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By

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ABSTRACT

THE INFLUENCE OF MOTIVATION ON COGNITIVE MECHANISMS INOVLVED IN PROBLEM SOLVING

By

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An increasing number of studies are showing a connection between emotion and motivation, and cognitive mechanism. The exact relationship between motivation and cognitive mechanisms however has not been explored. This work was designed to investigate the relationship between motivation and cognitive mechanisms in problem solving. To avoid the limitations of a correlational design, this work manipulated motivation by giving participants an incentive. Five experiments showed an increase in problem solving accuracy due to the incentive. Experiments 1a and 1b examined whether the increase in performance was caused by an increase in persistence with one problem solving approach. Participants completed incremental and insight problems, which should react to persistence with one approach differently. Results showed that the incentive increased problem solving for both types, indicating that the incentive does not influence performance through persistence with one problem solving approach.

Experiments 2a and 2b investigated incentive effects on problem solving duration and depth of processing. Participants in the incentive condition spent the same amount of time solving problems as participants in the non-incentive condition. However, participants in the incentive condition remembered more problems than participants in the non-incentive condition. These findings indicate that incentives lead to deeper processing of information without an increase in time spent on each problem.

Experiments 3 and 4 used a dual-task approach to examine how incentives influence attention allocation during problem solving. A concurrent tone monitoring task was designed to tax similar attentional resources as problem solving and performance decrements were found in Experiment 3. In Experiment 4 problem solving performance increased for participants given an incentive in the single task condition but not the dual-task condition. Participants in the single task condition given an incentive engaged in deeper processing of the underlying problem structures than participants not given an incentive. In the dual-task condition participants given an incentive showed more surface processing. These findings suggest that incentives lead to an increase in performance by causing a shift of attentional resources to the rewarded task. However, when no additional resources are available incentives lose their effectiveness and no increase in problem solving performance is seen.

To my family.

"Man muß das Unmögliche versuchen, um das Mögliche zu erreichen."

- Hermann Hesse

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1 INTRODUCTION

Motivation is generally seen as an important factor influencing performance (e.g., Deci, Koestner, & Ryan, 1999; Jenkins, Mitra, Gupta, & Shaw, 1998). Despite this, motivation has largely been ignored in regard to its influence on cognitive processes. This might be because the cognitive revolution has emphasized the passing of information between perceptual, memory, and motor components. Usually left out of this view is a role for motivation and emotion, which were issues that had been emphasized by the behaviorist theories that the cognitive revolution overturned. Even when the effect of motivation on cognition is considered, it is often done so to point out that it will not influence cognitive processes much. For example, Simon (1994) suggested that:

> "... when measuring problem solving skills, or the use of language or visual imagery, we usually take motivation for granted, and not without good reason. We have extensive experience with the fact that, within broad limits, people are very obliging at doing what researchers ask of them. ... Provided they direct their attention to the task and are not distracted, added increments of effort would not greatly alter their performance. Within broad limits, trying harder would not alter their performance much."(Simon, p. 10).

Simon does not appear to be alone in this assumption, since he pointed out that in most descriptions of experiments conducted in cognitive psychology laboratories motivation is only mentioned in terms of the amount of money participants were paid or the class credit they received.

More recently, however, a variety of behavioral results have suggested that cognitive psychologists should reconsider the importance of motivation and emotion.

Kuhl and Kazén (1999) found that by manipulating participant's emotion the Stroop effect can be eliminated. When participants were given a word with positive affect as a prime the amount of interference due to the Stroop effect was significantly smaller than when participants were presented with a neutral or negative prime. Vollmeyer and Rheinberg (1998) found motivation affected performance in a complex problem solving task such that participants with higher levels of motivation were more likely to persist with a systematic strategy whereas participants with lower levels of motivation would switch away from a systematic strategy adopting a guessing strategy. Similar influences of motivation on learning strategies and performance on geometry problems were found by Pokay and Blumenfeld (1990). Geometry students with higher motivation were more likely to use and persist with a variety of study strategies (general and geometry specific) compared to less motivated students. Looking at problem solving, Wieth and Burns (2000) found a correlation between motivation and problem solving performance. Participants with higher motivation were more successful at solving incremental or analytic problems than participants with lower motivation.

Advances in the study of the brain have also thrown into doubt the splitting of cognitive processes from emotion and motivation (Lezak, 1994). Damasio (1994) has found impaired decision making among patients with ventromedial prefrontal cortex lesions which seems to stem from their lack of normal emotional responses to decision making tasks (see Bechara, Tranel, & Damasio, 2000, for a summary). Gehring and Willoughby (2002) found that a loss in a decision making task rather than a gain led to riskier decisions on subsequent trials, and generated a larger negative-polarity event-related potential in a medial-frontal region of the cortex. This sensitivity to losses was not simply a reflection of detecting an error; gains did not elicit the medial-frontal activity when the alternative choice would have yielded a greater gain, and losses elicited the activity even when the alternative choice would have yielded a greater loss. Gehring and Willoughby see these results as neurophysiological evidence for the motivational impact of events guiding choice behavior.

Spaulding (1994) distinguished between motivation, emotion, and cognition, where *motivation* refers to the meaning and purpose of behavior, *emotion* to the experiential and psychophysiological phenomena that accompanies motivation processes, and *cognition* to the organismic activity that translates motivation and emotion into observable behavior. Thus, changes in motivation should change cognitive activity and produce different results. This work was designed to investigate the connection between motivation and cognitive activity by examining how motivation might influence cognitive mechanisms involved in problem solving. Finding effects of motivation on cognitive processes, however, has been notoriously hard (Rheinberg, Vollmeyer, & Burns, 2001), and has often relied on correlational designs linking motivation and performance. In order to avoid the limitations associated with correlational research, motivation was manipulated through the use of an incentive. An incentive is reward that is used to induce a desired type of performance or behavior from a person. Since incentives can be manipulated a greater number of conclusions regarding the relationship between motivation and problem solving performance can be drawn. Two major questions were investigated in this work. One, do incentives, and therefore motivation, influence problem solving performance? Two, what cognitive mechanisms involved in problem solving are influenced by incentives?

1.1 Incentive Effects on Performance

Positive effects of incentives. The question of how incentives relate to performance has been of special interest to those concerned with worker productivity. Overall it has been shown that incentives have positive effects on productivity. For example, Saari and Latham (1982) studied the performance of beaver trappers before the implementation of an incentive plan and under the incentive plan. It was found that the number of rodents trapped per hour increased significantly under the incentive plan (payment for each beaver trapped) compared to the base rate system of pay (a set hourly wage), which was in place before the incentive plan. Similarly, LaMere, Dickinson, Henry, Henry, and Poling (1996) found that truck drivers increased their productivity after an incentive pay system was introduced which rewarded the drivers for accomplishing each job they had to perform (e.g., delivering goods, loading and unloading goods) compared to a base rate system of pay (a set hourly wage). This increase in productivity was sustained over a period of nearly four years and was not accompanied by worker dissatisfaction or increases in accidents. Looking at the influences of incentives on productivity in a more controlled setting Riedel, Nebeker, and Cooper (1988) asked participants to do a clerical task that involved transferring data from handwritten questionnaires onto mark-sense forms. All participants earned a base rate of pay however some were given the opportunity to earn incentive pay if they performed above the standard of 5.75 questionnaires per hour. Participants earning incentive pay transferred significantly more data than participants in the non-incentive group. Overall incentives seem to have a positive effect on worker productivity.

Negative effects of incentives. Incentives, however, have also been shown to hurt performance. A meta-analysis of 128 studies by Deci, Koester, and Ryan (1999) examined the effects of incentives on motivation and found that incentives decrease a persons' inherent motivation and self-reported interest in the task which often leads to a reduction in performance. More specifically, incentives are considered forms of external motivation where participants' desires to perform a task are due to an outside influence (e.g., money) and not to their inherent interest in the task. External motivation has been shown to decrease a person's intrinsic motivation and once the external reward is removed people spend less time on the previously rewarded task and show decreased task interest (e.g., Deci, 1971, 1972a, 1972b; Lepper, Greene, & Nisbett, 1973).

Detrimental effects of incentives have also been seen on creativity. Kruglanski, Friedman, and Zeevi (1971) asked participants to read a variety of passages while either in the incentive or non-incentive condition. Participants in the incentive condition were promised a monetary reward for their participation in the experiment while the reward was not mentioned in the non-incentive condition. After reading the passages participants were asked to create as many titles as they could for each passage. Results showed that the titles produced by those participants that had been given an incentive were judged to be less creative than the titles given by the students not given an incentive. Similarly, Amabile, Hennessey, and Grossman (1986) had children tell a story based on a picture book either in an incentive condition or a non-incentive condition. Children in the incentive condition were promised the opportunity to take pictures with a Polaroid camera at the end of the experiment. It was found that children who were given the incentive (taking Polaroid pictures) told stories that were less creative than those children in the non-incentive condition. Consequently, it seems that incentives can also lead to negative effects on performance.

Based on the literature overall it is apparent that incentives have been shown to have both positive and negative effects. A recent review by Camerer and Hogarth (1999) of 74 experiments that manipulated incentives lends further support that incentives can lead to mixed effects. Camerer and Hogarth found that the modal finding in these experiments was no effect of incentives; however there were also studies that showed positive and negative effects. The question then becomes how incentives might influence problem solving?

1.1.1 Incentive Effects on Problem Solving

A few studies have examined the effects of incentives specifically on problem solving performance. McGraw and McCullers (1979) examined the influences of an incentive on performance of the water jar task. Participants were given nine set inducing water jar tasks of the style used by Luchins (1942) that could all be solved in the same way. Then participants were given the tenth problem that required breaking the mental set established in the first nine problems. Results showed that participants given an incentive were much slower to break mental set than participants not given an incentive. McGraw and McCullers concluded that their results were evidence for the detrimental effects of incentives. Similarly, Glucksberg (1962) found that incentives increased problem solving performance on an easy version of Duncker's candle problem (the tacks had already been removed from the tack box) but decreased problem solving on the regular version of the problem. Looking at the Wason four card selection task (Wason, 1966), which is a deductive reasoning task that asks participants to test the rule "If P then Q", Kemmelmeier, Bless, Schwartz, and Bohner (2004) found no effect of an incentive on the correct solution. Participants given an incentive were no more likely to find the correct solution than participants not given an incentive. Looking at participants incorrect answers however, results showed that participants given an incentive were less likely to include the obvious and correct card (the solution to the Wason card selection task requires testing two cards) than participants not given an incentive. Following Camerer and Hogarth (1999) incentive effects on problem solving type tasks also seem to be mixed.

1.2 Incentives and Cognitive Mechanisms

What might be the cause of these mixed findings? In order to understand how things work one must understand what underlying mechanisms are involved in their functioning. In order to understand how incentives influence problem solving one must understand how incentives might be influencing the cognitive mechanisms involved in problem solving performance. Once the influence of incentives on the cognitive mechanisms involved in problem solving is understood, the cause of the mixed incentive effects seen in the literature might be explained. A goal of this work was to investigate the underlying cognitive mechanisms that are influenced by an incentive. A variety of cognitive mechanisms were investigated to try to better understand how incentives influence problem solving performance.

Within the literature a variety of explanations have been put forth on how incentives might influence problem solving. None of them, however, look at cognitive mechanisms directly. For example, Eisenberger (1992), in his *learned industriousness theory* proposed that the relationship between incentives and performance is mediated by effort. Incentives ameliorate the aversive sensations associated with high effort and can therefore lead to an increase in performance. However, if an incentive is given for low effort tasks, performance will decrease as participants learn to associate low effort with rewards. Eisenberger goes on to argue that incentives given for divergent thought by encouraging a variety of approaches to a task will lead to increases in performance while incentives given for more narrow thought will lead to decreases in performance.

Cognitive evaluation theory put forth by Deci (1971) places a heavy emphasis on the person's interpretation of the incentive. More specifically, incentives, which are extrinsic forms of motivation, can be interpreted as controllers of behavior or as indicators of competence. When incentives are seen as controlling they reduce satisfaction of the need for autonomy, cause a more external perceived locus of control, and undermine intrinsic motivation. On the other hand, if incentives are seen as indicators of competence they provide satisfaction of the need for competence and enhance intrinsic motivation. This can lead to differences in performance due to different interpretations of the incentive.

Even though both of these theories are viable explanations of how incentives might influence performance, neither provides a clear answer as to how incentives might influence cognitive mechanisms involved in problem solving. Additionally, it is unclear what predictions they would make regarding the involvement of cognitive mechanisms in problem solving. One theory however does provide some guidance as to how incentives might influence cognitive processes. Amabile (1987) proposes that incentives will have different effects on performance depending on task characteristics. More specifically, Amabile argues that incentives motivate individuals to achieve their goal in the most direct or obvious manner. This direct approach is beneficial for tasks that are straightforward where the path to solution is clear and can be followed easily (algorithmic tasks) but harmful for tasks involving creativity that are open-ended without a clear path to the solution (heuristic tasks). Depending on task characteristics, incentives will have different effects on performance. A similar proposal has been made by Camerer and Hogarth (1999) in their review of incentive effects on performance. More specifically, Camerer and Hogarth have argued that positive incentive effects tended to be seen for "tasks where effort responds to incentives … and where increased effort improves performance" (Camerer & Hogarth, p. 8). Negative incentive effects tended to be seen for tasks in which it was possible to exert too much effort, for example choking or failing under pressure in sports, or in which people over-apply a heuristic, such as in insight problem solving. Based on Amabile and Camerer and Hogarth it is possible then that different types of problems might be influenced differently by an incentive depending on their task characteristics.

Incremental and insight problems. Incremental problems or analytic problems (Schooler & Melcher, 1995) require the solver to "grind out the solution" by taking a series of steps. Reaching the solution might take time but the solver usually has a good idea how to reach it early in the problem solving process. In contrast, insight problems are often solved suddenly with a "flash of illuminance" (Metclafe & Wiebe, 1987), or what has also been called an "Aha" experience where the solution seems to just pop into mind (Schooler & Melcher). Dominowski (1995) defined insight problems as containing three key features: (1) to reach the solution a change in view of the problem is required (2) some form of a unique response is required (in contrast to a memorized procedure or answer), and (3) no specialized knowledge is needed to solve the problem. More specifically, insight problems often lead to an impasse where problem solving comes to a halt because all possible solutions seem to be exhausted and the solver cannot think of a way to proceed. Here the solver must break away from the current representation of the problem and find an alternative way of structuring the problem space (e.g., Smith, 1995, Ohlsson, 1992). In contrast for incremental problem solving the solver usually has a good idea how to reach the solution early in the problem solving process, reaching a solution is usually just a matter of time. For a problem to be considered an insight problem its solution requires some form of new answer. Participants must create an answer by combining experience and not simply recall a memorized answer or habitual experience. The experiences might all be familiar but the combination is new therefore leading to a unique solution. Alternatively, incremental problems often require the solver to recall a memorized procedure (setting up an algebraic equation) to reach the solution. Finally, solving an insight problem does not require any specialized knowledge. Instead the problem is well within the competence of the solver and reaching the solution does not require any memorized procedures or equations. Incremental problems, on the other hand, do often involve previous knowledge that must be retrieved from memory to solve the problem.

Differences between these two types of problems have been demonstrated empirically by studies comparing their problem solving performance. In a study by Metcalfe and Wiebe (1987) participants were asked to rate how close they thought they were to the solution every 15 seconds while solving incremental and insight problems. The rating results showed that problem solvers had a good idea when they were close to the solution for incremental problems, but were unable to perceive when they were close to a solution for insight problems. Solutions for insight problems came suddenly and with little awareness that the solution was about to be found. Additionally, it was discovered that participants were more successful at predicting which incremental problems they could solve than which insight problems they could solve. These results indicate that there are distinct difference between incremental and insight problems, which could be caused by qualitative differences in underlying processes used to solve these two problems (Metcalfe & Wiebe). Further evidence that there are differences in the processes used to solve these two types of problems has been provided by studies that have had participants give verbal protocols while solving both incremental and insight problems (Schooler & Melcher, 1995; Schooler, Ohlsson, & Brooks, 1993). Schooler et al. found that participants asked to verbalize their problem solving strategies showed significantly impaired performance on insight problems but not on incremental problems. Additionally, it was found that participants paused more and tended to have a harder time articulating their thoughts while solving insight problems compared to incremental problems. Furthermore, the nature of the protocols also differed in that incremental problem protocols contained more logic or means-ends analysis statements than insight problems (Schooler & Melcher). These findings have been attributed to differences in the processes used to solve these two types of problems. Specifically, Schooler and Melcher and Schooler, et al. argued that the impairments during insight problem solving while verbalizing are due to the disruption of non-reportable processes that are critical to solving insight problems but are not necessary for solving incremental problems.

Additionally, Dominowski (1995) has argued that insight problems involve a greater degree of creativity than incremental problems because the solver is required to produce solutions that are less frequent than those that are more easily elicited. Furthermore, insight problems require more creativity because the solver has to re-represent the problem in order to reach the solution.

For the purpose of this dissertation insight problems will be defined as problems for which a change in view of the problem is required for solution, a unique response is required, and no specialized knowledge is needed to solve the problem (Dominowski, 1995).

1.2.1 Persistence with One Strategy

The characteristics of incremental and insight problems can easily be mapped onto the distinction Amabile (1987) draws between algorithmic and heuristic tasks. An algorithmic task has a clear and often obvious path to the solution. Incremental problems can be solved by sticking to a clear path to the solution. A heuristic task on the other hand often involves more creativity and is open ended without a clear path to the solution. Insight problems do not have a clear path to the solution and often require the solver to re-represent the problem. Amabile has argued that incentives discourage participants from exploring the problem space and encourage them to take the most straightforward and obvious path to the solution. This would be advantageous for incremental problem solving since the obvious path will often lead to the correct solution. However, the most obvious path will often lead to a solution which is not plausible for insight problems solving, therefore incentives may decrease insight problem solving performance.

These predictions also seem to flow from Vollmeyer and Rheinberg (1998) who found that motivation influenced performance via the use of a good strategy. More specifically participants were asked to figure out the underlying links of a complex system by changing one variable at a time. Vollmeyer and Rheinberg found that participants with higher motivation were more likely to stick with the instructed strategy and solve the task correctly, while participants with lower motivation were more likely to switch from the instructed strategy to a guessing strategy and therefore fail to solve the complex task. Vollmeyer and Rheinberg concluded that motivation leads to persistence with one good strategy or approach. Again, this kind of persistence would help solve incremental problems because it encourages solvers to stay on the obvious path even if the path is long and difficult. For insight problems, however, persistence with one approach might be harmful due to the creation of mental set effects (Luchins, 1942) where the solver cannot re-represent the problem. Persistence with one particular approach would most likely lead to an implausible solution since exploration of problem space is needed in order to solve insight problems successfully. It is possible then that incentives influence persistence with one approach to the problem. In order to test this possibility participants in Experiments 1a and 1b were asked to solve both incremental and insight problems while either given an incentive or not. It was predicted that if incentives lead to persistence with one problem solving approach then participants given an incentive should show an increase in incremental problem solving but a decrease in insight problem solving compared to participants not given an incentive.

1.2.2 Increased Time on Task

Another way incentives might influence problem solving is by increasing the amount of time participants spend on a task. For example, Miller and Hom (1990) found that participants given a monetary incentive for completing solvable and unsolvable anagrams spend more time trying to solve the unsolvable anagrams compared to participants not given an incentive. Similar effects have been seen in the worker productivity literature where incentives increased the amount of time participants spent with a task (e.g., Saari & Latham, 1982). In light of this, incentives may lead to an overall increase in the amount of time participants spend on each problem. Perhaps incentives lead participants to work on a problem longer increasing their chances of finding the correct answer. It is possible that an incentive that encourages accuracy might also encourage participants to spend more time on each problem to guarantee the correct answer to the problem. In Experiments 2a and 2b this possibility was investigated by measuring participants' problem solving duration. If incentives cause an increase in problem solving duration then participants given an incentive will spend more time solving problems than participants not given an incentive.

1.2.3 Deeper Processing

Finding an increase in the amount of time spent solving problems alone would not be remarkable. If incentives simply lead to an increase in time one could argue that incentives do not actually change any cognitive mechanisms and can therefore be ignored in certain circumstances (for example, building a model of task performance, and constructing training programs). It is possible, however that incentives are not just causing participants to do the same thing for a longer period of time, instead incentives might be causing participants to do more during the same amount of time. Vansteenkiste, Simons, Lens, Sheldon, and Deci (2004) have shown that motivation leads to a greater amount of deep processing of material compared to surface processing. More specifically, participants were asked to read a text passage after which they were asked to fill out a questionnaire assessing the degree to which they engaged the material in a superficial way (e.g., "I skipped parts of the text that I did not understand very well.") or a deep way (e.g., "I studied the text by associating the things I read with what I already knew."). Participants were also tested on the material in a written test and a group discussion. Results showed that participants with greater motivation engaged in deep processing much more frequently than superficial processing and were therefore able to remember more information they had read compared to participants with less motivation.

Looking at incentives, Eysenck and Eysenck (1982) found evidence for deeper processing on word list recall due to monetary incentives. Participants were asked to recall a mixed list of high and low monetary (10 pence and 2 pence, respectively) incentive words. During recall participants where given weak and strong retrieval cues (e.g., "TABLE associated with ______"); determined by word association norms. Results showed that high incentive words were recalled more than low incentive words with weak retrieval cues but there was no effect with strong retrieval cues. Eysenck and Eysenck argued that these findings indicate that low incentive words were processed based only on their most obvious and easily accessible features whereas high incentive words were processed in terms of both easily accessible and less accessible features. It is possible then that incentives will also lead to deeper processing during problem solving.

Both of these studies indicate that motivation can lead to deeper processing of information and therefore greater recall at test. What might deeper processing mean for problem solving? Craik and Tulving (1975) argued that encoding information in a more meaningful or semantic manner results in improved retention. Perhaps participants given an incentive represent problems in a more meaningful way by drawing greater connections between these problems and previous knowledge. This then may lead to greater retention for the problems. Experiments 2a and 2b tested this possibility by giving participants a surprise memory test after they had attempted several problems. In this memory test participants were asked to recall as many of the problems that they had just attempted in as much detail as possible. If incentives lead to deeper processing then participants given an incentive should remember more problems in greater detail than participants not given an incentive.

Deeper processing in problem solving could also lead to greater understanding of the problem. Perhaps participants given an incentive are more likely to look at the underlying structure of the problem than participants not given an incentive. Chi, Feltovich, and Glaser (1981) found that physics experts were more likely to organize each problem based on the underlying physics principles while novices organized problems on the mentioned objects. One does not need to be a physics expert to solve incremental and insight problems however this study can perhaps give some guidance as to what exactly deeper processing means in the domain of problem solving. There are two general approaches to solving problems. One approach would be to figure out the underlying structure of the problem (e.g., setting up an equation) while another would be to simply guess based on the conditions stated in the problem. For example, given the following problem "Ann is twice as old as her son. Ten years ago Ann was three times as old as her son. What are their present ages?" one could figure out the underlying structure and set up an equations (e.g., $3X = 2X + 10$) to solve the problem. This type of approach would require deeper processing of the problem as participants need to tie the current problem to their previous knowledge in order to set up an equation. On the other hand, one could simply guess the answer by picking two ages and seeing if they fit the conditions stated in the problem. For example, picking the ages 10 and 20 would satisfy the condition that Ann is currently twice as old as her son but would not satisfy the condition that ten years ago she was three times as old as her son. (Ten years ago the son would have been zero [10 – 10] and Ann ten [20 – 10].) A guessing approach would involve much shallower processing as participants do not need to link the currently problem to previous knowledge and only need to operate within the conditions given in the problem. It is possible then that deeper processing for problem solving also refers to greater processing of the underlying structure of the problem and less surface structure processing. Incentive might not only lead to an increase in memory for the problems but might also lead to greater recall of problem relevant information. In order to test this possibility irrelevant information was added to the problems in Experiment 4. The information added to each problem was not necessary for solving the problem; however this was not readily apparent when first encountering the problem. If incentives lead to deeper processing by causing participants to focus on the underlying structure of the problem then participants in the incentive condition should recall less irrelevant information than participants not given an incentive (indicating more surface processing).

1.2.4 Attention and Information Processing

Attention is essential in determining what information is processed, encoded into memory, and later retrieved (Broadbent, 1958; Cherry, 1953; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Logan & Etherton, 1994; Logan, Taylor, & Etherton, 1996; Naveh-Benjamin, Craik, Guez, & Dori, 1998; Treisman, 1964). In order to solve problems successfully one must properly allocate attentional resources responsible for information processing, encoding, and retrieval. When participants do not allocate the appropriate amount of resources learning or in this case problem solving will not occur. For example, in a study looking at word pair learning Logan and Etherton (1994) asked participants to make a judgment on a series of consistently paired words. Some participants were asked to look at both words in the pair to make the judgment while others were asked to look only at the colored word in the word pair. Results showed that those participants that looked at both words showed a performance advantage from the consistent pairing but those participants that only looked at one word did not show an advantage for the consistent pairing. These findings indicate that participants given the color cue consistently ignored the second word and only devoted their attention to the task relevant word. Perhaps this is also how incentives influence problem solving. Incentives might serve the same function as the color cue and direct participants attention to the rewarded task ensuring proper allocation of resources to complete the task. Kahneman (1973) argued that an individual's enduring dispositions, momentary intentions, and evaluation of the capacity demands will influence the allocation of attentional resources. Those tasks that are seen as more appealing, interesting, or important will receive more attention than tasks seen as unappealing, boring, and unimportant. It is possible then that incentives might lead to an increase in appeal, interest, and importance and cause participants to allocate more attention to the rewarded task.

This prediction also seems to follow from the goal setting literature which has examined the effects of goals on resource allocation. Each incentive usually encompasses a goal that specifies the conditions under which someone will receive the incentive. For example, giving participants the opportunity to leave the experiment early if four problems are solved correctly encompasses both an incentive, the opportunity to leave the experiment early, and a goal, solving four problems correctly. It is particularly useful then to look at research looking at goal setting and attention allocation. Locke and Latham (1990, 2002) have noted that one way goals influence performance is by directing resources and effort towards goal relevant tasks and away from goal irrelevant tasks. Rothkopf and Billington (1979) gave participants informational goals and tracked their reading times and eye movements while reading several text passages. It was found that goal-relevant sentences resulted in more and longer fixations than goal-irrelevant sentences. Additionally, participants recalled more goal-relevant information than goal-irrelevant information. These findings indicate that participants direct more attention to goal relevant information than goal-irrelevant information. Similarly, Locke and Bryan (1969) found that feedback on an automobile driving task only led to improvement for goal related tasks but not for non-goal related tasks (even when the feedback was about non-goal related tasks). For example, participants' instructed to keep their speed within a certain range would adjust their speed when given feedback but ignored any feedback regarding following distance between their car and other cars. It is possible then that incentives like goals direct attention to the goal-relevant or rewarded task. Experiment 4 was designed to examine the effects of an incentive on the allocation of attention. It was predicted that an incentive would increase the amount of attention devoted to the rewarded task.

Attention and a dual-task approach. One way of studying the allocation of attention is by using a dual-task approach. In a dual-task approach participants' limited resources are taxed by performing two tasks at once. Similarities between the two tasks determine the performance decrements seen. More specifically, Navon and Gopher (1979) argued that performance decrements can be seen for tasks that have the same "demand compositions" or resource requirements. Wickens (1980, 1984) expanded on this by proposing a three-dimensional space of task characteristics (stages of processing, codes, and modalities) that determines interference between tasks. Greater overlap in resource requirements between two tasks leads to performance decrements in both tasks if participants are performing the tasks simultaneously. In the context of this research if participants are performing a secondary task that has the same resource requirements as problem solving, performance decrements should be seen in both tasks. A dual-task approach however can also be used to investigate if participants are preferentially allocating their resources to one or the other task. Given that the two tasks tax the same resources, if participants' problem solving performance increases while their secondary task performance decreases, one can argue that participants are shifting their limited attentional resources to the problem solving task (and ignoring the secondary task). This makes a dual-task approach particularly useful in investigating incentive effects on attention allocation during problem solving. More specifically, if an incentive is similar to a goal and causes participants to shift their attentional resources to the rewarded task and away from the non-rewarded task then participants given an incentive in the dual-task condition should show greater problem solving performance but lower secondary task performance compared to participants not given an incentive. On the other hand, if participants are performing both tasks at the same time then very few additional resources will be available to devote to the rewarded task and the incentive should have no effect on problem solving performance.

Secondary task effects and higher order cognition. As noted a key to using the dual-task approach to investigate attention allocation is to find a secondary task that taxes the same resource requirements as problem solving. Very little research has investigated the influences of secondary tasks on problem solving. One exception is a study by Lavric, Forstmeier, and Rippon (2000) that asked participants listen to a concurrent tone task and count the number of target tones that occurred while solving Duncker's candle problem and the Wason card selection task. Results showed decreased performance on the Wason card selection task but not Duncker's candle problem when participants were asked to solve the problems and perform the concurrent counting task at the same time. Perhaps this indicates that the resource requirements for the concurrent counting task were not similar enough to the resource requirements of Duncker's candle problem and therefore the secondary task did not influence problem solving performance.

Further research that highlights the importance of overlapping resource requirements comes from a field that is closely related to problem solving, reasoning. Early studies by Baddeley and Hitch (1974; Hitch & Baddeley, 1976) asked participants to judge as quickly as possible whether a description of a sequence of letters matched the actual sequence of two letters presented while trying to either remember a digit preload or perform a concurrent articulation task. It was found that a six digit preload (but not a one digit or two digits preload) as well as a concurrent articulation tasks increased mean reasoning times significantly compared to single task reasoning performance. More specifically, the greatest increase in reasoning time was seen in the concurrent articulation task that required participants to repeat cyclically a random six digit sequence given to them. Similarly, Farmer, Berman, and Fletcher (1986) found small disruptive effects of concurrent articulation on simple grammatical reasoning tasks but not on simple visuospatial reasoning tasks. A concurrent spatial task produced the opposite results. Gilhooly, Logie, Wetherick, and Wynn (1993) examined the impact of concurrent articulation, articulatory suppression and a visuospatial secondary task on syllogistic reasoning tasks. It was found that syllogistic reasoning was disrupted by concurrent articulation and to a lesser extent by articulatory suppression, but not at all by the visuospatial task that involved tapping a visual pattern. Similar results were found by Toms, Morris, and Ward (1993) for conditional reasoning. Klauer, Stegmaier, and Meiser (1997) also found that a spatial tracking task only disrupted spatial reasoning and not propositional reasoning while a random number generation task and an articulatory suppression task led to inference for both spatial and propositional reasoning. Extrapolating from this research it can be seen that a secondary task that taxes the same resources as the primary reasoning task interferes with reasoning performance (a concurrent articulation task interferes with syllogistic reasoning) while a secondary task that used different resources as the primary task does not (a visuospatial tapping task does not interfere with syllogistic reasoning).

One can then look at the task characteristics of problem solving to determine what type of secondary task might lead to interference. Successful problem solving involves the active maintenance of goals and other relevant task information in memory (e.g., information given in the problem, intermediate problem states), comparing relevant information to information in memory to develop solution strategies, inhibiting irrelevant or distracting information, monitoring and evaluating progress towards goals, and planning and executing response actions (Hambrick & Engle, 2003). These problem solving components involve different processes (based on Baddeley & Hitch, 1974; Baddeley, 2002; Smith & Jonides, 1999). The maintenance of goals and task relevant information in problem solving involves executive processes for the continued maintenance of information. The phonological loop might also be involved as participants might store intermediate problem states in verbal form. There might also be involvement of the visuospatial sketchpad for those problems involving a visual/spatial component. Comparing relevant information to information in memory to develop a solution strategy again involves executive processes responsible for comparing information and planning a sequence of tasks to accomplish a goal. The process of inhibiting irrelevant or distracting information in problem solving depends on executive processes responsible for controlling inhibition and attention. Monitoring and evaluating progress towards a goal are important aspects of problem solving that involve executive processes responsible for updating and checking information in working memory to determine the next step. Lastly, planning and executing a response action during problem solving is controlled by executive processes involved in planning and task management. Following the above presented research and Navon and Gopher (1979) as well as Wickens (1980, 1984), a task that has the same resource requirements (working memory and executive processes) should then lead to problem solving performance decrements.

Concurrent tone monitoring tasks seem to tax much of the same executive processes involved in problem solving. A concurrent tone task requires the maintenance of a target tone in memory which involves executive processes for the continued maintenance of the tone. Perceiving each test tone involves the echoic store and comparing each test tone to the target tone held in memory involves executive processes involved in checking and comparing the presented tone with the target tone. Withholding or inhibiting responses to distracter tones relies on executive processes involved in inhibition and monitoring. Finally, planning and executing a response action also involves executive processes responsible for planning and task management. Both problem solving and a concurrent tone task involve executive processes responsible for maintenance, planning, checking and comparing, task management, monitoring, and inhibiting. These similarities in the two tasks' resource requirements should lead to a competition for resources which may lead to decrements in task performance when both tasks are performed at the same time (Navon & Gopher, 1979; Wickens, 1980, 1984).

A concurrent tone-monitoring task has been used by Beilock, Bertenthal, McCoy, and Carr (2004) and Beilock, Carr, MacMahon, and Starkes (2002) has shown decrements in primary task performance, namely golf putting. More specifically, it has been shown that the putting performance of novice golfers, which is under attentional control, is negatively influenced by the addition of the secondary tone-monitoring task while expert's putting performance, which is under proceduralized control that does not require constant attention, is not. However requiring experts to perform the secondary tone-monitoring task while performing puts with an unfamiliar putter (requiring non-proceduralized processes) also caused decrements in putting performance. These findings indicate that when the tone task is paired with a task that requires similar processes decrements are seen.

Golf putting and problem solving might seem very different on the surface, however, for novices performing the golf putting tasks there are similar demands on executive processes as in problem solving. More specifically, Beilock and Carr (2002) (as well as Anderson, 1987; Fitts & Posner, 1967) have argued that novices' performance is controlled by declarative knowledge that is held in working memory and attended to in a step by step fashion during performance. This indicates that during putt execution novice participants, just as in problem solving, are maintaining goals and task relevant information in memory (the distance of the hole, the weight of the putter etc.), comparing relevant information to information in memory (the declarative knowledge of the steps involved in performing a putt), and planning and executing response actions. These common resource requirements make it feasible to compare golf putting and problem solving and to therefore expect similar effects of a concurrent tone monitoring task on problem solving performance. If incentives influence attention then taxing attention with both a problem solving task and a concurrent tone monitoring task should elucidate a possible connection between incentives and attention allocation. If participants in the dual-task condition given an incentive show an increase in problem solving and a decrease in the concurrent tone monitoring performance then it would indicate that incentives cause a shift of all attentional resources to the rewarded task. On the other hand, if participants in the dual-task condition given an incentive show a decrease in both the problem solving and tone monitoring performance then it would indicate that incentives cause a shift of additional attentional resources. In other words, incentives only influence performance when spare attentional resources can be recruited for the rewarded task. Experiment 4 tested these two possibilities.

1.3 Summary of the Predictions

Experiment 1a and 1b were designed to show incentive effects on problem solving and test whether incentives lead to persistence with one problem solving approach. If incentives lead to an increase in persistence with one problem solving approach then incremental problem solving will increase while insight problem solving will decrease. Experiments 2a and 2b were designed to test whether incentives lead to an increase in problem solving duration or deeper processing. If incentives lead to an increase in problem solving duration then participants given an incentive would show longer problem solving durations than participants not given an incentive. If incentives lead to deeper processing of information then participants given an incentive should remember more problems in more detail than participants not given an incentive. Experiments 3 and Experiment 4 were designed to investigate incentive effects on attention allocation using a dual-task approach. Two possible predictions were tested: participants given an incentive shift all their attentional resources to the problem solving task at the expense of the secondary task, or participants given an incentive only shift resources to the problem solving task when additional resources are available. Additionally, Experiment 4 tested whether participants given an incentive engage in greater processing of the underlying structures of the problem compared to participants not given an incentive. If incentives lead to greater processing of the underlying structures of the problem then participants in the incentive condition will recall less problem irrelevant information than participants in the non-incentive condition.

2 INCENTIVES AND PERSISTENCE WITH ONE STRATEGY

2.1 Experiments 1a and 1b

Experiments 1a and 1b tested the prediction that an incentive will influence problem solving despite the widespread assumption that motivation can be ignored when examining cognitive processes. Moreover, Experiments 1a and 1b were designed to test whether an incentive differentially affects participants' performance on incremental and insight problems. If an incentive increases persistence with one approach then, based on the assumptions supported in the introduction, persistence should help incremental problem solving and hinder insight problem solving (due to possible mental set effects).

Half of the participants were given an incentive and half were not. The incentive was the opportunity to leave the experiment early if the participant solved a certain number of problems correctly. Money was not used as an incentive due to the possible contrary and often convoluted effects money can have on performance (Crano, 1991). Instead a leave early incentive was used because it was assumed to be particularly attractive to the undergraduate participant pool and it is cost efficient.

2.2 Method

Design. A 2x2 mixed design was used with a between-subjects factor of incentive (given or not) and a within-subjects factor of problem type (incremental and insight).

Participants. Two hundred and twenty-three Michigan State University students participated for course credit in Experiment 1a (mean age 19.3) and 206 in Experiment 1b (mean age 19.4). The majority of the sample was female (169 female, 53 male in Experiment 1a; 144 female, 62 male in Experiment 1b) reflecting the nature of the participant pool. In both Experiments 1a and 1b no gender effects were found.

Procedure. Participants were randomly assigned to either the incentive or non-incentive condition. At the beginning of the experiment participants completed a background questionnaire assessing their gender, age, year in school, and college entrance exam test scores. They were then given an easy incremental practice problem used to familiarize them with the procedure and the types of problems they would be solving. After completion of the practice problem participants were told that they would be solving a similar series of problems that would take until the end of the session to complete. Participants were informed that they would have six minutes for each problem and that once the time was up the problems would be collected regardless if they were completed or not. Participants in the incentive condition were then told about the incentive: the opportunity to leave the experiment early if they solved four of the problems correctly. In neither condition were participants told the total number of problems. After the instructions, problems were presented one at a time, alternating between insight and incremental problems. During the experiment participants in the incentive condition were given anonymous feedback after each problem by marking whether a person got a problem correct on a board visible to everyone in the experiment. Anonymous identification numbers were used and participants were allowed to leave once they had solved four problems correctly. If participants in the incentive condition did not solve four problems they left after attempting all the problems. Participants in the non-incentive condition always attempted all the problems. The experiment took about 50 minutes to complete.

Note that problems were collected only after six minutes were up, even if participants finished a problem earlier. This manipulation was critical to the success of the experiment, because it prevented participants in the incentive condition from employing the strategy of handing back problems they did not think they could solve and only working on easy problems. Had participants in the incentive condition been allowed to use this strategy it would almost certainly have resulted in the incentive and non-incentive groups attempting different sets of problems, and thus make them impossible to compare.

Materials. For Experiment 1a five problems were selected; three incremental and two insight problems (see Appendix A for the text of the problems). The problems were selected from Metcalfe and Wiebe (1987) and Schooler, Ohlsson, and Brooks (1993) and were chosen based on their difficulty level and solution rates from previous experiments (Wieth & Burns, 2000). Problems were presented in two different orders. An "easy" order that presented the problems in increasing difficulty and a "hard" order that presented the problems in decreasing difficulty. This allowed us to investigate whether our methodology was vulnerable to problem solving order effects, as well as whether the difficulty of the problems may interacted with the incentive we used. More specifically, we were concerned that the incentive may have a smaller influence on problem solving if participants initially did the harder problems, because failing to solve a problem may lead them to think they had little chance of obtaining the "leave early" incentive and thus render our incentive manipulation moot. In the easy order participants were first given the easy Dinner Party (incremental) problem, the Water Lilies (insight) problem, the medium Store (incremental) problem, the Checker Game (insight) problem, and then the hard Stakes (incremental) problem. The hard order was almost identical except that the Dinner Party and the Stakes problem were switched such that participants in the hard order started with the Stakes problem and ended with the Dinner Party problem. Both insight problems (Water Lilies problem and Checker Game problem), on the other hand, were chosen to have a medium solution rate (about 50%).

Experiment 1b did not manipulate order but two new sets of insight and incremental problems were given in order to generalize the results. Each set contained four different problems, two incremental problems (Set 1: *Card* problem, *Bachelor* problem; Set 2: *Store* problem, *Flower* problem) and two insight problems (Set 1: *Horse* problem, *Marriage* problem; Set 2: *Sock* problem, *Policeman* problem). The problems in each set were chosen to have a solution rate at or slightly above 50 percent. Solution rates for some of these problems were taken from Maier and Casselman (1970) or were determined from our own previous experiments (Wieth & Burns, 2000). The text of the problems can be found in Appendix A. A fifth problem (the *Job* problem) was presented to all participants that did not leave early to ensure that participants that met the incentive would actually leave before those that did not meet the incentive. This problem, however, was not included in any analyses.

2.3 Results

The incremental and insight problems were scored as either right or wrong. An *insight score* was calculated for each participant by summing the two insight problems of each experimental set and then dividing by two. The same procedure was used to calculate participant's *incremental score,* however in Experiment 1a only the *Dinner Party* and the *Store* incremental problems contributed to the incremental score. The hardest incremental problem (the *Stakes* problem) in Experiment 1a was not included in the incremental composite score because so few participants solved it correctly (4%), though all those that solved it were in the incentive condition. Additionally, our best incentive group participants never attempted the *Stakes* problem if given the easy condition, because they were able to solve the first four problems correctly and then leave without being given the last and most difficult problem. So we simply dropped the *Stakes* problem rather than analyzing it with a biased sample.

Experiment 1a. Based on four problems (excluding *Stakes*), the mean incremental and insight scores are presented in Table 1.

	Incremental	Insight
Experiment 1a		
Non-incentive (n = 111)	.75 (.30)	.47 (.39)
Incentive (n = 112)	.84 (.24)	.58 (.38)
Experiment 1b		
Set 1		
Non-incentive (n = 50)	.47 (.33)	.51 (.38)
Incentive (n = 52)	.61 (.39)	.56 (.35)
Set 2		
Non-incentive (n = 53)	.74 (.32)	.46 (.35)
Incentive (n = 51)	.80 (.27)	.64(.36)

Table 1. Mean incremental and insight scores (standard deviations in parentheses) for Experiments 1a and1b (two problem sets used).

A 2x2x2 mixed analysis of variance was performed on participants' insight and incremental problem solving scores with between-subject factors of order (hard first or easy first) and incentive (present or not), and a within-subject factor of problem type. Results showed that there was no evidence of an effect of order ($F[1, 219] = .65, p = .42$, $MS_e = .13$) or an interaction between order and type of problem ($F[1, 219] = .62, p = .43$, $MS_e = .10$) . Therefore all further analyses in these experiments will be presented pooled over the order factor. Note that although the data was categorical an analysis of variance rather than a loglinear modeling analysis was used. Lunney's (1970) simulations show that ANOVA is a valid analysis for categorical data with large sample sizes and an equal number of participants in each condition. Using an analysis of variance one can take advantage of the fact that participants did more than one problem, which is more problematic for loglinear analysis with its strong assumption of independence.

As Table 1 shows there was a significant effect of incentive ($F[1, 219] = 9.01, p < .01, MS_e = .13$) and problem type ($F[1, 219] = 81.84, p < .01, MS_e = .10$). All other effects and interactions with problem type were not significant. Of special interest was the interaction between incentive and type of problem, which was found not to be significant, $F(1, 219) = .11, p = .74, MS_e = .10$, indicating that the incentive influenced both insight and incremental problem solving in the same way (see Table 1). The solution rates for the four individual problems were also examined and it was found that participants in the incentive condition out-performed participants in the non-incentive condition on each of them.

Experiment 1b. Based on the four problems everyone attempted, Table 1 presents the mean incremental and insight scores separately for the two problem sets.

A 2x2x2 mixed analysis of variance was performed on participants' insight and incremental problem solving scores with between-subject factors of problem set (Set 1 or Set 2) and incentive (present or not), and a within-subject factor of problem type (insight or incremental). As in Experiment 1a, a significant effect of incentive was found, $F(1, 202) = 8.17, p < .01, MS_e = .14$, but no significant interaction between incentive and problem type, $F(1, 202) = .05, p = .82, MS_e = .10$. These findings, again, indicate that the incentive influenced both insight and incremental problem solving. Table 1 shows that the incentive increased the mean solution rates for all incremental and insight problems in both sets.

There was again a significant difference between the two problem types, $F(1, 202) = 13.24$, $p < .01$, $MS_e = .10$ and also a significant difference between the two sets $F(1, 202) = 11.98$, $p < .01$, $MS_e = .14$. This is not surprising given that the sets contained different problems with different underlying levels of difficulty. Of more interest however was that there was no interaction between incentive and either problem type (as shown above) or set, $F(1, 202) = .12$, $p = .73$, $MS_e = .14$. Additionally, there were no higher-order interactions with incentive.

2.4 Discussion

Experiments 1a and 1b showed that participants given an incentive outperformed participants not given an incentive on all problems regardless of problem type. These findings provide evidence that incentives do influence problem solving processes and more specifically that incentives influence problem solving positively. In neither experiment was there an interaction between the incentive and problem type, indicating that the incentive did not influence performance on insight and incremental problem solving differently. This was contrary to the prediction that the incentive would help incremental problem solving and hinder insight problem solving.

Previous studies examining incentive effects on problem solving have shown mixed effects of incentives on performance (e.g., Glucksberg, 1962, McGraw & McCullers, 1979). Why then did the incentive consistently increase problem solving across four different problem sets in Experiments 1a and 1b? It is possible that different incentive structures led to these differences in problem solving performance. For example, Glucksberg found evidence of incentives slowing solution to Duncker's candle problem when participants were paid on the basis of how fast they solved the problem. Rewarding participants as a function of speed of solutions (as opposed to simply solution accuracy, as in Experiments 1a and 1b) may encourage a strategy that is normally adaptive but happens to fail in the given context. Bruner, Goodnow and Austin (1956) found that when participants were given only a few trials to discover a concept they varied multiple aspects of the stimuli at a time. This strategy was not optimal for a guaranteed discovery of the concept, but gave participants the best chance to find it quickly. Similarly, the best chance of solving a problem quickly is to hope that the obvious solution works, and try it. For Duncker's candle problem which is an insight problem this is a poor strategy, but Glucksberg's participants did not know that they were faced with an insight problem. Thus Glucksberg's findings may have been due to his particular incentive structure, rather than because incentives are inherently harmful to insight problem solving.

McGraw and McCullers (1979) also found detrimental effects of incentives on 10 water-jar problems of the style used by Luchins (1942). They found that participants in the incentive group were slower than participants in the non-incentive group at solving the tenth problem that required breaking the mental set established in the first nine problems. McGraw and McCullers concluded that their results were evidence for the detrimental effects of incentives; however, as in the study by Glucksberg (1962) the measure of problem solving performance was confounded by the incentive structure. More specifically, in McGraw and McCullers the incentives were based on getting the problems correct, the measure of performance however was time on task. In fact, participants were specifically instructed that "they could take as long as they needed to find the correct answer to each of the problems, because time was not crucial" (McGraw & McCullers, p. 287). Furthermore the incentive scheme paid a bonus that tripled the maximum payoff if all ten problems were correct, so getting the tenth problem right was especially important for the incentive group as they were risking their bonus. Given the special status of the tenth problem for the incentive group, and the instructed irrelevance of time, it would be surprising if participants did not take longer to turn in a solution than the non-incentive group even if there was no mental set to break. Thus it is not clear what McGraw and McCullers' results say about the effects of incentives on insight problem solving. Experiments 1a and 1b represent a much cleaner test of the effects of incentives on problem solving because the dependent measure was solution rate and the incentive only related to solutions.

Experiments 1a and 1b, despite strong suggestions in the literatures, also showed no evidence for an interaction between incentive condition and problem type (incremental vs. insight). Amabile (1987) suggested that incentives should lead to negative effects on tasks involving creativity that are more open ended without a obvious path to the solution. Insight problem solving has been argued to involve more creativity than incremental problem solving because participants must re-represent each problem in order to solve it (e.g., see Sternberg & Davidson, 1995). Since research has shown that under some circumstances creativity can be hurt by incentives (Eisenberger & Cameron, 1996; Eisenberger & Selbst, 1994; Hennessey & Zbikowski, 1993) it seems natural to extrapolate the results of creativity research to insight problem solving. However, insight problem solving and creativity do differ in an important way; measures of creativity often rely on participants showing a divergence of solution (e.g., Amabile) whereas problem solving ultimately requires a single, correct, solution. Perhaps the findings of Experiments 1a and 1b, that incentives also help insight problem solving, suggest that the proposed link between insight and creativity needs to be treated with a little more skepticism.

The results of Experiments 1a and 1b that the incentive increases both incremental and insight problem solving indicate that there does not seem to be any evidence in these particular experiments that the incentive leads to an increase in persistence with one problem solving approach. It should be noted that Experiments 1a and 1b did not assess participants' problem solving approaches directly. It is therefore possible that the manipulation used in these experiments to assess persistence with one problem solving approach was too indirect and therefore did not reveal more subtle strategy changes due to an incentive. In order to more directly assess participant problem solving approaches a talk aloud methodology could be used where participants given an incentive are solving incremental and insight problems while talking about their problem solving processes out loud. This type of study would be a more direct measure of participants' problem solving approaches. A study such as this however is outside of the scope of this dissertation. The results of Experiments 1a and 1b however are clear in showing a consistent increase across incremental and insight problems indicating that the incentive influences a process that is helpful to both types of problem solving. The next experiment was designed to look more closely at what cognitive mechanisms might be influenced by an incentive in incremental and insight problem solving.

3 INCENTIVES, TIME ON TASK, AND DEEPER PROCESSING

3.1 Experiments 2a and 2b

Experiments 1a and 1b were able to demonstrate that an incentive does influence problem solving accuracy, however they did not provide any direct evidence about the mechanism by which the incentive had an effect. Experiments 2a and 2b were designed to test two possible mechanisms.

A possibility not explored in Experiments 1a and 1b is that an incentive leads to an increase in the overall time participants spend on a task. More specifically, it is possible that an incentive leads participants to increase the amount of time they spend solving each problem to ensure that they get the problem right. Research interested in worker productivity has often shown an increase in the amount of time workers spend at their task when they are given an incentive. For example, Saari and Latham (1982) found that in response to an incentive beaver trappers reduced their breaks and spent more time trapping beavers. Similarly, LaMere, et al. (1996) found that truck drivers' increased the amount of time they spent on the job. It is possible then that the increase in problem solving due to the incentive seen in Experiments 1a and 1b is due to an overall increase of time spent on each problem solving task. Note that although in Experiments 1a and 1b participants were given six minutes to solve each problem, it was often observed that participants would not spend all six minutes working on the problem (e.g., they would turn over their sheet indicating that they were finished). Thus although all participants had the same amount of time available to work on a problem, they appeared to choose how much of the available time they spent actually working on the problem. The group format of Experiments 1a and 1b, however, made it difficult to measure individual participants' problem solving duration. In order then to assess whether the incentive might lead to an increase in time spent, problem solving duration was directly measured in Experiments 2a and 2b.

An alternative possible mechanism by which incentives may improve problem solving is that they may encourage a change in thoroughness of processing, rather than a change in time on task. Evidence for deeper processing due to an incentive can be seen in Eysenck and Eysenck (1982). Participants were asked to recall a mixed list of high and low monetary (10 pence and 2 pence, respectively) incentive words. During recall participants where given weak and strong retrieval cues (e.g., "TABLE associated with ______"); determined by word association norms. Results showed that high incentive words were recalled more than low incentive words with weak retrieval cues but there was no effect with strong retrieval cues. Eysenck and Eysenck argued that these findings indicate that low incentive words were processed based only on their most obvious and easily accessible features whereas high incentive words were processed in terms of both easily accessible and less accessible features. It is possible then that the incentive might lead to deeper processing of the problems and results in better memory for the problems for participants in the incentive condition. This was investigated by giving participants a surprise memory test which asked participants to recall all the problems they had attempted so far.

In summary, if the incentive leads to an increase in time spent on each problem solving task then participants in the incentive condition would have longer problem solving durations than participants in the non-incentive condition. It is also possible however that the incentive leads to deeper processing without an increase in time on task which would lead to greater memory for the problems for participants in the incentive condition compared to participants in the non-incentive condition. Experiments 2a and 2b were designed to test these predictions.

Additionally, Experiments 2a and 2b addressed a possible confound in Experiments 1a and 1b. In Experiments 1a and 1b participants in the incentive condition were not only given the opportunity to leave the experiment early but also given feedback regarding their own and other participants' performance on each problem. Participants in the non-incentive condition were given neither the incentive nor any feedback on their problem solving performance. It was possible that the increase in problem solving performance in the incentive condition was not only due to the incentive but also due to the potentially motivating feedback participants received. This potential confound was addressed by eliminating any feedback during the experiment. Participants in the incentive condition were simply told when they could leave the experiment.

3.2 Method

Design. A 2x2 mixed design was used with a between-subjects factor of incentive (given or not) and a within-subjects factor of problem type (incremental and insight).

Participants. Two hundred and eight Michigan State University students participated for course credit in Experiment 2a (mean age 19.2) and 200 in Experiment 2b (mean age 19.1). Again, the majority of the sample was female (154 female, 54 male in Experiment 2a; 151 female, 49 male in Experiment 2b) reflecting the participant pool. No gender effects were found.

Procedure. Participants were randomly assigned to either the incentive or non-incentive condition. They were first given the background questionnaire from the previous experiments, then up to six problems alternating between incremental and insight problems. Since results from Experiment 1a showed no order effects (easy versus hard) we did not investigate this variable in Experiment 2. Unlike in Experiments 1a and 1b, the problems were presented by a computer (as web pages controlled by JavaScript, see Burns & McFarlane, 2003) that recorded participants' solutions (typed into a text box, though scratch paper was available for participants to use throughout the experiment) and the time they submitted them. Participants were given instructions on how to use the computer program and the experimenter took participants step by step through an example problem illustrating the procedure.

Participants were told they would be solving a series of problems and that they would have four minutes to solve each problem. The amount of time given was reduced from the previous experiments because in a pilot study it was found that participants could solve these particular problems in a much shorter time span than some of the problems presented in previous experiments. Participants were instructed to click a button to submit their answer after writing the answer in a textbox. If they wanted to change their answer before the four minutes were up, they could edit their text and re-submit. Pressing a button to submit their answers allowed us to measure the amount of time it took participants to provide an answer. After four minutes the computer automatically moved the participants on to the next screen, recording the last thing that had been written in the text box.

In order to address a potential confound in Experiments 1a and 1b participants in both conditions were not given any feedback regarding their performance after submitting an answer. Participants in the incentive condition were simply told by the experimenter when they could leave the experiment. Problems were presented in the same order to all participants alternating between incremental and insight problems. Participants were told that the experiment would take approximately one hour to complete. In addition, participants in the incentive condition were told that there was a special incentive for their group in that they would be able to leave early if they got four problems correct. After solving the appropriate number of problems, participants were asked to complete a surprise memory question that asked them to write down as many details of each problem as they could remember. There was no time limit for the memory question. Before starting the memory question the experimenter removed any scratch paper the participants might have used.

In Experiment 2a participants were given the memory question at the end of the experiment after completing all of their problems. This created a possible confound given that participants in the incentive condition potentially needed to recall only four problems to receive a perfect recall score (although few actually did get to leave early) whereas participants in the non-incentive condition always had six problems to recall. In Experiment 2b the memory question was always presented after the first four problems, thus all participants then had to try to remember the same number of problems for the memory question. Apart from this change, Experiment 2b was identical to Experiment 2a. Both Experiment 2a and 2b took about 45 minutes to complete.

Materials. A new set of insight and incremental problems were given in Experiments 2a and 2b, the text of which (plus solution rates) can be found in the Appendix A. For both experiments participants received the same two incremental (*Age* problem and *Water* problem) and two insight problems (*Month* problem and *Matchstick* problem) in the same order (*Age* problem, *Month* problem, *Water* problem, and *Matchstick* problem). Participants that did not solve the first four problems correctly and participants in the non-incentive condition completed up to two additional problems (*Job* problem and *Prisoner* problem). Problems were taken from Ash and Wiley (2002), Knoblich, Ohlsson, and Raney (2001), and Metcalfe and Wiebe (1987) and were chosen to match each other in difficulty such that each incremental problem would approximately match an insight problem in difficulty. To confirm this, the solution rate for each problem was first checked in a paper and pencil pilot study (non-incentive) with 64 participants.

3.3 Results

The insight and incremental problems were scored as either right or wrong. Solution rates were similar to the rates found in the paper and pencil pilot study. As in Experiment 1a and 1b participants' insight and incremental scores were calculated using the first four problems presented in the experiment, since participants in the incentive condition might never have attempted the last two problems. As in the previous experiments, most participants attempted all 6 problems (32 participants in the incentive condition got to leave early).

Incentive effects on solution. Table 2 presents the means and standard deviations for insight and incremental scores. A 2x2 analysis of variance was performed on these scores with a between-subjects factor of incentive (present or not) and a within-subjects factor of problem type (insight or incremental). As in the previous experiments there was a significant effect of the incentive (Experiment 2a, $F[1, 206] = 6.96$, $p < .01$, $MS_e = .17$; Experiment 2b, $F[1, 198] = 8.53$, $p < .01$, $MS_e = .19$) and a significant difference between the two problem types, insight and incremental but only in Experiment 2b (Experiment 2a, $F[1, 206] = .03, p < .87, MS_e = .01$; Experiment 2b, $F[1, 198] = 4.28, p < .01, MS_e = .39$). However there again was no interaction between problem type and incentive (Experiment 2a, $F[1, 206] = .23, p = .63, MS_e = .09$; Experiment 2b, $F[1, 198] = 1.98, p = .16, MS_e = .09$) and all other effects and interactions with problem type were not significant.

	Incremental	Insight
Experiment 2a		
Non-incentive (n = 104)	.51 (.37)	.52 (.37)
Incentive (n = 104)	.63 (.35)	.61 (.35)
Experiment 2b		
Non-incentive (n = 100)	.44 (.36)	.55 (.38)
Incentive (n = 100)	.61 (.39)	.63 (.36)

Table 2. Mean incremental and insight scores (standard deviations in parentheses) for Experiments 2a and 2b.

Problem solving duration. In order to further investigate the effects of the incentive participants' problem solving duration was recorded. Problem solving duration for correct answers was determined by analyzing the first time that participants answered the problem correctly. If an incorrect solution was submitted, then problem solving duration was determined by taking the time for the last unique answer provided. (Participants would often submit their final answer several times because pressing the submit button gave them an indication of how much time was left before the computer would move them on to the next problem). If participants did not submit an answer before the four minutes were up, their answer was scored as incorrect and a time of four minutes was assigned. Table 3 presents mean durations for each incentive condition both across and broken down by problem type. Only the durations of the first four problems were analyzed.

	Incremental	Insight
Experiment 2a		
Non-incentive	175.1 (58.4)	145.9 (79.5)
Incentive	180.3 (60.1)	144.7 (78.2)
Experiment 2b		
Non-incentive	173.8 (59.5)	146.2 (76.9)
Incentive	177.4 (61.7)	151.6 (77.1)

Table 3. Mean problem solving duration in seconds (standard deviations in parentheses) for incremental and insight problems in the non-incentive and incentive conditions for Experiments 2a & 2b.

In order to investigate whether participants' problem solving duration differed for problems they got correct compared to problems they got incorrect a 2x2x2 analysis of variance on problem solving duration was performed with incentive (given or not), problem type (insight or incremental), and whether or not the problem was solved correctly (correct or incorrect). An analysis that includes correctness is important because correctness could have a complex relationship with duration. However, in order to analyze the correct/incorrect factor each problem for each participant has to be treated as a single case. This is not an ideal way of analyzing the problem solving data because it creates a large number of cases that could lead to significant differences that are in reality very small. Unfortunately, there are no other analyses that can be used to look at the connection between problem solving duration and problem correctness as they are directly linked. In both experiments participants in the incentive condition had statistically significantly greater problem solving durations than participants in the non-incentive condition (Experiment 2a, $F[1, 824] = 6.6$, $p < .05$, $MS_e = 3332.05$; Experiment 2b, $F[1, 792] = 9.75$, $p < .01$, $MS_e = 3545.27$). However as Figure 1 shows, these difference were only a few seconds out of a total possible time of 240s. The smallness of these effects is illustrated by the effect sizes: $d = .03$ for Experiment 2a, $d = .06$ for Experiment 2b. Despite the statistically significant effects of incentive on duration, they seem too small to explain the large (averaging 21.6% across all experiments) increases in problem solving when an incentive was given.

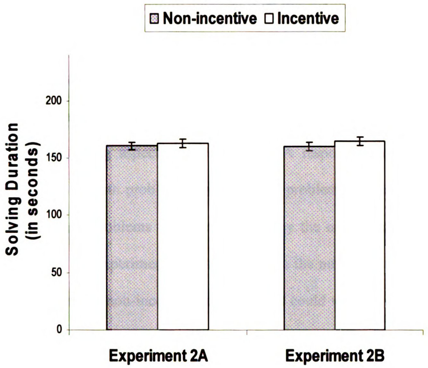

Figure 1. Mean problem solving duration for participants in the non-incentive and incentive condition for Experiments 2a and 2b. Error bars represent standard errors.

Participants consistently spent more time on incremental problems than insight problems and on problems they got correct. However, there were no statistically significant interactions between incentive and problem type or problem correctness. There was a significant interaction between problem type and correctness (Experiment 2a: $F[1, 824] = 8.67, p < .01, MS_e = 3332.05$, Experiment 2b: $F[1, 792] = 8.16, p < .01, MS_e = 3545.27$) indicating that participants spent less time on insight problems when they got them correct. This is consistent with the nature of insight problem solving as duration depends on when the insight occurs, rather than requiring time to work through a procedure for arriving at the solution.

Memory. The memory question was a free recall measure designed to investigate participants' memory for the problems that they had just attempted. Several analyses were run using the information obtained from the memory measure.

First a *coarse memory* measure was created that was the proportion of all the problems that participants had any memory of. All problems were scored blind to condition, and a problem was counted as remembered if the participant mentioned any unique, identifying aspect of the problem. A response that only mentioned that the problem was a math problem or an equation problem was not counted as remembered. The number of problems was then divided by the number of problems the participant attempted in the experiment. In Experiment 2a the number attempted was always six for participants in the non-incentive condition but could vary between four and six for those in the incentive condition depending on whether they solved enough problems to leave early (35% did less than six). In Experiment 2b the memory question was given to all participants after their fourth problem, thus all had attempted the same number of problems when their memory was tested, regardless of condition.

A 2x2 analysis of variance was run on the *coarse memory* measure with incentive (given or not) and problem type (incremental and insight) as factors (see Table 4). For both Experiment 2a and Experiment 2b a significant effect for incentive was found (Experiment 2a: $F\,(1, 206) = 7.15, p < .01, MS_e = .04$, Experiment 2b: $F(1, 198) = 6.31, p < .05, MS_e = .03$). There was no effect of problem type (Experiment 2a: $F\,(1, 206) = 1.36$, $p = .24, MS_e = .06$, Experiment 2b: $F[1, 198] = .40, p = .53, MS_e = .03$) nor an interaction between problem type and incentive (Experiment 2a: $F\,(1, 206) = .80, p = .37, MS_e = .06$, Experiment 2b: $F[1, 198] = .90, p = .35, MS_e = .03$). As Figure 2 shows participants in the incentive condition remembered a greater proportion of the problems than participants in the non-incentive condition regardless of problem type. In order to be able to compare the effect of incentives on problem solving duration and the memory measure, effect size was again calculated. In both Experiment 2a and 2b the incentive had a small to medium effect on the coarse memory measure (Experiment 2a: d = .37, Experiment 2b: d = .36), indicating that the incentive had a greater effect on memory than on problem solving duration.

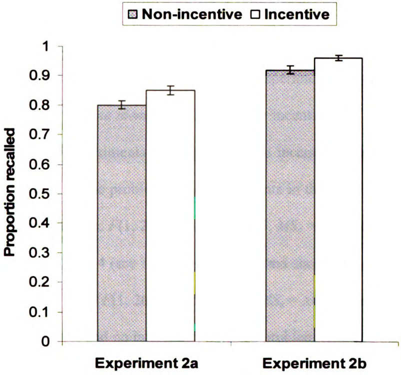

Figure 2. Proportion of problems recalled (coarse memory measure) for participants in the non-incentive and incentive condition for Experiments 2a and 2b. Error bars represent standard errors.

For the coarse memory measure participants only had to refer to a problem for it to be counted as remembered, however, participants' responses would often be much more elaborate. In order to get a better sense of participants' responses, a *fine memory* measure was also created by scoring the participants' responses to the memory questions for the amount of detail or descriptiveness, of each problem. Two raters, blind to condition, independently scored each of the problem responses on a rating scale ranging from 1 to 4 designed to differentiate between the amounts of detail participants provided. A score of 1 was assigned to responses with very little or no detail about a problem, while a score of 4 was given to responses that had all or almost all the details of a problem (see Appendix B for details). If participants did not mention a problem at all a score of 0 was assigned for that particular problem. Scoring of the fine measure is more subjective than the coarse measure, but inter-rater reliability was found to be satisfactory for both experiments (Experiment 2a: $K = .88$, Experiment 2b: $K = .86$). A 2x2 analysis of variance of the *fine memory* measure using incentive and problem type as factors found that in both experiments participants in the incentive condition provided more detailed descriptions of the problems than participants in the non-incentive condition (see Figure 3), Experiment 2a: $F(1, 206) = 5.85, p < .05, MS_e = 1.5$, Experiment 2b: $F(1, 198) = 4.11, p < .05, MS_e = 1.4$ (see Table 3 for means and standard deviations). There was no effect for problem type ($F[1, 206] = .95, p = .33, MS_e = .62$, Experiment 2b: $F[1, 198] = .06, p = .81, MS_e = .40$) and no interaction between problem type and incentive ($F[1, 206] = .41, p = .52, MS_e = .62$, Experiment 2b: $F[1, 198] = .01, p = .99, MS_e = .40$).

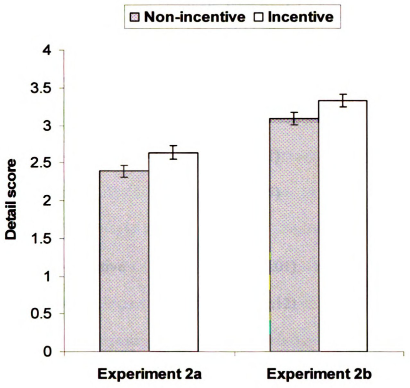

Figure 3. Mean amount of problem detail given (fine memory measure) for participants in the non-incentive and incentive condition for Experiments 2a and 2b. Error bars represent standard errors.

Again, effect size was calculated and was found to be a small to medium effect (Experiment 2a: d = .29, Experiment 2b: d = .29). Thus, across the two experiments, participants in the incentive condition displayed better memory for the problems whether their memories were scored using a loose criterion (coarse memory measure) or a strict criterion (fine memory measure) than participants in the non-incentive condition. Most importantly, both of these problem memory measures showed substantially larger effect sizes than problem solving duration.

	Incremental	Insight
Experiment 2a		
Coarse		
Non-incentive	.83 (.21)	.78 (.21)
Incentive	.86 (.25)	.85 (.21)
Fine		
Non-incentive	2.38 (1.01)	2.40 (.94)
Incentive	2.62 (1.12)	2.75 (1.08)
Experiment 2b		
Coarse		
Non-incentive	.93 (.19)	.92 (.17)
Incentive	.95 (.15)	.98 (.11)
Fine		
Non-incentive	3.08 (.99)	3.10 (.94)
Incentive	3.32 (.96)	3.34 (.89)

Table 4. Mean memory scores (standard deviations in parentheses) for the coarse and fine measure for incremental problems, insight problems, and their totals across both problem types in Experiments 2a & 2b.

3.4 Discussion

Experiments 2a and 2b were designed to investigate the mechanisms by which incentives influence problem solving. Results replicated the findings from Experiments

1a and 1b, showing that the "leave early" incentive increased problem solving performance, and provided further evidence that incentives do influence cognitive processes. Additionally, Experiments 2a and 2b replicated the finding that the incentive influenced incremental and insight problems equally, as performance on both problem types increased in the incentive condition. These results provide evidence that findings from Experiments 1a and 1b were not simply caused by a confound in the incentive condition (participants receiving feedback), instead it shows that the incentive (the opportunity to leave the experiment early) alone is a strong motivator.

Critically, Experiments 2a and 2b produced evidence for incentives leading to an increase in performance via deeper processing of information. It was found that participants in the incentive condition had greater memory for each of the problems they attempted than participants in the non-incentive condition. Yet the incentive had only a very small effect on a measure of how much time participants spent trying to solve each problem. This suggests that incentives affect problem solving by leading to more though processing of information rather than simply by increasing time spent on the task.

4 INCENTIVES AND ATTENTION

Experiments 2a and 2b provided evidence that participants in the incentive condition engaged in deeper processing of the problems than participants in the non-incentive condition. The question then becomes what is the cognitive mechanism behind this increase in processing? Attention has been shown to be an important factor for recall performance (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Logan & Etherton, 1994; Logan, Taylor, & Etherton, 1996; Naveh-Benjamin, Craik, Guez, & Dori, 1998). More specifically, it has been shown that attention during encoding is essential for successful processing and retrieval as large decrements in retrieval can be seen when attention is divided during encoding (e.g., Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Naveh-Benjamin, Craik, Guez, & Dori, 1998). Perhaps the increase in memory for participants in the incentive condition in Experiments 2a and 2b was due to an increase in attention to the problem solving task. Research on goal setting has shown that participants shift their resources and attention to goal relevant information and away from goal irrelevant information (e.g., Rothkopf & Billington, 1979). Since incentives usually encompass a goal, as well as a reward, it is possible that incentives also lead to an increase in attention to the rewarded task. In Experiments 2a and 2b participants in the incentive condition recalled more problems in more detail, indicating deeper processing. Given the importance of attention during encoding it is possible then that participants given an incentive allocated more attention to the problem solving task compared to participants not given an incentive.

In order to test this possibility a dual-task approach was tested in Experiment 3. It has been shown that performing two tasks with similar resource requirements simultaneously will lead to decrements in task performance (Navon & Gopher, 1979; Wickens, 1980, 1984). Giving participants a task that taxes the same cognitive resources as problem solving should therefore affect performance. A dual-task approach then can be used to investigate if incentives lead to an increase in attention to the rewarded task. If incentives during single task performance normally lead to an increase in attention to the rewarded task then taxing participants' attentional resources with a problem solving task and a secondary task at the same time may lead to two possible outcomes. Participants may shift all their attention to the problem solving task and ignore the concurrent tone monitoring task, as suggested by the goal setting literature. On the other hand, it is possible that incentives only cause a shift of additional or spare attentional resources to the rewarded task. This then would lead to the elimination of the problem solving advantage seen for participants in the incentive condition.

There has been virtually no research investigating secondary task effects on problem solving. One exception however is a study by Lavric, et al. (2000) that recorded ERP responses while participants solved what the authors referred to as an incremental problem (a version of the Wason card selection task) and an insight problem (Duncker's candle problem) while concurrently counting auditory stimuli. It was found that incremental problem solving performance was impaired by the concurrent counting task however insight problem solving was not. Additionally, at the electrophysiological level peak and time-window average P300 (a measure sensitive to working memory function) showed greater amplitude in the frontal region in response to counting tones during incremental problem solving compared to insight problem solving and the counting task alone. Since P300 is a measure reflecting working memory, Lavric, et al. believe that these findings show greater competition for working memory resources between the concurrent counting task and the incremental problem task than the insight problem task. It is possible then that a secondary task might tax incremental and insight problems differently. In order to investigate this possibility Experiment 3 retained both incremental and insight problems despite the null problem type effects found in Experiments 1a and 1b as well as Experiments 2a and 2b.

Even though there has been very little research on secondary task effects in problem solving there has been research looking at secondary task effects on reasoning. Overall findings in this literature are consistent with Navon and Gopher (1979) and Wickens (1980, 1984) that performance decrements are seen when the two tasks have the same resource requirements and therefore tax the same resources. For example Farmer, et al. (1986) found small disruptive effects of concurrent articulation on simple grammatical reasoning tasks but not on simple visuospatial reasoning tasks. A concurrent spatial task on the other hand led to disruptive effects on a visuospatial task but not on a grammatical reasoning task. Similarly, Gilhooly, et al. (1993) found that syllogistic reasoning was disrupted by concurrent random number generation and to a lesser extent articulatory suppression, but not at all by the visuospatial task that involved tapping.

4.1 Experiment 3

If a dual-task approach is going to be used to investigate incentive effects on attention in problem solving, then it is important to find a secondary task that will tax the same attentional resources as the incremental and insight problem used in Experiments 2a and 2b. Problem solving involves maintaining information and goals in memory, comparing new information to stored information, inhibiting irrelevant pieces of information, monitoring and evaluating ones progress towards goals, and planning and executing responses (Hambrick & Engle, 2003). These problem solving components involve executive processes responsible for maintenance of information, monitoring, updating and checking, inhibiting irrelevant information, and planning responses and actions (based on Baddeley & Hitch, 1974; Baddeley, 2002; Smith & Jonides, 1999). In this experiment a concurrent tone monitoring task was used because of its similar task requirements to problem solving. More specifically, participants were asked to listen to a series of tones and respond by pressing a foot pedal every time they heard a target tone. This concurrent tone task requires the maintenance of a target tone in memory which like problem solving involves executive processes for the continued maintenance of the tone. Comparing each test tone to the target tone held in memory involves executive processes involved in checking and comparing while withholding or inhibiting responses to distracter tones relies on executive processes involved in inhibition and monitoring. Finally, as in problem solving, planning and executing a response to a target tone also involves executive processes responsible for planning and task management. These similarities in the two tasks' resource requirements should lead to decrements in task performance in both the problem solving tasks and the concurrent tone monitoring task.

Experiment 3 was designed to investigate the impact of the concurrent tone monitoring task on problem solving. It was predicted that if the concurrent tone monitoring task has similar resource requirements as problem solving then decrements in problem solving performance should be seen. Additionally, if this is the case decrements in tone monitoring performance should also be seen when participants are performing the tone monitoring task while solving problems compared to participants performing the tone monitoring task alone. Since there has been very little work looking at secondary task effects on problem solving Experiment 3 was also designed to test different parameters for the concurrent tone task. Participants were presented with either a 2-tone monitoring task (their target tone and another tone) or a 3-tone monitoring task (their target tone and two other tones) to determine whether or not difficulty of the concurrent tone monitoring task varied across these two conditions. Additionally, participants' target tone was varied such that some participants in the 2-tone condition could be given either the low tone or the high tone as their target. In the 3-tone condition participants could be given either the low, medium, or high tone as their target. Target tone was varied in order to determine if any of the tones used in the task were more or less distinguishable from each other; potentially causing performance differences across target tone.

4.1.1 Method

Design. A 2x2x2 mixed design was used with between-subjects factors of task (single task or dual-task) and number of tones (two or three), and a within-subjects factor of problem type (incremental and insight). Participants in the single task condition only solved incremental and insight problems while participants in the dual-task condition solved incremental and insight problems and performed the tone task with either two or three tones simultaneously. All participants completed the tone task (either two or three tones) by itself before and after the problems. Additionally, participants' target tone was manipulated. Participants in the 2-tone condition received either the low tone or the high tone as their target. Participants in the 3-tone condition received either the low tone, medium tone, or high tone as their target.

Participants. One hundred and thirty Michigan State University students participate in Experiment 3 for course credit (mean age 19.38). The majority of the sample was female (103 female, 27 male). No gender effects were found.

Procedure. Participants were randomly assigned to either the single task (n = 65) or dual task condition (n = 65). After obtaining consent participants completed the background questionnaire used in the previous experiments. Participants were given an overview of the experiment and then instructed on how to use the computer program. The computer program used in this experiment was the same as in Experiments 2a & 2b except that it was modified to accommodate the dual-task aspect of this study. The experimenter took participants step by step through an example problem solving task illustrating the procedure. Participants were told they would be solving a series of problems and that they would have four minutes to solve each problem. Participants were instructed to click a button to submit their answer after writing the answer in a textbox. If they wanted to change their answer before the four minutes were up, they could edit their text and re-submit. As in Experiments 2a & 2b, after four minutes the computer automatically moved the participants on to the next screen, recording the last thing that had been written in the text box.

After explaining the problem solving procedure, the experimenter explained the tone monitoring task. Each participant put on headphones and the target tone was played three times at an interval of one tone every two seconds. Participants then completed a practice tone monitoring task where they were asked to press a foot pedal every time they heard the target tone. Participants would be presented with one tone every two seconds and were either given two different tones (their target tone and another tone) or three different tones (their target tone and two other tones). The target tone was either one of the two or three tones presented and was determined randomly. Similarly, whether participants were in the 2-tone or 3-tone condition was determined randomly. The computer randomly generated the sequence of tones presented to each participant. The practice tone monitoring task lasted for two minutes. After the practice task the experimenter checked each participants hit rate. If the hit rate was less than ninety percent participants were asked to listen to the target tone again and repeat the practice task. After everyone successfully completed the practice tone monitoring task, participants were presented with the actual tone monitoring task. The tone monitoring task was exactly the same as the practice task except that participants were presented with tones for four minutes. Again participants were reminded to hit the foot pedal every time they hear the target tone.

After the tone monitoring task participants were given an easy incremental practice problem and were reminded of the problem solving instructions. Participants in the dual-task condition were told that they would have to solve the problem and do the tone monitoring task concurrently. Participants in the single task condition were simply told to solve the problem. After completing the practice problems participants were asked if they had any more questions, then they were presented with an additional four problems (two incremental and two insight) in four different orders. Note all participants in this experiment attempted only four problems, unlike in the previous experiments where participants could potentially attempt up to six problems. Each order ensured that participants would be presented with incremental and insight problems in an alternating fashion. Participants in the dual-task condition engaged in the tone monitoring task at the same time as solving all four problems. Participants in the single task solved all the problems without hearing tones. Between each problem participants were presented with a screen that gave them the opportunity to listen to their target tone again. Participants clicked on a link to move on to the next problem whenever they were ready.

After finishing all the problems participants were asked to complete the surprise memory question that asked them to write down as many details of each problem as they could remember. As in the previous experiments, there was no time limit for this particular question and participants were not presented with tones. If participants had used any scratch paper while solving the problems the experimenter removed it before the participant started the memory question.

To test for possible tone task practice effects, participants then completed the tone monitoring task again. Each participant regardless of condition was asked to listen to their target tone one more time and then they completed the tone task. The tone monitoring task lasted four minutes and the characteristics of the task (but not the actual series of tones) were identical to the tone task participants completed earlier. Once participants were done with the final tone monitoring task they were debriefed and sent on their way. The experiment lasted about 60 minutes.

Materials. The first four problems from Experiments 2a and 2b were used, the text of which can be found in the Appendix A. Since a new methodology was used, problem order was manipulated to ensure that there are no order effects in a dual-task context. Problems were presented in four different orders such that participants received the two incremental (*Age* problem and *Water* problem) and two insight problems (*Month* problem and *Matchstick* problem) in an alternating fashion.

A concurrent auditory tone monitoring task was used as a secondary task while problem solving. The tone monitoring task was based on work by Beilock, et al. (2004) and Beilock, et al. (2002) which have shown decrements in primary task performance due to a similar tone monitoring task. The tone task in this experiment asked participants to listen to a series of tones and press a foot pedal every time they heard a target tone. The series of tones was randomly generated by the computer program that also presented participants with the problem solving tasks. The tones (500 ms each) occurred once every two seconds. The series of tones was composed of either two tones (a low tone and a high tone) or three tones (a low tone, a medium tone, and a high tone). The tones chosen were 300 hertz, 900 hertz, and 1500 hertz. Participants were randomly assigned to one of these tones as their target tone.

4.1.2 Results

The insight and incremental problems were again scored as either right or wrong. As in the previous experiments participants' insight and incremental scores were calculated using the four problems presented in the experiment.

Dual-task effects on solution. Table 5 presents the means and standard deviations for insight and incremental scores.

	Incremental	Insight
Single task		
2-tones (n = 29)	.55 (.39)	.41 (.33)
3-tones (n = 36)	.65 (.33)	.50 (.38)
Dual-task		
2-tones (n = 25)	.40 (.32)	.36 (.37)
3-tones (n = 40)	.50 (.39)	.35 (.30)

Table 5. Mean incremental and insight scores (standard deviations in parentheses) in the single and dual-task 2-tones and 3-tones conditions for Experiment 3.

A 2x2x2 analysis of variance was performed on the incremental and insight scores with a between-subject factors of task (single or dual), and number of tones (two or three), and a within-subjects factor of problem type (insight and incremental). Results showed that there was no evidence of an effect of order ($F[3, 126] = .15$, $p = .21$, $MS_e = .22$) nor any interactions with order. Therefore all further analyses in this experiment will be presented pooled over this factor. There was a significant effect of the task ($F[1, 126] = 7.00$, $p = .009$, $MS_e = 1.02$) such that performance under dual-task conditions decreased for both incremental and insight problem solving (see Figure 4). These findings indicate that the concurrent tone monitoring task has similar resource requirements as problem solving which led to the decrease in solution rate. There was also a significant difference between the two problem types, insight and incremental ($F[1, 1268] = 8.66$, $p = .004$, $MS_e = .91$) where incremental problems had a higher solve rate than insight problems. It was attempted to match problem difficulty between incremental and insight problems, however, solution rates of problems often differ between samples and can therefore be difficult to match perfectly. There was a slight trend for the number of tones (F[1, 126] = 2.08, p = .15, MS_e = .30) such that participants' solve rate in the 2-tone condition was lower than in the 3-tone condition (see Table 5). This may indicate that the 2-tone condition is more similar to the concurrent tone monitoring task and therefore causes a greater decrease in problem solving than the 3-tone condition. This possibility will be discussed further in the discussion section of this study. Unlike Lavric, et al. (2000) there was no interaction between task and problem type (F[1, 126] = .38, p = .54, MS_e = .04), indicating that the secondary task did not influence incremental and insight problem solving differently. Reasons why Lavric, et al.'s results were not replicated in this study will be discussed in the discussion section following this experiment. All other interactions were also not significant. Overall the decrease in problem solving seen for both incremental and insight problems indicates that the concurrent tone monitoring task seems to have similar resource requirements as problems solving.

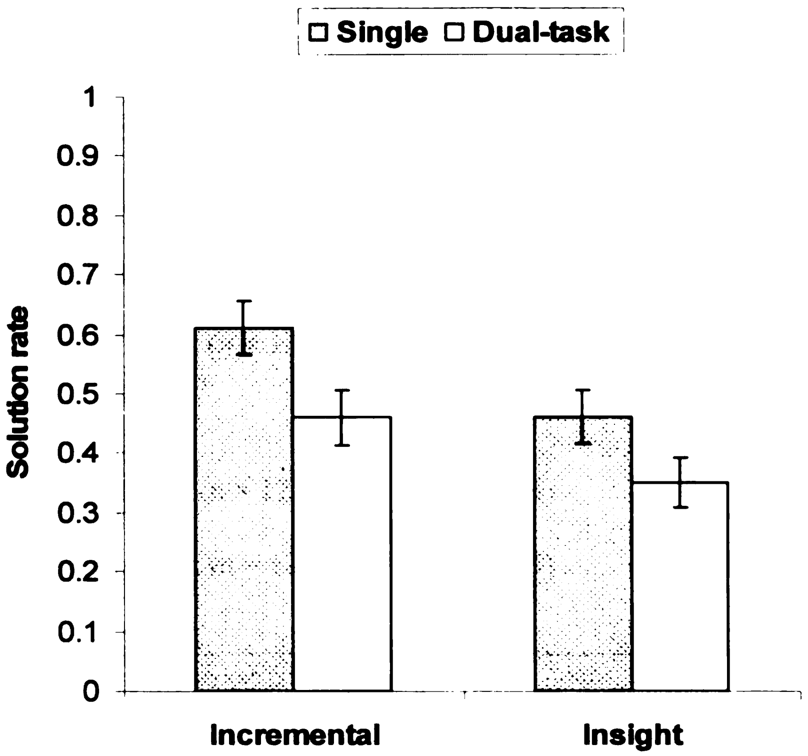

Figure 4. Mean solution rates for incremental and insight problems in the single and dual-task conditions for Experiment 3. Error bars represent standard errors.

In order to investigate whether the target tone influenced solution rate two analyses were run, one analysis for participants in the 2-tone condition and one for participants in the 3-tone condition. One large analysis obviously could not be run as there would be a missing cell in the 2 tone condition since participants could never have gotten the medium target tone. A 2x2x2 analysis of variance was performed on the incremental and insight scores for participants in the 2-tone condition with between-subjects factors of task (single or dual) and target (low or high), and a within-subjects factor of problem type (insight and incremental). Results showed that there was no effect of target ($F[1, 50] = 1.13, p = .30, MS_e = .14$) nor any significant interactions with target. These findings indicate that problem solving performance did not differ across target for participants in the 2-tone condition (see Table 6).

	Incremental	Insight
Single task		
low target (*n* = 16)	.50 (.45)	.34 (.24)
high target (*n* = 13)	.62 (.30)	.50 (.41)
Dual-task		
low target (n = 12)	.29 (.26)	.46 (.40)
high target (n = 13)	.50 (.35)	.27 (.33)

Table 6. Mean incremental and insight scores (standard deviations in parentheses) for participants in the 2-tone condition across target for Experiment 3.

Looking at participants in the 3-tone condition, a 2x3x2 analysis of variance was performed on incremental and insight scores with between-subjects factors of task (single or dual) and target (low, medium, or high), and a within-subjects factor of problem type (insight or incremental). In this condition there again, was no effect of target ($F[2, 70] = 1.23$, $p = .30$, $MS_e = .19$). However there was a trend for the interaction between task and target ($F[2, 70] = 2.62$, $p = .08$, $MS_e = .40$) such that solution rates for participants in the dual-task condition were lower when they were given the medium or high target tone than the low target tone (see Table 7). These findings might be due to the confusability of the medium and high tone. Whereas the tones chosen for the tone task were equally spaced in terms of frequency, subjectively the medium and high tone sounded much more similar to each other than the low tone. It should also be noted that the power for this analysis is very low and therefore the results should be interpreted with caution.

	Incremental	Insight
Single task		
low target (n = 13)	.65 (.32)	.50 (.41)
medium target (n = 13)	.69 (.38)	.58 (.34)
high target (n = 10)	.60 (.32)	.40 (.39)
Dual-task		
low target (n = 13)	.69 (.33)	.42 (.28)
medium target (n = 13)	.35 (.43)	.23 (.26)
high target (n = 14)	.46 (.37)	.39 (.35)

Table 7. Mean incremental and insight scores (standard deviations in parentheses) for participants in the 3-tone condition across target for Experiment 3.

Problem solving duration. As in Experiments 2a and 2b problem solving duration was again determined for the last unique answer provided. A 2x2x2x2 analysis of variance on problem solving duration (in seconds) was performed with between-subjects factors of task (single or dual), problem type (insight or incremental), number of tones (2 or 3), and whether the problem was solved correctly (correct or incorrect). In order to analyze the correct/incorrect factor each problem for each participant was again treated as a single case (for means and standard deviations see Table 8).

	Incremental	Insight
Single task		
2-tones (n = 58)	168.88 (67.65)	165.36 (84.56)
3-tones (n = 72)	161.27 (66.16)	152.47 (77.10)
Total (n = 130)	164.67 (66.68)	158.22 (80.45)
Dual-task		
2-tones (n = 50)	183.08 (54.53)	171.59 (98.57)
3-tones (n = 80)	170.88 (63.17)	163.34 (75.51)
Total (n = 130)	175.57 (60.07)	166.51 (84.85)

Table 8. Mean problem solving duration in seconds (standard deviations in parentheses) for incremental and insight problems in the single task and dual-task conditions divided by number of tones for Experiment 3.

Examining the effect of the concurrent tone monitoring task on problem solving duration it was found that there was no effect of task (F[1, 504] = .01, p = .93, MS_e = 31.69). Participants' problem solving duration did not increase in the dual-task condition (M = 171.04, SD = 73.51) compared to the single task condition (M = 161.44, SD = 73.81). These findings indicate that the concurrent tone monitoring task did not influence problem solving duration. There was a significant main effect for correctness, (F(1, 504) = 151.87, p < .01, MS_e = 640521.90) such that participants spent less time on problems they got correct (M = 129.3, SD = 66.46) than on problems they got incorrect (M = 199.15, SD = 63.73). In order to make sure that this effect was not only caused by those participants that did not answer a problem and were therefore assigned the maximum amount of time (240 seconds) the same analysis was run excluding cases where participants took all the time allotted. The exact same pattern of results was found. Participants also spent significantly more time solving incremental problems (M = 170.12, SD = 63.57) than insight problems (M = 162.36, SD = 82.62), $F(1, 504) = 9.65$, p = .002, MS_e = 40721.32. This difference however was only eight seconds which is relatively small given the total amount of problem solving time available. Number of tones did not influence problem solving duration differently, (F[1, 504] = .38, p = .54, MS_e = 1617.28). As for solution rate the interaction between task and problem type was not significant (F[1, 504] = .00, p = .97, MS_e = 5.62), again indicating that task did not influence incremental and insight problem solving differently. Any other interactions were also not significant.

Again two separate analyses were run to determine whether or not the different target tones influenced problem solving duration differently. A 2x2x2x2 analysis of variance was performed on problem solving duration for participants in the 2-tone condition with factors of task (single or dual), target (low or high), problem type (insight or incremental), and whether or not the problem was solved correctly (correct or incorrect). Target tone did not affect problem solving duration (F[1, 200] = .85, p = .36, MS_e = 4007.91) and the interaction between task and target (F[1, 200] = 2.87, p = .19, MS_e = 13532.94) was not significant.

Looking at participants in the 3-tone condition, a 2x3x2x2 analysis of variance was performed on problem solving duration with factors of task (single or dual), target (low, medium, or high), problem type (insight or incremental), and whether or not the problem was solved correctly (correct or incorrect). There also was no effect of target tone (F[1, 280] = .82, p = .44, MS_e = 3134.76) and no significant interactions with target. These findings indicate that problem solving duration did not differ across target tone for participants in the 3-tone condition.

Secondary task performance - accuracy. Performance on the tone monitoring task was analyzed for when participants were performing the task alone at the beginning of the experiments and at the end of the experiment. In order to investigate the impact of the problem solving task on the tone monitoring task participants performance while solving incremental and insight problems was also analyzed.

In order to assess performance on the concurrent tone monitoring task at the beginning of the experiment, participants' hit rate (the proportion of target tones correctly identified) and false alarm rate (the proportion of tones incorrectly judged to be the target tone) was calculated. Participants were given the tone-monitoring task by itself before attempting any problems. Overall, tone accuracy (the hit rate minus the false alarm rate, M = .94, SD = .18) was significantly different from zero (t[128] = 59.52, $p < .01$, MS_e = .02) indicating that participants were able to reliably detect the target tone when given the tone task by itself. No difference in performance was found between participants in the 2-tone condition (M = .96, SD = .17) and participants in the 3-tone condition (M = .93, SD = .19), F (1,127) = .51, p = 48, MS_e = .02. Looking at target effects, there was a trend (F[1, 54] = 2.92, p = .09, MS_e = .08) for participants in the 2-tone condition such that participants given the high target tone (M = .92, SD = .24) were less reliable at detecting than participants given the low target tone (M = .99, SD = .01). There was also a trend for participants in the 3-tone condition (F[2, 740] = 2.3, p = .11, MS_e = .08) such that participants in the medium tone condition (M = .88, SD = .29) were less reliable than participants in the high tone (M = .93, SD = .14) and low tone condition (M = .99, SD = .02) at the detecting the target tone.

In order to determine the impact of the problem solving task on participants' accuracy on the tone task, participants' tone task performance while solving problems was compared to their tone task performance only both at the beginning and at the end of the experiment. Participants were given four minutes to solve each problem and were asked to respond to the tone task for the whole four minutes. However, in order to get an accurate reflection of participants' performance on the secondary task while they were actually solving problems (not just responding to the tone task while waiting for the computer to move them on to the next problem) performance on the secondary task was tied to participants' submission of their answers. More specifically, participants hit rate and false alarm rate was calculated up to the point when participants submitted their last unique answer. (This point in time also corresponds to participants' problem solving duration.) An incremental and insight problem hit rate and false alarm rate were then calculated by averaging across the hit rates and false alarm rates for the incremental and insight problems. Again the false alarm rate was subtracted from the hit rate to calculate a tone accuracy measure. A 2x4 analysis of variance was run on the accuracy measure with a between subjects factor of number of tones (2 or 3) and a within subjects factor of dual performance (tone only beginning, tone incremental, tone insight, and tone only end).

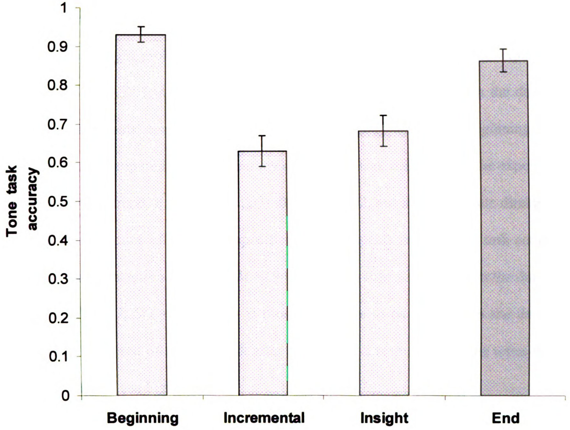

Figure 5. Mean tone task accuracy in Experiment 3 for the tone task at the beginning of the experiment, the tone task while solving incremental problems, the tone task while solving insight problems and the tone task at the end of the experiment. Error bars represent standard errors.

There was a main effect of dual performance ($F[3, 11] = 12.89, p <.01, MS_e = .60$). Post-hoc tests showed that tone detection accuracy while participants were solving incremental problems ($t[47] = 8.46, p < .01, MS_e = .04$) was significantly lower than accuracy for the tone task alone at the beginning of the experiment. The same was true for tone task accuracy during insight problem solving ($t[46] = 7.11, p < .01, MS_e = .04$). There was no difference in tone detection accuracy between incremental and insight problems ($t[38] = -1.83, p = .21, MS_e = .02$). Participants' accuracy on the tone task during incremental problem solving was also significantly lower than on the tone task at the end of the experiment, $t(47) = -4.68$, $p < .01$, $MS_e = .05$. Tone detection accuracy was also lower while solving insight problem compared to the tone task at the end of the experiment, $t(47) = -3.61$, $p = .001$, $MS_e = .05$. In order to test for practice effects in the dual-task condition participants' tone detection accuracy for the tone task at the beginning of the experiment was compared to their accuracy on the tone task at the end of the experiment. Results showed a trend, $t[126] = 1.75$, $p = .08$, $MS_e = .02$, but in the opposite direction as predicted by a practice effect. More specifically, participants in the single task condition had greater tone detection accuracy ($M = .94$, $SD = .21$) than participants in the dual-task condition ($M = .87$, $SD = .30$). This is most likely due to participants in the dual-task condition getting tired of the tone task after listening and responding to the tones for the whole experiment, see Figure 5.

In the overall analysis there was also a trend for number of tones ($F[1, 37] = 3.13$, $p = .09$, $MS_e = .39$) such that participants in the 2-tone condition were more accurate overall ($M = .86$, $SD = .12$) than participants in the 3-tone condition ($M = .72$, $SD = .25$) The interaction between number of tones and dual performance was found not to be significant ($F[3, 111] = .27$, $p = .85$, $MS_e = .01$). An analysis looking at the effects of tone accuracy based on target tone for both the 2-tone and 3-tone condition was not possible due to extremely small cell sizes.

In order to test whether participants in the dual-task condition traded off their performance on the tone task for their performance on the problem solving task a 2x2x2 analysis of variance on tone response time was performed with between-subjects factors of problem type (insight or incremental), number of tones (2 or 3), and whether or not the problem was solved correctly (correct or incorrect). In order to analyze the correct/incorrect factor participants tone task accuracy for each individual problem was again treated as a single case. Results showed that there were no effects of correctness (F[1, 210] = .20, p = .15, MS_e = .20) indicating that participants were not more likely to ignore the tone task when they got a problem correct than when they got a problem incorrect.

Overall the results indicate that problem solving influences tone monitoring accuracy. When participants were solving problems their tone monitoring accuracy decreased providing further evidence that problem solving and the tone monitoring task have similar resource requirements.

Secondary task performance – response time. Participants' response time to the target tone was measured both while performing the tone task only and while solving the problems. For this particular measure only the response time for hits was analyzed because there were very few false alarms with reliable response times. Response times were taken up until the participants submitted their final solution; then an average response time for hits was created. A 2x4 analysis of variance was run on response time (in milliseconds) with a between subjects factor of number of tones (2 or 3) and a within subjects factor of dual performance (tone only beginning, tone incremental, tone insight, and tone only end). There was an overall main effect of dual performance (F[3, 63] = 19.56, $p < .01$, MS_e = 260953.58). Post-hoc tests revealed that participants responded slower to the target tone while solving incremental problems than when only performing the task at the beginning (t[22] = 5.81, $p < .01$, MS_e = 35.812) and at the end of the experiment (t[22] = 5.19, $p < .01$, MS_e = 43.28). This was also the case comparing tone response times for the tone task at the beginning ($t[23] = 6.09$, $p < .01$, $MS_e = 29.43$) and the end ($t[23] = 6.17$, $p < .01$, $MS_e = 32.61$) to response times during insight problem solving. There was no difference in tone response times between incremental and insight problems ($t[22] = 1.27$, $p = .22$, $MS_e = 29.86$) nor between the tone task at the beginning of the experiment and the end of the experiment ($t[562] = .19$, $p = .85$, $MS_e = 16.37$), see Figure 6.

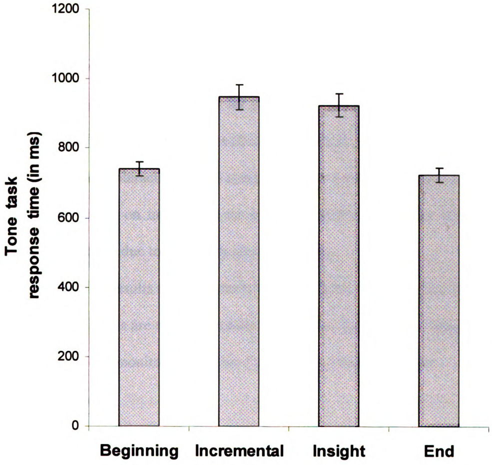

Figure 6. Mean tone task response time (in ms) in Experiment 3 for the tone task at the beginning of the experiment, the tone task while solving incremental problems, the tone task while solving insight problems and the tone task at the end of the experiment. Error bars represent standard errors.

As for accuracy there was no main effect of number of tones in the overall analysis (F[1, 21] = .57, p = .60, MS_e = 222052.42) and no interaction between number of tones and dual performance (F[2,42] = .76, p = .69, MS_e = 8969.78). These findings indicate that response times to the target tone decreased as participants were asked to perform both the tone task and the problem solving task.

To investigate any possible speed-accuracy trade off effects a 2x2x2 analysis of variance on tone response time was performed with between-subjects factors of problem type (insight or incremental), number of tones (2 or 3) and whether or not the problem was solved correctly (correct or incorrect). In order to analyze the correct/incorrect factor participants' tone task response time for each individual problem was again treated as a single case. There was no effect for correctness (F[1,85] = .04, p = .84, MS_e = 2094.10) and no significant interactions with correctness. An analysis looking at the effects of response time based on target tone for both the 2-tone and 3-tone condition was not possible in this study due to extremely small cell sizes.

Overall the results show an increase in response times for the tone monitoring task when participants are solving problems. This provides further evidence that problem solving and the tone monitoring task have similar processing demands.

4.1.3 Discussion

Experiment 3 was designed to find a suitable concurrent task that would tax similar resources as problem solving. Results showed that a concurrent tone monitoring task led to decrements in problem solving performance. Participants' problem solving accuracy while performing the tone monitoring task decrease significantly compared to participants' problem solving accuracy alone. Problem solving duration, however, did not seem to be affected by the concurrent tone task. There was no increase in the amount of time participants spend solving each problem in the dual-task condition compared to the single task condition. Nevertheless, the decrease in problem solving accuracy alone provides good evidence that the concurrent tone monitoring task has similar resource requirements as problem solving. Navon and Gopher (1979) argued that if two tasks have the same resource requirements then decrements should be seen in both tasks. This experiment also showed that problem solving interfered with tone task performance. Tone task accuracy, hit rate minus false alarm rate, while solving problems was significantly lower than tone task performance alone. Reaction time for the tone task also increased significantly while participants were solving problems compared to when they were performing the tone task alone. These results provide evidence that the concurrent tone monitoring task and problem solving share the same basic resources, which in turn leads to decrements in task performance. Having shown that the tone monitoring task can tax attentional resources it can be used in the next experiment to investigate incentive effects on attention allocation.

Another purpose of this experiment was to establish the parameters of the concurrent tone task for Experiment 3. Participants were either presented with a 2-tone monitoring task or a 3-tone monitoring task. In the 2-tone monitoring task participants were presented with their target tone and one other tone, in the 3-tone monitoring task participants were presented with their target tone and two other tones. Problem solving accuracy results showed a slight trend such that participants' problem solving performance was lower in the 2-tone condition than the 3-tone condition. Perhaps these findings indicate that the 2-tone condition shares more resources with problem solving than the 3-tone condition. In the 2-tone condition participants had to respond to their target tone by pressing the foot pedal more often compared to the 3-tone condition. It is possible then that planning and executing a response to a target tone interferes more with problem solving than inhibiting a response to a non-target tone. Since participants in the 2-tone condition had to plan and execute a response more often than participants in the 3-tone condition, it is possible that the trend for decreased problem solving accuracy in the 2-tone condition might indicate greater similarities between that version of the tone task and problem solving.

Participants' target tone was also manipulated such that participants in the 2-tone condition were given either the low or the high tone as their target, while participants in the 3-tone condition were given either the low, medium, or high tone as their target. There were no effects of target tone on participants' problem solving accuracy or problem solving duration for the 2-tone condition. In the 3-tone condition results showed that participants given the medium or high tone had lower problem solving accuracy than participants given the low tone. This might be due to the similarity between the medium and high tone. The tones were picked to be equally spaced in frequency but the medium and the high tone sound much more similar compared to the low tone. It is possible that participants had more trouble differentiating the medium and high tone leading to greater decrements in problem solving performance. Looking at participants' tone task performance, this was found to be the case. Participants in the 3-tone condition were less accurate when given the medium or the high target tone compared to the low target tone. Additionally, it was noted that participants in the 3-tone condition were much more likely to start consistently responding to another tone that was not their given target tone than participants in the 2-tone condition. In order to avoid this type of confusion and since there seem to be an indication of greater problem solving decrements the 2-tone condition will be used in Experiment 4.

Throughout this experiment both incremental and insight problems were used to investigate possible differences in how the concurrent tone monitoring task might affect these two types of problems. Lavric, et al. (2000) found negative effects of a secondary task on incremental problem solving but not insight problem solving. Experiment 3 did not replicate these findings; instead the secondary task reduced both incremental and insight problem solving. Why did Experiment 3 not replicate these previous findings? Lavric, et al. used a secondary tone task that was similar to the tone task used in this experiment, however, participants were asked to count the number of target tones instead of responding by pressing a foot pedal. Keeping track of the number of tones involves working memory to a greater degree than the responding to a target tone at the appropriate moment in time. It is possible then that Experiment 3 did not replicate the results found by Lavric, et al. because of differences in the secondary task. Perhaps a secondary task that taxes working memory to a greater degree would lead to different effects on incremental and insight problem solving. Another possibility why Experiment 3 did not replicate Lavric, et al. is that they used only one incremental problem and one insight problem in their study. It is possible that the differential secondary task effects are actually a reflection of the properties of the problems that were chosen and not incremental and insight problems overall. Further work will have to be done to investigate these possibilities.

In summary, Experiment 3 showed that a concurrent tone monitoring task taps the same resources as problem solving. Performance on both problem solving and the tone monitoring task was reduced in the dual-task condition. This methodology can then be used to test whether incentives lead to an increase in attention to the rewarded task. Taxing participants' attention by having them engaged in both the tone monitoring task and the problem solving task should lead to a reduction in attention available for the rewarded task (in this case problem solving) and may eliminate the incentive advantage as participants do not have any additional attentional resources that can be shifted to the rewarded task. Alternatively, if the problem solving task is protected by the incentive, then performance on the concurrent tone monitoring task may drop without a change in the incentive advantage seen for problem solving. These possibilities were tested in Experiment 4.

4.2 Experiment 4

Experiment 4 was designed to test whether an incentive leads to a shift in attention to the rewarded task. In order to test this, a dual-task approach was used. Experiment 3 showed that a concurrent tone monitoring task taxes similar attentional resources as problem solving. Performing both the tone monitoring task and problem solving tasks simultaneously led to decrements in both tasks indicating a sharing of resources by the two tasks. A concurrent tone task can therefore be used to test whether incentives influence attentional mechanisms. In Experiment 4 it was predicted that if incentives lead to a shift of all attentional resources to the rewarded task then problem solving performance will increase even in the dual-task condition. On the other hand, if incentives only lead to a shift of spare or additional resources then the incentive should have no effect in the dual-task condition.

Additionally, Experiment 4 was designed to test whether an increase in attention to the rewarded task due to an incentive can lead to deeper processing of the problems. In Experiments 2a and 2b participants given an incentive showed greater recall for the problems and their details than participants not given an incentive. It is possible then that an increase in attentional resources leads to deeper processing of the problems and therefore the increase in memory seen in Experiments 2a and 2b. Given this it was predicted that performing a secondary task while solving problems will reduce participants' memory for the problems. Additional attention could also lead to a greater level of understanding of the underlying structures of the problems. If this was the case participants given an incentive would be more likely to recall problem details that are directly related to solving the problem while participants not given an incentive might also recall irrelevant details. A post-hoc examination of participants' memory recall in Experiments 2a and 2b showed that this seemed to be the case for one problem (*Age* problem) which included an irrelevant piece of information. The problem was taken from Ash and Wiley (2002) who asked participants to rate the importance of different problem components for finding a solution. In their study the irrelevant piece of information was rated as very unimportant for solving the problem. Scoring participants' memory recall from Experiments 2a and 2b for the irrelevant piece of information it was found that participants given an incentive were less likely to recall the irrelevant information than participants not given an incentive. This could be an indication that participant not given an incentive are engaging in more surface processing of the problems while participants given an incentive are engaging in more processing of the underlying structure of the problem. Experiment 4 tested this possibility by adding irrelevant information to all the problems and scoring participants memory recall for it. If incentives lead to an increase in resources which causes deeper processing of the underlying structure of the problem then it was predicted that participants in the incentive condition will recall less irrelevant information than participants not given an incentive.

4.2.1 Method

Design. A 2x2x2 mixed design was used with between-subjects factors of incentive (given or not) and task (single task or dual-task), and a within-subjects factor of problem type (incremental and insight). Again all participants completed the tone task alone at the beginning of the experiment but unlike Experiment 3 the tone task at the end of the experiment was dropped.

Participants. Three hundred and twenty Michigan State University students participate in Experiment 4 for course credit (mean age 19.62). Again, the majority of the sample was female (215 female, 105 male) reflecting the participant pool. No gender effects were found.

Procedure. Participants were randomly assigned to either the incentive or non-incentive and either the single task or dual task condition. The procedure was the same as in Experiment 3 except for the following changes. Participants in the incentive condition were informed of the incentive, the opportunity to leave the experiment early if they solve four problems correctly, at the beginning of the experiment. All participants were presented with the 2-tone monitoring task and participants were randomly assigned to either the low or high target tone condition. Participants completed the practice tone monitoring task and the actual tone monitoring task but in this experiment the final tone task at the end was not given. Participants, as in Experiments 2a and 2b, completed up to six problems (three incremental and three insight). After four problems participants were asked to complete the surprise memory question that asked them to write down as many details of each problem as they could remember. The experiment took about 60 minutes to complete.

Materials. The same set of problems as in Experiments 2a and 2b was used, however an irrelevant piece of information was added to the text of each problem. The irrelevant piece of information was not needed for solving the problem but this was not necessarily apparent when first looking at the problem. The text of the modified problems can be found in the Appendix A. Problems were again presented in four different orders ensuring that incremental and insight problems were presented in an alternating fashion.

The 2-tone monitoring condition from Experiment 3 was used as the secondary task in this experiment. This version of the secondary task was chosen because it showed greater problem solving performance decrements than the 3-tone condition. Additionally, fewer participants in the 2-tone condition compared to the 3-tone condition confused their target tone with another tone.

4.2.2 Results

The insight and incremental problems were again scored as either right or wrong. As in the previous experiments participants' insight and incremental scores were calculated using the first four problems presented in the experiment.

Incentive and dual-task effects on solution. Table 9 presents the means and standard deviations for incremental and insight scores.

	Incremental	Insight
Single task		
Non-incentive (n = 80)	.53 (.34)	.36 (.33)
Incentive (n = 80)	.66 (.36)	.48 (.39)
Dual-task		
Non-incentive (n = 80)	.47 (.36)	.29 (.32)
Incentive (n = 80)	.48 (.36)	.29 (.33)

Table 9. Mean incremental and insight scores (standard deviations in parentheses) for participants in the single and dual-task conditions divided by incentive for Experiment 4.

As in Experiment 3 there were no order effects ($F[3, 316] = 1.23$, $p = .30$, $MS_e = .19$). Additionally there were no target effects ($F[3, 318] = 1.99$, $p = .17$ $MS_e = .31$) indicating that performance did not differ between participants that received the low or the high target tone. Therefore all further analyses in this experiment will be presented collapsed across order and target tone. A 2x2x2x2 analysis of variance was performed on the incremental and insight scores with between-subjects factors of task (single or dual) and incentive (given or not), and a within-subjects factor of problem type (insight and incremental). There was a significant effect of task ($F[1, 316] = 17.36$, $p < .01$, MS_e = 2.500) indicating that performance in the dual-task condition decreased for both incremental and insight problem solving (see Table 9). There was also a significant effect for incentive indicating that participants given an incentive outperformed participants not given an incentive ($F[1, 316] = 5.25$, $p = .02$, $MS_e = .76$). However, the significant interaction between incentive and task ($F[1, 316] = 3.92$, $p = .049$, $MS_e = .56$) indicates that the incentive effect is being driven by participants in the single task condition. Post-hoc test showed that the incentive increase problem solving performance in the single task condition ($F[1, 159] = 8.63$, $p = .004$, $MS_e = .66$) but not in the dual-task condition ($F[1, 159] = .05$, $p = .82$, $MS_e = .004$), see Figure 7. There was a significant main effect of type of problem ($F[1, 316] = 51.92$, $p < .01$, $MS_e = 5.26$), indicating that participants were more successful solving incremental problems than insight problems. However there were no significant interactions with problem type indicating that the dual-task and the incentive did not influence incremental and insight problems differently. No other interactions were significant.

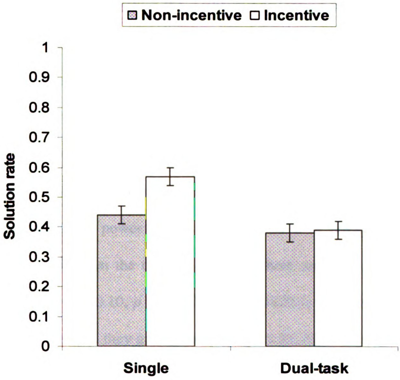

Figure 7. Mean solution rates for problems in Experiment 4 for the single and dual-task conditions for participants either given an incentive or not. Error bars represent standard errors.

Overall these results show that incentives lead to an increase in problem solving only in the single task condition. Participants' performance in the dual-task condition did not increase when given an incentive. These findings provide evidence that incentives cause an increase in attention to the rewarded task only when additional or spare resources are available. When participants do not have any additional attentional resources that can be shifted (as in the dual-task condition) incentives do not have an impact.

Problem solving duration. As in the previous experiments problem solving duration was again determined for the last unique answer provided. A 2x2x2x2 analysis of variance on problem solving duration (in seconds) was performed with between subjects factors of task (single or dual), incentive (given or not), problem type (insight or incremental), and whether the problem was solved correctly (correct or incorrect). In order to analyze the correct/incorrect factor each problem for each participant was again treated as a single case. There was a significant main effect for task, (F[1, 1264] = 4.79, p = .03, MS_e = 18469.19) such that participants spent less time on problems in the single condition (M = 169.09, SD = 69.56) than in the dual-task condition (M = 171.45, SD = 71.95). However, as the means indicate this difference is only two seconds and given the large amount of power behind this analysis it is unlikely that this is a meaningful difference between the two conditions. There was also a main effect for correctness, (F[1, 1264] = 370.10, p < .01, MS_e = 1425820.1) indicating that participants spent less time on problems they got correct (M = 135.26, SD = 69.83) than on problems they got incorrect (M = 198.36, SD = 57.78). As in the previous experiments the same analysis was run excluding cases where participants took all the time allotted (240 seconds). The exact same pattern of results was found. Participants spent significantly more time solving incremental problems (M = 175.71, SD = 63.23) than insight problems (M =

164.81, SD = 77.19), $F(1, 1264) = 48.62$ $p < .01$, MS_e = 187318.82. This again is not surprising given the nature of insight problems where participants can find the appropriate representation of the problem at any time. There was no effect for incentive, ($F[1, 1264] = .35$, $p = .56$, MS_e = 1344.69) but a significant interaction between incentive and task, ($F[1, 1264] = 7.86$, p =.005, MS_e = 30261.68). Post-hoc tests showed that participants in the dual-task condition who were not given an incentive spent more time solving problems (M = 179.96, SD = 70.31) than participants in the dual-task condition given an incentive (M = 164.87, SD = 73.10), $F(1, 635) = 5.31$ $p = .02$, MS_e = 27291.5. In the single task condition participants who were given an incentive (M = 168.27, SD = 71.33) spend the same amount of time solving problems than participants not given an incentive (M = 169.91, SD = 67.82), $F(1, 643) = .09$ $p = .76$, MS_e = 435.9. These findings indicate that the dual-task leads to slower problem solving unless participants are given an incentive. Whether this finding is actually meaningful and reliable however is questionable and needs to be replicated. All other interactions were found not to be significant.

Secondary task performance - accuracy. In order to assess performance on the concurrent tone monitoring task at the beginning of the experiment, participants' hit rate (the proportion of target tones correctly identified) and false alarm rate (the proportion of tones incorrectly judged to be the target tone) were calculated. Participants were given the tone-monitoring task alone before attempting any problems. Overall, tone accuracy (the hit rate minus the false alarm rate, M = .97, SD = .10) was significantly different from zero ($t[319] = 167.94$, $p < .01$, MS_e = .006) indicating that participants were able to reliably detect the target tone when given the tone task by itself. Again, participants' tone detection hit rate and false alarm rate were calculated for when solving incremental and insight problems. A 2x3 analysis of variance was run on the accuracy measure with a between subject factor of incentive (given or not) and a within subjects factor of dual performance (tone only, tone incremental, and tone insight). There was a main effect of dual performance (F[2, 316] = 129.49, p <.01, MS_e = 2.44). Post-hoc tests revealed that tone monitoring accuracy decreased when participants were solving incremental problems (M = .74, SD = .21) compared to when they were performing the tone task alone (M = .97, SD = .12), t(159) = 14.47, p < .01, MS_e = .02. This was also the case for tone accuracy when participants were solving insight problems (M = .77, SD = .23), t(159) = 11.35, p < .01, MS_e = .02. Tone task accuracy did not differ across incremental and insight problem solving (t[159] = .81, p = .21, MS_e = .08). There was no incentive effect (F[1, 158] = .41, p = 52, MS_e = .03) indicating that the incentive did not influence tone monitoring accuracy differently, see Figure 8.

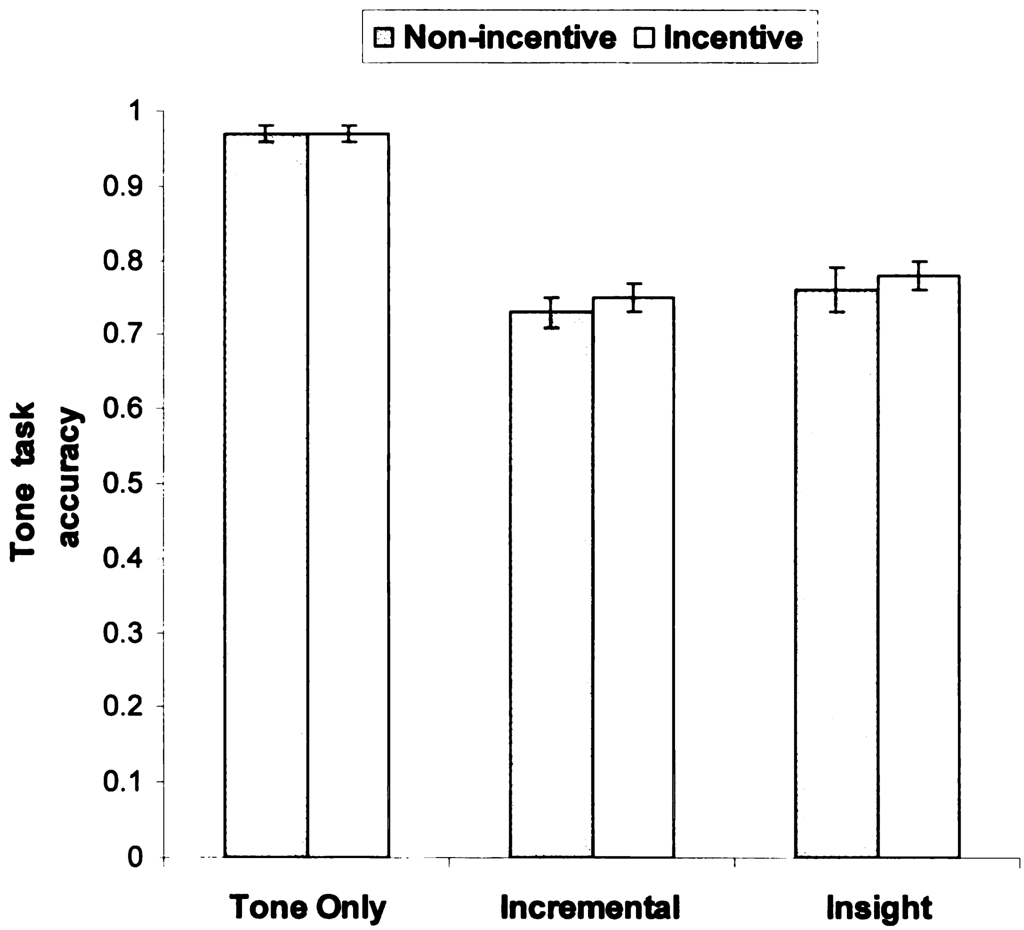

Figure 8. Mean tone task accuracy in Experiment 4 for participants in the incentive and non-incentive conditions performing the tone task alone, the tone task while solving incremental problems, and the tone task while solving insight problems. Error bars represent standard errors.

In order to check for a possible tradeoff effect between problem solving performance and tone monitoring accuracy a 2x2x2 analysis of variance on tone accuracy was performed with between-subjects factors of incentive (given or not), problem type (insight or incremental), and whether or not the problem was solved correctly (correct or incorrect). In order to analyze the correct/incorrect factor participants tone task accuracy for each individual problem was again treated as a single case. There was a significant effect for correctness, (F[1, 632] = 9.05, p = .003, MS_e = .53), however it was in the opposite direction as would be expected. Participants were more accurate at responding to the tone task when they got the answer correct (*M* = .79, *SD* = .23) than when they got the answer incorrect (*M* = .73, *SD* = .25). Perhaps this is due to participants ignoring the tone task when they realized they could not easily solve a problem. Most importantly however there was no effect of incentive ($F[1, 632] = 1.71$ $p = .20$, $MS_e = .10$) and no interaction between incentive and correctness ($F[1, 632] =.53$, $p = .47$, $MS_e = .03$). These findings indicate that participants' relative engagement with the tone task and the problem solving task did not differ as a function of whether they solved the problem correctly.

Secondary task performance – response time. As in Experiment 3 participants' response time to the target tone was measured both while performing the tone task alone and while solving the problems. Again since participants generally had very few false alarms only the response times for hits were analyzed. A 2x3 analysis of variance was run on response time (in milliseconds) with a between subject factor of incentive (given or not) and a within subjects factor of dual performance (tone only, tone incremental, and tone insight). There was a significant effect for dual performance ($F[2, 316] = 194.70$, $p < .01$, $MS_e = 2741991.3$). Post-hoc tests revealed that participants were slower at responding to the tone task while solving incremental (*M* = 955.63, *SD* = 162.04) problems compared to tone task only performance (*M* = 728.36, *SD* = 214.32), $t(159) = -15.67$, $p < .01$, $MS_e = 14.71$. Tone task response time while solving insight problems (*M* = 947.77, *SD* = 178.76) was also slower compared to tone task only response time (*M* = 728.36, *SD* = 214.32), $t(159) = -15.07$, $p < .01$, $MS_e = 14.78$. Tone task response times while solving incremental problems and insight problems were not significantly different form each other, $t(159) = .83, p = .41, MS_e = 9.53$ (see Figure 9).

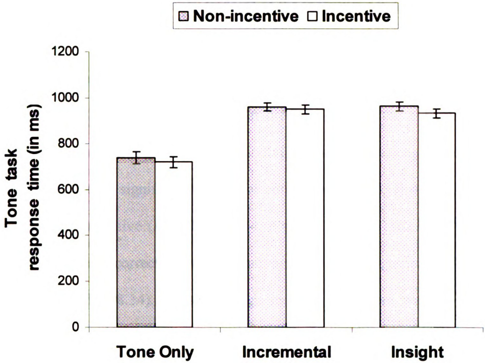

Figure 9. Mean tone task response times (in ms) in Experiment 4 for participants in the incentive and non-incentive condition while performing the tone task alone, the tone task while solving incremental problems, and the tone task while solving insight problems. Error bars represent standard errors.

There was no effect of incentive ($F[1,158] = .63, p = .43, MS_e = 50082.1$) indicating that tone response time did not differ between participants given an incentive ($M = 865.94$, $SD = 160.10$) and participants not given an incentive ($M = 886.37$, $SD = 165.48$). There were no significant interactions. Overall these findings indicate that participants' tone task response times increased while solving problems compared to their tone task performance alone. Incentive had no effect on response times.

Again it is possible that participants in the dual-task condition given an incentive were slower to respond to the tone task in order to increase accuracy on the problems. To test for a possible speed-accuracy tradeoff in the incentive condition a 2x2x2 analysis of variance on tone response time was performed with between-subjects factors of incentive (given or not), problem type (insight or incremental), and whether or not the problem was solved correctly (correct or incorrect). In order to analyze the correct/incorrect factor participants' tone task response for each individual problem was again treated as a single case. There were no significant effects for correctness (F[1,632] = 1.36, p = .24, MS_e = 38068.71) and incentive (F[1,632] = 1.44, p = .23, MS_e = 51862.09). Additionally, the interaction between correctness and incentive was also not significant, F(1,158) = .97, p = .33, MS_e = 36808.34). These findings indicate that there was no speed-accuracy tradeoff for participants given the incentive.

Memory. As in Experiments 2a and 2b a coarse memory measure and a fine memory measure were created from participants responses to the memory question. A 2x2x2 analysis of variance was run on the coarse memory measure with between subjects factors of task (single or dual) and incentive (given or not), and a within subjects factor of problem type (incremental and insight). See Table 10.

	Incremental	Insight	Total
Single task			
Non-incentive (n = 80)	.79 (.27)	.86 (.26)	.83 (.19)
Incentive (n = 80)	.79 (.33)	.88 (.25)	.84 (.23)
Total (n = 160)	.79 (.30)	.87 (.26)	.83 (.21)
Dual-task			
Non-incentive (n = 80)	.68 (.35)	.77 (.34)	.73 (.27)
Incentive (n = 80)	.77 (.30)	.84 (.30)	.82 (.23)
Total (n = 160)	.74 (.33)	.80 (.32)	.77 (.25)

Table 10. Mean coarse memory scores for incremental and insight problems (standard deviations in parentheses) in the single and dual-task divided by incentive as well as the totals across conditions for Experiment 4.

There was an effect for task (F [1, 316] = 5.50, p = .02, MS_e = .59) indicating that participants in the single task condition recalled more problems than participants in the dual task condition. There was also an effect of incentive (F [1, 316] = 3.94, p = .048, MS_e = .43) indicating that participants' given an incentive recalled more problems than participants not given an incentive. However looking at the means in Table 10 one can see that the incentive effect seems to be predominantly in the dual-task condition. The interaction between task and incentive however was not significant (F [1, 316] = 2.64, p = .11, MS_e = .28). Post-hoc tests revealed that, as expected from the means, there is no effect of the incentive on participants' coarse memory for the single task condition (F [1, 159] = .08, p = .78, MS_e = .004). There is however a significant effect for participants in the dual-task condition, (F [1, 159] = 5.66, p = .02, MS_e = .35). These findings are surprising given the consistent findings in Experiments 2a and 2b that incentives increase coarse memory recall. Perhaps this is an indication that the coarse memory measure is not a good measure of participants' problem memory. There was a significant effect of problem type (F [1, 316] = 10.65, p = .001, MS_e = .79) such that participants remembered more insight problems than incremental problems. This difference might have been due to the fact that one insight problem is quite short and therefore might be easier to remember than longer problems. There were no significant interactions.

As in the previous experiments a *fine memory* measure was created by scoring the participants' responses to the memory questions for the amount of detail or descriptiveness, of each problem (see Appendix B). Two raters, blind to condition, independently scored each of the problem responses and inter-rater reliability was found to be satisfactory (K = .89). A 2x2x2 analysis of variance was performed on the *fine memory* measure with between subjects factors of task (single or dual), and incentive (given or note), and a within subjects factor of problem type (incremental and insight). See Table 11.

	Incremental	Insight	Total
Single task			
Non-incentive (n = 80)	2.35 (1.19)	2.50 (1.19)	2.43 (1.01)
Incentive (n = 80)	2.58 (1.33)	2.73 (1.12)	2.65 (1.07)
Total (n = 160)	2.46 (1.26)	2.62 (1.16)	2.54 (1.04)
Dual-task			
Non-incentive (n = 80)	1.97 (1.31)	2.08 (1.28)	2.03 (1.10)
Incentive (n = 80)	2.47 (1.28)	2.48 (1.23)	2.48 (1.25)
Total (n = 160)	2.21 (1.32)	2.28 (1.27)	2.25 (1.12)

Table 11. Mean fine memory scores for incremental and insight problems (standard deviations in parentheses) in the single and dual-task incentive and non-incentive conditions s well as the totals across conditions for Experiment 4.

As in the coarse memory measure there was an effect for task, $F(1, 316) = 5.87, p = .02, MS_e = 13.51$, indicating that participants in the dual task condition remembered fewer problem details than participants in the single task condition. There was also an effect of incentive ($F[1, 316] = 7.92, p = .005, MS_e = 18.22$), such that participants in the incentive condition remembered more problem details than participants in the non-incentive condition. Post-hoc tests showed that unlike the coarse memory measure participants in both the single task ($F[1, 159] = 1.92, p = .049, MS_e = 2.21$) and the dual task ($F[1, 159] = 6.64, p = .01, MS_e = 8.1$) remembered more problem details when given an incentive than when not given an incentive. There was no effect for problem type ($F[1, 316] = 1.47, p = .23, MS_e = .90$) and no significant interactions.

Overall the results for the coarse and fine memory measure show that incentives increase problem recall even in the dual-task condition. This is somewhat surprising since it was hypothesized that the increase in problem recall seen in Experiments 2a and 2b is due to an increase in attention to the rewarded task. In the dual-task the results show that participants are not able to shift additional attentional resources to the problem solving task, how then is there still an increase in problem memory? Perhaps the increase in problem recall in the single and dual-task is due to different mechanisms that both lead to an increase in memory. This was further investigated by looking at participants' recall of irrelevant information.

Irrelevant information. Participants' memory recall was scored for the irrelevant information that had been added to the problems (see Appendix A). If a participants' problem recall contained the irrelevant information it was scored as a 1, if it did not it was scored as a 0. An irrelevant incremental score and irrelevant insight score was then calculated by averaging across the appropriate scores. A 2x2x2 analysis of variance was run on the irrelevant scores with between subjects factors of task (single or dual) and incentive (given or not) and a within subjects factor of problem type (incremental and insight). For means and standard deviations see Table 12.

	Incremental	Insight
Single task		
Non-incentive (n = 80)	.20 (.33)	.28 (.32)
Incentive (n = 80)	.16 (.29)	.21 (.28)
Dual-task		
Non-incentive (n = 80)	.13 (.26)	.24 (.32)
Incentive (n = 80)	.21 (.34)	.33 (.35)

Table 12. Mean irrelevant information scores for incremental and insight problems (standard deviations in parentheses) in the single and dual-task divided by incentive for Experiment 4.

There was no effect of task, (F[1, 316] = .24, p = .63, MS_e = .03) nor an effect of incentive, (F[1, 316] = .36, p = .55, MS_e = .05). There was an effect for problem type (F[1, 316] = 20.34, p < .01 MS_e = 1.27) such that participants remembered more irrelevant information for insight problems than incremental problems. Again this might be due to one insight problem being shorter which might lead people to remember it more. Interestingly, there was a significant interaction between task and incentive (F[1, 316] = 6.52, p = .01, MS_e = .86). Post-hoc tests revealed that in the dual-task condition participants given an incentive recalled more pieces of irrelevant information than participants not given an incentive (F[1, 159] = 4.66, p = .03, MS_e = .33). There was a slight trend in the single task condition (F[1, 159] = 2.05, p = .16, MS_e = .13) and the means suggest the opposite pattern of findings from the dual-task condition. Participants given an incentive recalled fewer pieces of irrelevant information than participants not given an incentive, see Figure 10.

Overall these findings may suggest qualitative differences in processing between participants given an incentive in the single task and dual-task conditions. Participants in the single task condition given an incentive may be processing the underlying structure of each problem and may therefore be less likely to recall the irrelevant information. Alternatively, participants given an incentive in the dual-task condition may still want to reach the incentive but are not be able to shift any additional attentional resources to the problem solving task. This may then lead participants to engage in more superficial processing of the problem which requires fewer resources. Superficial processing may then lead to a greater verbatim recall and therefore greater recall of the irrelevant information.

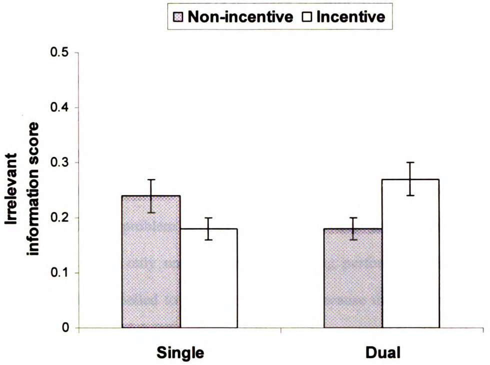

Figure 10. Mean irrelevant information score for problems in Experiment 4 for the single and dual-task conditions for participants either given an incentive or not. Error bars represent standard errors.

4.2.3 Discussion

Experiment 4 was designed to investigate whether incentives lead to an increase in problem solving performance by causing either a shift of all attentional resources or only spare or additional resources to the rewarded task. Results showed that incentives led to an increase in problem solving accuracy only in the single task condition. In the dual-task condition participants' problem solving accuracy was equal to participants not given an incentive. These results indicate that incentives lead to a shift in resources to the rewarded task only if additional attentional resources are available. This suggests that the incentive used in this work is at least in part different from a goal. Research on goal setting has shown that participants will allocate their resources to goal-relevant tasks while ignoring goal-irrelevant tasks (e.g., Locke & Bryan, 1969). If incentives functioned exactly like goals then participants given an incentive in the dual-task condition of this experiment should have shown an increase in their problem solving performance and a dip in their concurrent tone task performance. Instead the incentive did not increase problem solving performance in the dual-task condition, indicating a shift of attention only when spare resources are available. It is somewhat surprising that participants performed both the problem solving and the tone task so diligently given that the incentive was based only on their problem solving performance. It is possible that participants felt compelled to perform both tasks because the experimenter was in the room at all times and could have noticed when a participant stopped responding to the target tone. Another possibility however is that the participants underestimated the disruptive effects of the tones on their problem solving abilities. This underestimation may have led participants to believe their problem solving performance was greater than it actually was, eliminating any need to ignore the unrewarded tone task. Further studies including a think out loud methodology or detailed questioning after each problem would help elucidate these possibilities.

Problem solving duration was again found to be a less reliable factor than problem solving accuracy. As in the previous experiments, problem solving duration was not influenced by incentives. There was however an interaction between incentive and task such that participants in the dual-task condition that had not been given an incentive spent more time solving problems than participants in any other condition. The meaning and reliability of this finding however is unclear and should be replicated before being interpreted.

The incentive also did not seem to have an impact on secondary task performance. Tone monitoring accuracy and response time did not differ between participants given an incentive and participants not given an incentive. Additionally, there were no tradeoffs between problem solving performance and tone monitoring accuracy and response time. It was possible that the incentive would have caused participants to simply ignore the secondary task since participants had a lot to gain from performing well on the problem solving task but not from the secondary task. However, overall secondary task performance indicates that participants in the incentive condition were trying to complete both tasks at the same time.

In Experiments 2a and 2b it was found that participants given an incentive recalled more problems and more details about the problems than participants not given an incentive. Results looking at participants memory recall in this experiment showed that the incentive again increased problem memory. The incentive increased problem recall for both the single and the dual-task condition despite problem recall being lower in the dual-task condition than in the single task condition. These findings are surprising in light of the problem solving accuracy data indicating a shift of attentional resources only for the single task condition. If there are no additional attentional resources for participants to shift to the problem solving task in the dual-task condition, how then are participants in the dual-task condition able to remember more problems when given an incentive? It is possible that participants in the dual-task condition are using a different mechanism for remembering problems than participants in the single task condition. Perhaps the single task condition participants can use the additional attention that has been shifted to the problem solving task to engage in more processing of the underlying structure of the problem. Deeper processing then would lead not only to an increase in problem solving performance but also better memory for the problems. On the other hand, participants in the dual-task condition do not have additional resources but they do want to reach the incentive. This might lead participants to engage in more superficial processing by using a guessing strategy because it requires fewer resources. A guessing strategy simply requires surface processing of the problems as the solver needs to operate only within the realm of the problem. (Processing the underlying structure of a problem, however, requires the solver to step outside of the realm of the problem to link this problem with their previous knowledge, such as how to set up an algebraic equation.) It is possible then that participants in the dual-task condition given an incentive were still trying to solve the problem but were unable to devote as many resources, leading to a more surface processing of the problem. Surface processing then would lead to lower problem solving but could still increase problem recall. This recall however should be qualitatively different from the recall produced by participants given an incentive in the single task condition. Results looking at the amount of irrelevant information in participants' memory recall provide evidence for this possibility. It was found that participants given an incentive in the dual-task condition recalled more irrelevant pieces of information than participants not given an incentive. The opposite pattern was true for participants in the single task condition; participants not given an incentive recalled more irrelevant information than participants given an incentive. These results suggest that participants given an incentive in the single task condition seem to be more likely to process the problems' underlying structures while participants in the dual-task condition seem to be more likely to process the problems on a surface level. These findings provide further evidence that incentives lead to systematic changes in cognitive processes involved in problems solving.

Overall, the results of Experiment 4 show that incentives seem to lead to a shift of attentional resources when spare or additional resources are available. These additional resources then lead to deeper processing of information and greater problem solving performance.

5 GENERAL DISCUSSION

5.1 Summary of Experimental Results

This work set out to answer two major questions. One, do incentives, and therefore motivation, influence problem solving performance? Two, what cognitive mechanisms involved in problem solving are influenced by incentives? Across five experiments (Experiments 1a and 1b, Experiments 2a and 2b, and Experiment 4) including four different problem sets, the incentive reliably increased overall problem solving performance. The incentive, the opportunity to leave the experiment early, was consistently effective such that it increased problem solving performance for all sixteen problems presented. The probability of all 16 problems showing an effect in the expected direction by a sign test is .000015. On average, the increase in solution rates in the incentive conditions, as a percentage of solution rates in the non-incentive conditions was above 20%. These findings provide good evidence that incentives do influence problem solving.

Another purpose of this work was to investigate the nature of the mechanism by which incentives might influence problem solving. One possibility investigated was that incentives lead to persistence with one problem solving approach. Persistence with one problem solving approach would lead to differences in problem solving performance between incremental and insight problems. Experiments 1a and 1b specifically investigated the effect of an incentive on incremental and insight problems however both types of problems were used throughout all the experiments in this work, in essence further testing the predictions. In Experiments 1a and 1b participants were either in the incentive condition or in the non-incentive condition and completed several incremental and insight problems. Across all the problems in Experiments 1a and 1b (as well as Experiments 2a and 2b and Experiment 4) the incentive increased both incremental and insight problem solving. The interaction between problem type and incentive that would be predicted by a mechanism that leads to an increase in persistence with one approach was never found in any experiments in this work. More specifically, the hypothesized interaction was rejected with an average *p* value of .59 across different samples, different problems, and different levels of problem difficulty. These findings indicate that the increase in problem solving due to the incentive is not caused by an increase in persistence with one approach; instead the incentive is influencing a mechanism that is beneficial to both incremental and insight problem solving.

Another mechanism investigated in this work was problem solving duration. There has been some research showing that individuals given an incentive will spend more time on their task than individuals not given an incentive (e.g., Miller & Home, 1990). Experiments 2a and 2b measured participants' problem solving duration. Results showed that participants in the incentive condition spent about the same amount of time solving problems as participants in the non-incentive condition. These findings indicate that an increase in problem solving duration does not seem to be the factor leading to the incentives effects seen throughout the experiments in this dissertation.

Experiments 2a and 2b also investigated participants' depth of processing. Previous research has shown that motivation can lead to deeper processing of information (e.g., Eysenck & Eysenck, 1982). Experiments 2a and 2b investigated whether incentives lead to deeper processing of information by assessing participants' memory for the problems they completed. It was predicted that if incentives lead to an increase in problem solving by causing deeper processing then participants in the incentive condition should remember more problems and their details than participants in the non-incentive condition. Results of Experiments 2a and 2b showed exactly this. Participants in the incentive condition remembered more problems and gave more details about the problems than participants in the non-incentive condition. These findings indicate that incentives seem to lead to deeper processing which leads to an increase in memory for the problems. Looking across both problem solving duration and the memory measure, the results of Experiments 2a and 2b suggest that incentives lead to deeper processing of the problems without causing a major increase in the time spent on each task.

In order to further investigate the increase in memory due to the incentive, Experiments 3 and 4 were designed to investigate incentive effects on attention allocation using a dual-task approach. Little research has investigated the effects of a secondary task on problem solving; therefore Experiment 3 was run to establish a secondary task that would lead to performance decrements in problem solving. More specifically a concurrent tone monitoring task was tested to determine how it would influence problem solving performance. Additionally, different parameters for the task were investigated. Results showed decrements in both problem solving performance and tone monitoring performance when participants were asked to perform the two tasks simultaneously. These decrements indicate that the tone monitoring task and the problem solving tasks tax the same resources and were therefore suitable to use in a dual-task context.

Experiment 4 was designed to investigate whether incentives lead to an increase in problem solving by causing a shift of attentional resources to the rewarded task. Taxing participants' attentional resources by using a dual-task approach allows an investigation of how participants allocate their attention to the tasks they are performing. In Experiment 4 participants in the incentive and non-incentive condition solved incremental and insight problems while either in a single task or dual-task context. Results showed that problem solving performance only improved for participants given an incentive in the single task condition. Participants' performance in the dual-task condition did not differ across incentive. These findings indicate that incentives seem to cause a shift in attention to the rewarded task but only when additional attention is available. When participants do not have any or very few additional resources that can be shifted to the rewarded task then incentives are ineffective and do not lead to an increase in performance.

Additionally, Experiment 4 tested whether incentives lead participants to engage in more processing of the underlying problem structure. This was examined by adding irrelevant information to each of the problems presented and then scoring participants memory recall for the amount of irrelevant information mentioned. Results showed a trend such that participants given an incentive in the single task condition recalled fewer pieces of irrelevant information than participants not given an incentive. However, in the dual-task condition the findings were reversed. Participants given an incentive recalled significantly more pieces of irrelevant information than participants not given an incentive. These findings indicate that when participants can shift additional attentional resources to the rewarded task (as in the single task condition) greater processing of the underlying problem structure occurs. In the dual-task condition however participants do not have additional resources to devote to the problem solving task leading to more surface processing and therefore greater recall of irrelevant information.

5.2 Incentives and Attentional Resources

Attention allocation. Experiments in this dissertation have shown that incentives lead to an increase in problem solving accuracy and deeper processing of information when additional attentional resources are available. Attention allocation then is an important component of processing that influences the effectiveness of incentives. Participants must have additional resources available for an incentive to increase problem solving performance. If there are no additional resources incentives are ineffective, as seen in the dual-task condition in Experiment 4. What then determines how much attention is allocated to the rewarded task? In Experiment 4 of this dissertation participants were asked to both solve problems and respond to the concurrent task simultaneously however the incentive was based only on their problem solving performance. Despite this participants allocated their attention across both problem solving tasks and the concurrent tone monitoring task. Yet in the goal setting literature it has been found that participants will ignore any goal-irrelevant information and only allocate their resources to goal-relevant information. What might be causing this difference in how participants allocate their attention in response to either a goal or an incentive? Kahneman (1973) proposed that an individual's momentary intentions will influence the allocation of attentional resources. Participants in Experiment 4 in this dissertation were asked to practice the tone task and reach a certain level of proficiency before they were allowed to proceed with the experiment. Perhaps this influenced the relative amount of importance that participants attributed to their tone task performance. On the other hand, participants in the goal setting experiments reviewed in this dissertation (e.g., Locke & Bryan, 1969; Rothkopf & Billington, 1979) did not engage in any practice or previewing of the goal-relevant and goal-irrelevant information. As mentioned earlier, it is also possible that participants in Experiment 4 perceived the situation to be easier than it actually was. Participants might have thought they were able to perform the tone task and solve problems correctly simultaneously without decreases in performance. In the goal setting experiments participants might have been more aware of their limitations. Participants' interpretation of the situation and allocation of their attention might be the first step in determining how incentives will influence performance. Once participants have interpreted the situation and allocated their attentional resources accordingly the incentive steps in. If there are spare resources and the incentive is interpreted as important, additional resources will be shifted to the rewarded task and performance will increase. If however there are no additional resources to spare, no further attention can be shifted to the rewarded task, rendering the incentive ineffective at improving performance.

Perhaps attention allocation also explains the mixed incentive effects found in the literature. As mentioned in the introduction Camerer and Hogarth (1999) have found positive, negative, and null effects of incentives on performance. Positive effects might be seen when participants have plenty of additional resources available (as in the single task condition in Experiment 4) while null effects are seen when participants' have no additional resources (the dual-task condition of Experiment 4). The question then becomes how do negative incentive effects occur? Since an important aspect of incentive effects might be how participants' interpret the experimental situation, it is possible that negative effects are seen because of misinterpretations of the situation. Participants might interpret a situation and allocate their attention that is inconsistent with the question of interest. For example, as mentioned in the discussion of Experiments 1a and 1b, McGraw and McCullers (1979) gave participants an incentive for solving water jar problems based on accuracy but used problem solving duration as an indicator of incentive effects (despite telling participants that time on task is not crucial). Results showed an increase in problem solving duration for participants in the incentive condition which McGraw and McCullers believed to be evidence for detrimental incentive effects. However, given the instructions that time does not matter, this finding seems to be more a reflection of participants' interpretation of the situation than of incentive effects. Participants interpreted the situation correctly by allocated their attentional resources to maximize problem solving accuracy to reach the incentive. The incentive did not mention time on task, therefore participants ignoring that variable. It is possible then that the negative incentive effects seen in the literature are caused by participants' allocating their attentional resources in a manner that is inconsistent with the question of interest in the research.

A similar argument that has been made by Kemmelmeier, et al. (2004) that have shown misinterpretation effects on the Wason card selection task due to an incentive. More specifically, results showed that participants in the incentive condition gave more complex answers than participants in the non-incentive condition (e.g., participants were less likely to include the most obvious card in their answers) when they got the problem wrong. Kemmelmeier, et al. believe that this is an indication that participants given an incentive are interpreting the problem solving situation differently than participants not given an incentive.

Surface versus deep processing. Experiment 4 in this dissertation showed that incentives do not have any effect on problem solving performance when no additional resources are available to be shifted to the rewarded task. Do incentives then have absolutely no effect unless there are additional resources? Are participants simply discounting the incentive? The findings from the memory question in Experiment 4 indicate that the incentive still seems to cause an increase in processing of sorts even when participants do not have the additional resources to increase problem solving. In the dual-task condition of Experiment 4 participants given an incentive still showed an increase in memory for the problems and their details. Their recall however contained a greater amount of information irrelevant for solving the problems than participants given an incentive in the single task condition. These findings suggest that participants given an incentive in the dual-task condition engaged in more surface processing of the problems while participants in the single task condition engaged in more structural level processing of the problems. This provides evidence that participants in the dual-task condition are not just discounting the incentive; instead giving an incentive seemed to encourage participants to do more of whatever their resources available allowed them to do. For example, in Experiment 4 participants given an incentive in the dual-task condition had very few additional or spare resources but still seemed to want to reach the incentive; this led participants to engage in more surface processing perhaps by trying to guess the answer to the problems. A guessing strategy does not require a lot of resources and is therefore ideal in situations where resources are limited. Since a guessing strategy requires very little processing of the problems' underlying structure, participants were less likely to distinguish between pieces of information that are relevant and irrelevant for solving the problem. This suggests that incentives will lead to an increase in performance when additional resources that are required for successful task completion are available. When no additional resources are available participants might try to find different compensation strategies to still meet the incentive. These strategies however are much less effective at increasing performance.

These findings obviously have several implications for the effectiveness of incentives in certain situations. For example, in a classroom setting if students are given problems that are difficult and do not leave many spare attentional resources, an incentive might actually encourage more superficial or surface processing of the problems. On the other hand, if an incentive is given for problems that do not tax all attentional resources they may be effective in encouraging students to understand the underlying structure of the problems. This surely would not be the desired effect in a classroom setting. Further studies need to be done to investigate when incentives lead to deeper processing and when they lead to surface processing. Once this is better understood incentives can be used appropriately.

5.3 Insight versus Incremental Problems

Throughout the experiments in this work both incremental and insight problems were used due to their proposed underlying differences (see Metcalfe & Wiebe, 1987; Schooler & Melcher, 1995; Schooler, et al., 1993). Incremental problems are argued to be solved in a step by step fashion with a clear path to solution while insight problems are argued to be solved with an "Aha" experience and have no clear path to solution. It is surprising then that no differences between incremental and insight problem solving were found. Experiments 1a and 1b, Experiments 2a and 2b, as well as Experiment 4 showed no differences in how the incentive affected incremental and insight problem solving.

The incentive consistently increased performance for both types of problems. Additionally, Experiment 3 and Experiment 4 showed no difference in how the secondary task affected incremental and insight problems. Instead results consistently showed a negative effect due to the secondary task for both insight and incremental problems. Why, despite the proposed underlying problem solving differences did the incentive and the secondary task influence incremental and insight problem solving equally? One possibility is that the problems used in this dissertation were poorly defined as incremental and insight problems. Problems used were taken from previous studies that defined each as either incremental or insight. There was no independent assessment done specifically for this dissertation. Perhaps this was an oversight that would have resulted in a different classification of problems and therefore different results. However, given the large variety of problems used in this dissertation and the general acceptance of the problems uses as incremental and insight problems within the literature I doubt this would have changed the findings much.

Another possibility is that incremental and insight problems are not as different as proposed in the literature. Chronicle, MacGregor, and Ormerod (2004) recently demonstrated that some hill-climbing processes used in transformation (or incremental) problems are also present in insight problems. More specifically, results showed that participants experienced the same difficulties conceptualizing the next step to take in a traditional 6-coin problem (where participants need to rearrange 6-coins to form a certain pattern) and a modified 6-coin problem requiring insight to find the solution. Chronicle, et al. argue that these findings suggest that there should be a common framework for understanding both incremental and insight problems. Similarly, Weisberg (1992) has argued that all problem solving, including insight problem solving, should be seen as a step-by-step cyclical process that involves retrieval of information from memory and attempts to apply the information. If the retrieved information does not lead to a solution a new search is initiated. The results from this dissertation, that the incentive and the secondary task influence incremental and insight problem solving equally, are certainly consistent with the notation that incremental and insight problems may share more problem solving processes than previously conceptualized. Future research needs to be done to investigate the commonalities and differences between incremental and insight problem solving. A dual-task approach (as well as incentives) may be particularly useful in exploring problem solving processes as different secondary tasks can be used to tax different aspects of problem solving.

5.4 Cognitive Psychology and Motivation

Historically cognitive psychology has seen motivation and incentives as a factor irrelevant to the study of cognition. As mentioned in the introduction Simon (1994) even went so far as to suggest that motivation would not greatly alter participants' performance. If Simon's proposal was correct then the leave early incentive in this dissertation should have had a very small to no effect on problem solving. Instead the incentive increase problem solving across all the experiments presented in this work. Additionally, Experiment 4 presents good evidence that the incentive seems to lead to an increase in performance by causing a shift of additional resources to the rewarded task. The availability of attentional resources is seen as having systematic effects on cognition; therefore if motivation affects cognition via changes in attentional resources then motivation differences will have systematic effects on cognition. This work then provides evidence that motivation does alter performance by influencing cognitive mechanisms and suggests that the current position, that motivation can always be ignored when studying cognitive processes, needs to be re-evaluated.

5.5 Future Directions

The experiments in this work represent the first steps to understanding how motivation influences cognitive mechanisms. However there are still many questions left unanswered. Experiment 4 showed that incentives lead to a shift in attentional resources when participants have additional resources available to them. This can be further investigated by pairing problem solving with a variety of secondary tasks. If incentives lead to a shift in additional resources then depending on the secondary tasks' resource requirements a range of problem solving performance may be seen. Secondary tasks whose resource requirements are more similar to the resource requirements of problem solving may leave fewer additional resources that can be shifted to the rewarded task; this then may lead to smaller incentive effects. On the other hand secondary tasks whose resource requirements are different from the resource requirements of problem solving may leave plenty of additional resources that can be shifted to the rewarded task; this then might lead to better performance for participants given an incentive. For example, in a pilot study I conducted participants were presented with two nonsense words before attempting each problem and were asked to try to remember each nonsense word. After four minutes, at the end of each problem, participants were asked to recall the nonsense words. Results showed that participants in the incentive condition outperformed participants in the non-incentive condition and the secondary task had no effect. This relatively easy pre-load task and problem solving do not share as many resource requirements as the concurrent tone monitoring task and problem solving, leaving additional resources available to shift to the rewarded problem solving task. Perhaps this is why no secondary task effects were seen in this pilot study and the incentive increased problem solving even in the dual-task condition.

Another way of investigating a continuum of incentive effects is by manipulating how participants interpret the experimental situation. In the dual-task condition of Experiment 4 participants seemed to devote enough attention to both problem solving and the tone task to perform both tasks reasonably successfully. However, the amount of attention participants devote to each aspect of the two tasks could be manipulated by differentially emphasizing the two tasks. The more emphasis there is on the problem solving task the more likely the incentive should be to increasing problem solving performance. Alternatively, the more emphasis there is on the secondary task the less likely it is that the incentive will improve problem solving performance. This type of design could show differential effects of incentives depending on the attention available for the rewarded task.

Deeper processing of information. Experiment 4 provided some evidence that incentives can lead to more processing of the underlying structure of the problem than surface processing. There was a trend such that participants given an incentive in the single task condition recalled fewer pieces of irrelevant information than participants not given an incentive. Additionally, participants given an incentive in the dual-task condition recalled significantly more pieces of irrelevant information than participants not given an incentive. These findings are quite intriguing and suggest incentives lead to more structural processing but only when additional resources are available. The irrelevant information used in Experiment 4 was added without any controls and assumed to be irrelevant for solving the problems. A better controlled experiment needs to be run where the importance of each problem component for solving the problem is known. In order to determine the importance of each problem component a pilot study can be run where participants rate the importance of each component for solving the problem (a similar study was done by Ash & Wiley, 2002). If the results of Experiment 4 are due to more structural processing then it would be predicted that participants in the incentive condition would recall more problem solving components rated as important to the problem solving process than participants not given an incentive. In a dual-task condition the opposite effect would be expected. Another possible way of exploring this effect would be to look at unrelated irrelevant information such as background color of the screen or paper that the problem was presented on. If incentives focus participants on the underlying structure of the problem then this type of unrelated irrelevant information would be unlikely to be remembered by participants in the incentive condition compared to participants in the non-incentive condition.

Similarly, a transfer experiment could also be used to test whether incentive lead to more structural processing. Participants could be given a series of problems that have different surface features but whose underlying structure is the same. If incentives lead to more structural processing then participants in the incentive condition may be able to transfer their knowledge from problem to problem and greater problem solving performance may be seen compared to participants in the non-incentive condition. Participants not given an incentive may engage in more surface processing and see each problem as different. This might lead to less transfer between problems and lower problem solving performance compared to participants in the incentive condition.

Individual differences and incentives. If incentives do lead to a shift in resources it may also be interesting to explore the role of individual difference variables in the relationship between incentives and problem solving performance. One individual difference that has recently received a lot of attention is working memory capacity. Hambrick and Engle (2003) define working memory capacity as the limited-supply cognitive resource that can be allocated flexibly depending on the demands of the task. Working memory's function is to bring memory representations into the focus of attention, and to keep these representations in a highly activated and accessible state as long as they are needed. It is possible then that the degree to which an incentive increases problem solving performance depends on individual differences in working memory capacity. For example participants with high working memory capacity might be able to take advantage of the incentive to a greater degree leading to greater problem solving performance than participants with low working memory capacity. Since participants with high working memory have more resources available to them overall, they may have more spare or additional resources available to shift to the rewarded task. Participants with low working memory capacity are already operating with a smaller amount of resources which leaves them with fewer additional resources to move to the rewarded task. These possible differences could be investigated by assessing participants' working memory span and correlating it with participants' problem solving performance in the incentive and non-incentive condition. Participants working memory capacity would be predicted to lead to differences in how an incentive affects problem solving performance.

5.6 Conclusions

Whereas this dissertation does not answer all the questions regarding motivation and cognitive mechanisms involved in problem solving it does however answer two major questions. One, despite the mixed results found by Camerer and Hogarth (1999) results consistently show that incentives and therefore motivation can influence problem solving (and by extension, other cognitive tasks). Two, incentives do influence cognitive mechanisms. More specifically, incentives were found to lead to deeper processing due to a shift of additional attentional resources to the rewarded task. These findings suggest that a complete understanding of cognitive processes also requires understanding how motivation affects them.

APPENDIX A

Text and solution rates of the problems used in Experiments 1a and 1b, Experiments 2a and 2b, Experiment 3, and Experiment 4.

Experiment 1a and Experiment 1b

Incremental Problems

Dinner Party Problem (solution rate: 89%)

Mary won't eat fish or spinach, Sally won't eat fish or green beans, Steve won't eat shrimp or potatoes, Alice won't eat beef or tomatoes. If you are willing to give such a bunch of fussy eaters a dinner party, which items from the following list can you serve: green beans, creamed codfish, roast beef, roast chicken, celery, and lettuce.

Store Problem (solution rate: 71%)

Smith is a butcher and president of the street storekeepers' committee, which also includes the grocer, the baker, and the pharmacist. They all sit around a table.

- Smith sits on Jones' left.
- Davis sits at the grocer's right.
- Bailey, who faces Jones, is not the baker.

Assign each storekeeper to the correct store.

Stakes Problem (solution rate: 4%, not included in any analyses)

Three people play a game in which one person loses and two people win each round. The one who loses must double the amount of money each of the other two players has at that time. The three players agree to play three games. At the end of three games, each player has lost one game and each person has $8. What was the original stake of each player? (Hint: at all times the total amount of money between the three players must add up to $24)

Card Problem (solution rate: 55%)

Three cards from an ordinary deck are lying on a table, face down. The following information is known about those three cards (all the information refers to the same three cards):

- To the left of a Queen, there is a Jack.
- To the left of a Spade, there is a Diamond.
- To the right of a Heart, there is a King.
- To the right of a King, there is a Spade.

Can you assign the proper suit to each picture card?

Bachelor Problem (solution rate: 53%)

Five bachelors, Andy, Bill, Carl, Dave, and Eric, go out together to eat five evening meals (Fish, Pizza, Steak, Tacos, and Thai) on Monday through Friday. It was understood that Eric would miss Friday's meal due to an out of town wedding. Each bachelor served as the host at a restaurant of his choice on a different night. The following information is known:

- Carl hosted the group on Wednesday.
- The fellows ate at a Thai restaurant on Friday.
- Bill, who detests fish, volunteered to be the first host.
- Dave selected a steak house for the night before one of the fellows hosted everyone at a raucous pizza parlor.

Which bachelor hosted the group each night and what food did he select?

Flower Problem (solution rate: 61%)

Four women, Anna, Emily, Isabel, and Yvonne, receive a bunch of flowers from their partners, Tom, Ron, Ken, and Charlie. The following information is known:

- Anna's partner, Charlie, gave her a huge bouquet of her favorite blooms; which aren't roses.
- Tom gave daffodils to his partner (not Emily).
- Yvonne received a dozen lilies, but not from Ron.

What type of flowers (carnations, daffodils, lilies, or roses) were given to each woman and who is her partner?

Job Problem (solution rate: 81%, not included in any analyses)

Lebrun, Lenoir, and Leblanc are, not necessarily in that order, the accountant, warehouseman, and traveling salesman of a firm. The salesman, a bachelor, is the youngest of the three. Lebrun, who is Lenoir's son in law, is taller than the warehouseman. Who has what job?

Insight Problems

Water Lilies Problem (solution rate: 44%)

Water lilies double in area every 24 hours. At the beginning of the summer, there is one water lily on a lake. It takes 60 days for the lake to become completely covered with water lilies. On what day is the lake half covered?

Checker Games Problem (solution rate: 61%)

Two men play five checker games and each wins an even number of games, with no ties. How is that possible?

Horse Problem (solution rate: 58%)

A man bought a horse for $60 and sold it for $70. Then bought it back for $80 and sold it for $90. How much money did he make in the horse business?

Marriage Problem (solution rate: 49%)

A man in a town married 20 women in the town. He and the women are still alive, and he has had no divorces. He is not a bigamist and not a Mormon and yet he broke no law. How is that possible?

Sock Problem (solution rate: 50%)

If you have black socks and brown socks in your drawer, mixed in the ratio of 4:5, how many socks will you have to take out to be sure of having a pair the same color?

Policeman Problem (solution rate: 61%)

A woman did not have her driver's license with her. She failed to stop at a railroad crossing, then ignored a one-way traffic sign and traveled three blocks in the wrong direction down the one-way street. All this was observed by a policeman, yet he made no effort to arrest the woman even though there was nothing stopping him. Why?

Experiments 2a and 2b and Experiment 3

Incremental problems

Age Problem (solution rate: 59%)

Ann is twice as old as her son. They were both born in June. Ten years ago Ann was three times as old as her son. What are their present ages?

Water Problem (solution rate: 36%)

Given containers of 163, 14, 25, and 11 ounces, and a source of unlimited water, obtain exactly 77 ounces of water.

Job Problem (solution rate: 57%, not included in any analyses, not given in Experiment 3)

Lebrun, Lenoir, and Leblanc are, not necessarily in that order, the accountant, warehouseman, and traveling salesman of a firm. The salesman, a bachelor, is the youngest of the three. Lebrun, who is Lenoir's son in law, is taller than the warehouseman. Who has what job?

Insight problems

Month Problem (solution rate: 67%)

What occurs once in June and twice in August, but never occurs in October?

Matchstick Problem (solution rate: 44%)

Correct the arithmetic statement expressed in Roman numerals by moving a single matchstick from one position in the statement to another.

XI = III + III

Prisoner Problem (solution rate: 56%, not included in analyses, not given in Experiment 3)

A prisoner was attempting to escape from a tower. He found in his cell a rope that was half long enough to permit him to reach the ground safely. He divided the rope in half, tied the two parts together, and escaped. How could he have done this?

Experiment 4

Irrelevant information in bold.

Incremental problems

Age Problem (solution rate: 65%)

Ann is twice as old as her son. **They were both born in June.** Ten years ago Ann was three times as old as her son. What are their present ages?

Water Problem (solution rate: 36%)

Given containers of 163, 14, 25, and 11 ounces, and a source of unlimited water, obtain exactly 77 ounces of water **(1 milliliter = .034 ounces)**.

Job Problem (solution rate: 51%, not included in any analyses)

Lebrun, Lenoir, and Leblanc are, not necessarily in that order, the accountant, warehouseman, and traveling salesman of a firm. The salesman, a bachelor, is the youngest of the three. Lebrun, who is Lenoir's son in law, is taller than the warehouseman. Who has what job?

Insight problems

Month Problem (solution rate: 46%)

What occurs once in June and twice in August, but never occurs in October regardless if you are looking **at a Gregorian or Julian calendar**?

Matchstick Problem (solution rate:26%)

Correct the arithmetic statement expressed in Roman numerals by moving a single matchstick from one position in the statement to another. **Remember putting a smaller number in front of a larger number means subtraction.**

XI = III + III

Prisoner Problem (solution rate: 61%, not included in any analyses)

A prisoner was attempting to escape from a tower. He found in his cell a rope that was half long enough to permit him to reach the ground safely. He divided the rope in half, tied the two parts together, and escaped. How could he have done this?

APPENDIX B

Scoring guide (and examples of participants' responses) for the fine memory measure used in Experiments 2a & 2b, and Experiment 4.

Score of 1

An answer should receive a score of 1 when there are very few or no details given about the problem. Questionnaires that only list problem names or very sparse details about each problem should receive a 1. For example:

Age problem: Age problem between Ann and her son

Month problem: Problem with months

Water problem: Water problem

Matchstick problem: The matchstick problem

Job problem: Job problem

Prisoner problem: Prison problem

Score of 2

An answer should receive a score of 2 when there are some details about the problem given but most of the details of the problems are still unclear or not given. For example:

Age problem: The first problem was about Ann and her son. It was about their ages.

Month problem: The month problem where you say what happens in two months and not another on.

Water problem: getting an exact amount of water in a container

Matchstick problem: Arithmetic matchstick problem having to move one matchstick

Job problem: There was a problem about three men that had different jobs and you had to match each man with their job.

Prisoner problem: There was a problem about a rope and how he could have escaped.

Score of 3

An answer should receive a score of 3 when most of the major details about the problem are given but the problem might be lacking an important detail or there might be some major mistakes within the problem. For example:

Age problem: Ann and her son 2x now 3x 10 years ago.

Month problem: 1 in June, 2 in August, none in October.

Water problem: A question that wanted you to get exactly 77 ounces of water using 4 different amount containers.

Matchstick problem: Another asked about match sticks and roman numerals. You were supposed to move one match to make the problem correct.

Job problem: Leblanc, Lebrun, Louis have different occupations traveling salesman for a firm, warehouse worker, and something else, Leblanc was the youngest, bachelor.

Prisoner problem: The rope problem with a man trying to escape out of a tower with only one rope. He split the rope in half and escaped.

Score of 4

An answer should receive a score of 4 when all the essential details needed to solve the problem are given. For example:

Age problem: Ann is twice the age of her son, ten years ago, she was three times the age of her son, how old is Ann and her son?

Month problem: What happens once in June, twice in August, and never in October?

Water problem: You are given a container with 163, 25, 14, and 11 ounces and an unlimited source of water, put exactly 77 ounces of water into one container.

Matchstick problem: Given, "XI=III+III in Roman Numerals, move one of the matchsticks to make the statement correct.

Job problem: Leblanc, Lenoir and Lebrun are brothers. One of them is a salesman, one's an accountant and one's warehouseman. Lenoir is Lebrun's father-in-law. The salesman is the youngest and a bachelor. Lenoir is taller than the warehouseman.

Prisoner problem: A prisoner is trying to escape from prison. In his jail cell find a rope. The rope is only half long enough for him to make it safely down from his cell. The prisoner divides the rope in half and is able to safely make it down. How is this possible?

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