expense and difficulty associated with the implementation of problem solving experiments lasting several days or weeks, it is likely that short-term designs will continue to be used to examine the affects of affective variables on cognition. The quality and usefulness of this type of "one day" research would improve through the implementation of the following recommendations:

(1) Time limits of the type used in this experiment should be avoided. Rather than requiring subjects to solve a given problem (or set of problems) within a fixed period of time, subjects should be allowed as

much time as they require (or wish to use) to solve problems. Comparisons of the amount of time devoted by by subjects demonstrated varying levels of interest in a given topic area or task would provide a clearer indication of effort and would allow for direct examinations of the relationship between effort, persistence and problem solving.

(2) Operational definitions of sustained persistence and concentration should be employed to serve as an index of effort expended. In addition to documenting the amount of time required for problem solving, researchers should develop experimental contexts that allow motivated subjects to engage in supplementary activities as a means of facilitating problem solving. For example, resource materials related to the problem solving task (i.e., books, maps, audio-visual aids) placed conspicuously in a classroom setting may be used more frequently (or for longer periods of time) by subjects with high topic interest or task interest than by subjects with lower degrees of interest.

In addition to continued attempts to examine the influence of individual interest on cognitive problem solving, future problem solving research should also be directed towards interest-related variables not addressed by this study. Most important among these variables would seem to be perceived competence (self-efficacy expectations). As

Deci (1992) points out, there is some preliminary evidence to suggest that people tend to be interested in those activities for which they have the greatest ability (Grolnick, Ryan, & Deci, in press; Ryan & Deci, 1986). This is consistent with Bandura's (1977) social learning theory of motivation, which maintains that peoples' expectation of self-efficacy can have a substantial impact on their interest in a task and generally determines level of motivation for performing the task. If the determining factor in whether an individual is able to solve a given heuristic problem is the number of strategy selection and evaluation cycles performed in the problem solving space (leading to either solution or abandonment), it is reasonable to conclude that self-efficacy expectations can have a significant impact on the problem solving process.

Perhaps a key element in determining whether individuals will continue the iterations necessary to solve the problem is the extent to which they believe they can solve the problem. The basic research paradigm used in this study could easily be adapted to allow for the measurement of subjects' perceived competence to solve problems like the radiation problem (measured via the same type of survey used in this study to gauge task interest and science interest). It might even be possible to manipulate self-efficacy expectations by providing some subjects with a series of success experiences with heuristic problems similar to the

radiation problem. Applying Bandura's theory that similar *performance accomplishments* have the strongest influence on perceived competence to complete a given task, it would seem logical to predict that subjects who solved a series of heuristic problem before attempting to solve the radiation problem would be better able to do so (transferring prior knowledge) than subjects who had not had these success experiences. Another source of information cited by Bandura that can affect subjects' self-efficacy expectations, *verbal persuasion* (prompting, coaxing, praising, and similar supportive statements made by others) might also be used to manipulate subjects' interest in and perceived competence to solve the radiation problem in analogical transfer study. For example, immediately prior to and during the problem solving phase, subjects in the verbal persuasion group could be offered frequent one-to-one encouragement and support by an experimenter. The performance of this 'persuaded' group could then be compared that of subjects not offered any type of encouragement. Perhaps to a greater extent than the interest variables examined in the present investigation, studies of the influence of intrinsic motivational variables like self-efficacy expectations on the spontaneous transfer process will yield significant effects.

Towards More Practical Interest Research: Some Final Thoughts

Despite the results of the present investigation with

regard to the influence of interest variables on problem solving, Deci's (1992) contention that "interest is a powerful motivator" must continue to ring true to anyone who has observed children devoting numerous hours to solving the type of problems posed by video game systems such as Nintendo. Indeed, it would be difficult for the adult observer to come to any conclusion other than that it is the children's marked interest in the games that keeps them in front of the screen, attempting to solve each new challenge posed to the "Mario Brother" whose fate they control. Researchers intent on determining the manner in which intrinsic motivational variables influence problem solving and learning would be well-advised to determine what it is about video games systems that elicit so much interest and prolonged problem solving behavior.

Deci (1992) contends that in addition to perceived competence to complete a task, a key factor in determining intrinsic motivation is the level of challenge posed by the task. Specifically, he proposes that regardless of level of proficiency, people are more interested in activities that provide optimal challenge. The findings of this study with respect to post-experiment interest ratings (subjects who failed to solve the problem during Trial 1 rated the radiation problem more interesting than subjects who solved the problem during Trial 1 or who never solved the problem) offer empirical support for Deci's theory. Future problem

solving research should be directed towards task attributes that elicit feelings of competence and challenge.

Although the results of this experiment would appear to provide surface support for Brown et al.'s (1983) contention that academic cognition is relatively "isolated" and "cold," it must be recalled that numerous studies have demonstrated that affective variables can influence cognitive performance. Indeed, to claim that cognition is impervious to affect is to deny the multitude of experiments that found a significant relationship between reading comprehension tasks and interest variables. Clearly, under certain conditions, motivational variables can directly impact academic performance. Viewed from this perspective, studies that fail to find a significant relationship between affect and cognition should not be viewed as supporting the position that cognition is a "cold" process, but rather as empirical examinations of the boundaries of the affect/cognition relationship.

The results of the present investigation suggest that interest variables have little influence on transfer when only a short period of time separates the origin and transfer tasks. As discussed above, however, it is tenable that motivation may be found to influence transfer when experiments are conducted over longer periods of time. As more and more studies investigate the manner in which various affective variables influence the gamut of cognitive

performance variables, a clearer picture of the affect/cognition relationship should emerge. Ultimately, then, research which pursues lines of inquiry like that examined by this study will determine the conditions under which affective variables can influence cognitive performance.

APPENDIXES

Appendix A

Table 10

Correlation Matrix of Continuous Independent Variables

	G. P. A	Task Interest	Science Interest	Post-Exp Interest	Post-Exp Motiva.
G. P. A.	1.0				
Task Interest	.0927	1.0			
Science Interest	.0765	.2520 (p=.001)	1.0		
Post-Exp Interest	-.0763	.2879 (p=.000)	.2498 (p=.001)	1.0	
Post-Exp Motiva.	.0062	.2825 (p=.000)	.3490 (p=.000)	.7293 (p=.000)	1.0

Appendix B

Two Story Analogs to the Radiation Problem

(Gick and Holyoak, 1983)

"The Brilliant General"

A small country fell under the rule of a ruthless dictator who ruled the land from a strong fortress. The fortress was situated in the middle of the country, surrounded by farms and villages. Many roads radiated outward from the fortress like spokes on a wheel. A great general arose who raised a large army at the border and vowed to capture the fortress and free the country from the dictator. The general knew that if his entire army could attack the fortress at once it could be captured. His troops were poised at the head of one of the roads leading to the fortress, ready to attack. However, a spy brought the general a disturbing report. The ruthless dictator had planted mines on each of the roads. The mines were set so that small bodies of men could pass over them safely, since the dictator needed to be able to move troops and workers to and from the fortress. However, any large force would detonate the mines. Not only would this blow up the road and render it impassable, but the dictator would then destroy many villages in retaliation. A full-scale direct attack on the fortress therefore appeared impossible.

The general, however, was undaunted by the mines. He divided his army up into small groups and dispatched each group to the head of a different road. When all was ready, he gave the signal and <u>each group charged down a different road</u>. All of the small groups passed safely over the mines, and the army then attacked the fortress in full strength! In this way, the general was able to capture the fortress and overthrow the dictator.

The general attributed his success to an important principle: If you need a large force to accomplish some purpose, but are prevented from applying such a force directly, many smaller forces applied simultaneously from different directions may work just as well.

"Red Addair"

An oil well in Saudi Arabia exploded and caught fire. The result was a blazing inferno that consumed an enormous quantity of oil each day. After initial efforts to extinguish it failed, famed firefighter Red Adair was called in. Red knew that the fire could be put out if a huge amount of fire retardant foam could be dumped on the base of the

well. There was enough foam available at the sight to do the job. However, there was no hose large enough to put the foam on the fire fast enough. The small hoses that were available could not shoot the foam quickly enough to do any good. It looked like there would be a long, costly delay before any serious attempt could be made to put out the fire.

Red knew just what to do. He stationed men in a circle all around the fire, with all of the available hoses. When everyone was ready all of the hoses were opened up and foam was directed at the fire from all directions. In this way a huge amount of foam quickly struck the source of the fire. The blaze was extinguished, and the Saudis were satisfied that Red had earned his million dollar fee.

Appendix C

Two Versions of the Radiation Problem With Instructions

"Interesting" Version

Directions: *You were asked to participate in this experiment due to your academic skills and interest in science. Below is a version of puzzle that many scientists (and students of science) have found both fun and challenging. The original version was developed by Dr. Stephen Hawking for "MENSA" (the society for individuals with high IQ's) and has been published in complex riddle books and intelligence tests. Your task is to solve the puzzle. You have 10 minutes to do so. Please read the puzzle twice before attempting to solve it. Enjoy!*

"The Radiation Puzzle"

The year is 2006. After completing college and medical school you have become a nationally renowned medical scientist specializing in the diagnosis and treatment of malignant tumors. You are frequently consulted by physicians throughout the world and have aided in the treatment of several prominent individuals.

Late one night you receive a call from the Chief White House Physician. The ten year old son of the President of the United States has been stricken with a potentially deadly form of stomach cancer. The boy is in considerable pain and his mother, the president, is inconsolable. Tests indicate the child may die in less than a week unless the malignant tumor is destroyed. Due to the tumor's location it is impossible to operate on the patient. No incisions of any kind can be made in the body and no device can be directed at the tumor through the mouth or other body openings. You know of a new experimental ray (radiation beam) that can be used to destroy the tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed, severely injuring the patient. At lower intensities the rays are harmless to healthy tissue, but they will also not affect the tumor. Can you think of a procedure (using the ray) that might be used to destroy the tumor, and at the same time avoid destroying the healthy tissue? Please write all the solutions you can think of in the space below and on the next page.

"Dull" Version

Directions: *Below is a problem to solve. It was excerpted from a 10th grade textbook commonly used in neighboring school districts. It is not necessary that you be familiar with the technical terms in the problem to solve it. Please read through the problem below at least twice before writing solutions. You have ten minutes arrive at correct solutions. If you have any questions about the problem, please raise your hand to signal the proctor.* ***YOU WILL BE GIVEN $5 FOLLOWING THE EXPERIMENT IF YOU SOLVE THE PROBLEM CORRECTLY.***

The Tumor Problem

Tumors, also known as "neoplasms," can develop in all regions of the body. Medical dictionaries define neoplasms as a mass of new tissue that persists and grows independently of its surrounding structures, and which has no physiologic use. Many types of neoplasms have been identified. They include the following: cellular tumors (tumors made up chiefly of cells in a homogeneous stroma); connective-tissue (any tumor developed from some structure of the connective tissue); desmoid (a hard, fibrous tumor); heterologous tumors (made up of tissue which differs from that in which it grows); malignant (those that are likely to reoccur and that may terminate life); and sebaceous tumors (cysts formed by the retention of the secretions of a sebaceous gland).

Suppose a doctor has a patient with a malignant tumor in his abdominal cavity (epigastric region). Due to the tumor's location, it is impossible to operate on the patient. No incisions of any kind can be made in the body and no device can be directed at the tumor through the esophagus or intestines. There is a kind of ray (radiation beam) that can be used to destroy this type of tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed, injuring the patient. At lower intensities the rays are harmless to healthy tissue, but will also not affect the tumor. Can you think of a procedure (using the ray) that might be used to destroy the tumor, and at the same time avoid destroying the healthy tissue? Please write all the solutions you can think of in the space below and on the next page.

Appendix D

Task Interest/Science Interest Survey

Directions: We would like to know how interesting you find problems like the one below. After reading through it, please circle the number which reflects your degree of interest in solving this type of problem. Do not attempt to solve the problem now. You will be given time to solve it later.

The Two-String Problem

You are standing in a room in which two strings hang straight down from the ceiling with the ends approximately two feet from the floor. *Your task is to tie the two strings together.* The strings are hung too far apart to allow one end to be reached when the other is grasped. The strings can not be detached from the ceiling. A standard card table and a small folding chair are at one end of the room, but are bolted to the floor and may not be moved. The only other objects in the room are as follows: a softcover book; a pair of pliers; a box of wooden matches; four paper clips; three small sheets of paper; and, a five-inch candle. All items but the table and chair can be moved or manipulated in any way you desire. The correct use of one or a combination of the items in the room will enable you to complete the task.

1 2 3 4 5 6 7 8 9 10

Not interested Mildly Interested Very Interested

Write your approximate grade point average here:

_____

PLEASE TURN TO THE NEXT PAGE OF THIS SURVEY AND ANSWER THE QUESTIONS FOUND THERE.

<u>Directions</u>: We are curious about your degree of interest in science. After you have responded to the items below, please raise your hand to signal to the proctor that you have completed the survey.

1. Please indicate on the scale below how interested you are in "science" as a general subject area. Circle the number that best reflects your degree of interest.

1 2 3 4 5 6 7 8 9 10
Not interested Mildly Interested Very Interested

2. Please indicate on the scale below your degree of interest in pursuing a career in a science-related field.

1 2 3 4 5 6 7 8 9 10
Not interested Mildly Interested Very Interested

3. Circle the number below that best reflects your interest in reading about famous scientists and their discoveries.

1 2 3 4 5 6 7 8 9 10
Not interested Mildly Interested Very Interested

4. Circle the number below that best reflects your interest in the science courses taken in high school.

1 2 3 4 5 6 7 8 9 10
Not interested Mildly Interested Very Interested

5. Circle the number below that best reflects your interest in developing science projects and conducting science experiments.

1 2 3 4 5 6 7 8 9 10
Not interested Mildly Interested Very Interested

6. Circle the number below that best reflects your interest in the medical sciences (i.e., research on the causes and treatment of disease).

1 2 3 4 5 6 7 8 9 10
Not interested Mildly Interested Very Interested

Appendix E

Post-Experiment Survey

Directions: Please circle the number on the line below that best indicates the extent to which you found the problem you just worked on interesting.

1 2 3 4 5 6 7 8 9 10

Not interesting Mildly Interesting Very Interesting

Please circle the number on the line below that best reflects the extent to which you were motivated to solve the problem.

1 2 3 4 5 6 7 8 9 10

Not motivated Mildly Motivated Very Motivated

Did any of the stories you studied earlier actually make it easier for you to solve the problem?

Circle one: Yes No

If you circled "yes," please write the title of the story on this line: _____

Other than information given to you in this experiment, do you have any prior knowledge of radiation therapy that made it easier to solve the problem?

Circle One: Yes No

If you circled "yes," please elaborate upon your prior knowledge in the space below.

Appendix F

Example of Parental Consent Letter

Dear Parents:

On (*date inserted here*), a brief educational research study will be conducted at Midwood High School. The study is part of a larger series of experiments being conducted by Christopher Kaufman of the City University of New York on memory and problem solving processes. Those students who agree to participate in the study as subjects will do so on a voluntary basis. The experimenters will provide participants with a detailed discussion of the experiment following its completion. This follow-up presentation will also provide interested students with detailed information regarding cognitive science and relevant social science research methodology.

Those students who agree to participate will be asked only to solve amusing riddles and to complete memorization tasks (i.e., the memorization of short paragraphs). No aspect of the experiment is even remotely physically or psychologically dangerous. The entire experiment lasts about one hour and would be scheduled for a period of the day that is least disruptive to participants' academic schedule. *The results of the experiment will be kept strictly confidential. Subjects' names and other potentially identifying characteristics will be omitted from any reports on the experiment.*

As noted above, only those students who agree to participate in the study will be recruited as potential subjects. In accordance with Board of Education policy, we may only include those students in the study whose parents have provided written consent for participation. If you give permission for your child to participate, please sign on the appropriate line below. Your child should then return the form to (*name of school contact person inserted here*) prior to (*date inserted here*).

Thank you.

Christopher Kaufman
The City University of New York

I give permission for my son/daughter to participate in the study described above.

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(Parent's Signature) (Date)

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