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#### **Title**

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<https://escholarship.org/uc/item/581019r0>

#### **Journal**

Proceedings of the Annual Meeting of the Cognitive Science Society, 22(22)

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#### **Publication Date**

2000

Peer reviewed

# Motivation in Insight versus Incremental Problem Solving

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## Abstract

Previous studies have shown a correlation between initial motivation and subsequent performance (e.g. Vollmeyer, Rheinberg, & Burns, 1998). However, it is possible that this relationship is due to a third factor such as general ability. To address this issue, our participants completed insight as well as incremental problems. These two types of problems have been shown to differ both theoretically and empirically due to differential underlying processes (e.g., Metcalfe & Wiebe, 1987). Results showed that motivation (in particular, *interest*) correlated with incremental problem solving but not with insight problem solving. The results were replicated with two different sets of problems solved by different groups of participants. Motivation was measured before solving the problems, so the difference between these two types of problems provides us with evidence that motivation is causal in producing better problem solving performance. Further, it suggests that when processes differ, motivational effect on performance will differ.

## Introduction

It has been difficult to demonstrate conclusively an effect of motivation on problem solving. This is partly because the difficulty of manipulating motivation reliably has forced research designed to examine this issue to rely on correlational studies. Studies such as Vollmeyer and Rheinberg (1998) and Vollmeyer, Rheinberg, & Burns, (1998) have shown a correlation between initial motivation and performance in a complex problem solving task. Although motivation is predictive of performance in these studies, it could still be argued that the correlation is due to a third factor. It is plausible that people with higher general ability at problem solving may not only be better at this task, but also be more highly motivated when faced with such a task. So motivation may not be a causal factor.

In order to learn more from correlational studies of motivation, a slightly different methodology is required. If we give problem solvers qualitatively different problems to solve and find that motivation has a different relationship to performance on these different types of problems, then we would have good evidence that it is not a general ability factor that accounts for any relationship found between motivation and problem solving performance. Two types of

problems that can have a similar form, but have been shown to be qualitatively different, are insight and incremental problems (e.g., Metcalfe & Wiebe, 1987). This makes them good candidates for a methodology looking for qualitatively different motivational influences on problem solving. So in this study we compared the effect of motivation on insight and incremental problem solving.

## Motivation and Problem Solving

It has long been acknowledged that motivation is important, for example, Simon (1967) emphasized the importance of motivational and emotional influence on cognition. However, for the most part motivation and its relationship to cognitive processes has been largely ignored by cognitive scientists. Investigating this influence has been seen as unnecessary because differences in motivation have been treated as background noise that that can be ignored when investigating specific cognitive processes. Even though the operation of Anderson's (1993) ACT-R depends crucially on the goal of the actor and how likely they think an action will be successful, he specifically rules out having to consider the more general goals of the actor. Although Anderson acknowledges the importance of wider goals, he takes the stance that once the actor is committed to doing something in a situation, the actor's more general motivation is irrelevant.

Whether it is sustainable to routinely ignore motivation and emotion when studying cognition is something that has come into question. For example, Kuhl and Kazén (1999) have shown that one of the most well-known of cognitive phenomena – the Stroop effect – can be wiped out by manipulating emotion. Recent research has also started to address the relationship between motivation and cognition (e.g., Kanfer & Ackerman, 1989; Lord & Levy, 1994; Pokay & Blumenfeld, 1990; Vollmeyer & Rheinberg, 1998; Vollmeyer, et al., 1998). With respect to problem solving, Vollmeyer and Rheinberg (1998) fitted their cognitive-motivational process model to a complex problem solving task called *Biology-lab*. The cognitive-motivational process model proposes an interaction between motivation and cognition such that initial motivation affects the motivational state during learning which in turn influences strategy use and acquisition of knowledge. In *Biology-lab* participants have to learn how to manipulate a complex learning environment by controlling several inputs and output variables. In particular, Vollmeyer & Rheinberg have shown that participants with higher motivation were

more likely to use a systematic strategy for acquiring knowledge and therefore performed better during the knowledge application phase. The results of this study and similar studies by Vollmeyer and colleagues using the *Biology-lab* simulation indicate that motivation can influence cognitive processes, such as strategy systematicity, and therefore lead to differential knowledge acquisition and performance.

Similarly, Pokay and Blumenfeld (1990) investigated the effect of motivation on learning strategies and performance on geometry proofs. In this study questionnaires assessing motivation and learning strategies were given to high school students in geometry classes at various points in the semester. The results of this study indicated that various motivational factors predicted strategy use, which in turn influenced performance on geometry tests (especially proofs) throughout the semester. This study provides further evidence for an interaction between motivation and cognition. These conclusions are consistent with other researchers such as Locke and Latham (1990) that have also argued that motivation affects performance via the processes used in a particular task.

### **Insight versus Incremental Problems**

Incremental problems require the solver to take a number of incremental steps in order to solve the problem. Incremental problems have also been referred to as *analytic* (Schooler & Melcher, 1995) or “grind-out-the-solution” problems since people can often solve these types of problems by persisting at the task. It might take time to reach the solution, but the solver has a good idea of how to get there. In contrast, insight problems are those in which the solver has a high probability of meeting an impasse, at which point the solver does not know what to do next (Schooler & Melcher, 1995). Insight problems are usually solved by a “flash of illuminance” (Metcalf & Wiebe, 1987), or by what has been referred to as an “Aha” experience where the solution is suddenly obtained (Schooler & Melcher, 1995).

Differences between these two types of problems have been demonstrated empirically by studies comparing performance on the two types. In a study by Metcalfe & 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 (Metcalf & Wiebe, 1987). Weisberg (1992) has argued that the procedures used in the experiments by Metcalfe & Wiebe (1987) are questionable.

However, it appears that he agrees with the notion that there are different processes involved in solving insight and incremental problems (Weisberg, 1995). 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, 1995). These findings have been attributed to differences in the processes used to solve these two types of problems. Specifically, Schooler & Melcher and Schooler, et al. argued that the impairments during insight problem solving while verbalizing are due to the disruption of nonreportable processes that are critical to solving insight problems but are not necessary for solving incremental problems.

In an effort to better understand what these nonreportable processes might be, Schooler and Melcher (1995) cite unpublished data by Schooler, McCleod, Brooks, & Melcher (1993) that examined the correlation between a variety of ability measures (e.g., recognizing out of focus pictures, finding remote associates) and success at solving both incremental and insight problems. It was found that the measures predicting performance on the two types of problems were generally different. Anagrams and categorization tasks correlated with incremental problem solving, whereas the embedded figures and out of focus pictures tasks correlated with insight problem solving. These differential patterns of findings lend further support that the two problems draw on qualitatively different processes (Schooler et al.).

It has been suggested that these underlying differences arise from the way we solve insight and incremental problems. Insight problems require searching for an appropriate way to represent the problem and are often easily solved once the correct representation has been found. On the other hand, representation is not the focus for incremental problem solving, instead figuring out what steps to take to reach the solution is often the focus (Kaplan & Simon, 1990; Ohlsson 1984).

These empirical and theoretical differences in incremental and insight problems lend themselves very well to our aim: finding a differential influence of motivation on incremental and insight problems.

### **Motivation Effects on Both Problem Types**

How to get to the solution may be clear when solving incremental problems, but following the required strategy may require some effort and persistence. Vollmeyer and Rheinberg (1998) found that motivation influenced

performance via the use of a good strategy. They suggested that motivation keeps people persisting with the good strategy instead of trying to find some less effortful shortcut. Similarly Sweller (1988) has explained poor problem solving performance as due to the cognitive load imposed by effortful strategies such as means-ends analysis. Based on this we predicted that motivation would influence incremental problem solving. However, not all aspects of motivation may equally relate to performance. Schiefele (1996) argues that interest in the task should be particularly highly related to performance. Therefore, we focused particularly on this aspect of motivation.

In order to argue that any relationship that we may find between problem solving and motivation is not due to some third factor, we wanted to show that motivation does not just correlate with everything. From the above discussion, it appears that insight problems should provide this contrast. As mentioned before, the process of solving insight problems differs from that for incremental problem solving. It is process that Vollmeyer and Rheinberg (1998) and Locke and Latham (1990) focus on. In particular, Vollmeyer and Rheinberg believe motivation influences performance by encouraging participants to persist with a good strategy, yet for insight problems there is no good strategy to follow or to fail to persist with. Persistence may even be detrimental due to the creation of Einstellung effects (Luchins, 1942). Incubation, instead, has been found to be effective for solving insight problems. (Silveira, 1971). (Experienced problem solvers may learn heuristic strategies for insight problem solving, but our participants were not such experts.) The work reviewed above on insight problem solving suggests there is no conscious strategy to be followed in insight problem solving, so we predicted that there would be no relationship between motivation and insight problem solving.

The discovery of such a contrast between insight and incremental problem solving would argue that motivation plays a causal role in how well people solve problems, especially if motivation was measured before the task began. Evidence for this contrast would be finding a higher correlation between motivation and incremental problem solving than between motivation and insight problem solving. However neither of these correlations would be expected to be high given that ability rather than motivation should be the best predictor of problem solving performance.

## A Study

### Method

**Participants.** Two hundred and ninety-two Michigan State University students participated in this experiment for course credit.

**Materials.** Participant's initial motivation was assessed using the Questionnaire of Current Motivation (QCM, Vollmeyer & Rheinberg, 1998). This motivation questionnaire consists of 37 items which have been shown to measure four independent factors of motivation:

Challenge ("This task is a real challenge for me"), confidence in Success ("I think I am up to the difficulty of the task"), Fear of failure ("I am a little bit worried"), and Interest ("I would work on this task even in my free time"). The QCM is designed to measure motivation for a specific task (originally the *Biology-lab* task of Vollmeyer, Burns, & Holyoak, 1996), so some items had to be modified to fit this problem solving task. However, none of the items used to measure the four factors had to be modified and a check of the psychometric qualities of the questionnaire found the same factor structure (see Rheinberg, Vollmeyer, & Burns, under review).

Two separate sets of problems were created, each consisting of one insight problem and two incremental problems. The problems were randomly selected from problems previously studied by Metcalfe & Wiebe (1987) and Schooler, et al. (1993). The actual problems used in the two sets are presented in the Appendix.

Each problem also included a state motivation questionnaire consisting of five questions (see Vollmeyer & Rheinberg, 1998) in order to assess participants motivation towards solving each given problem.

**Procedure.** Participants solved their set of problems in the middle of a 45-50 minute group testing session composed of short unrelated tasks. Group size ranged from five to ten individuals. At the beginning of the session participants were asked to complete the QCM, which was then followed by one of the two sets of three problems (two incremental and one insight). Within each set, the three problems were given in a random order. When solving the set of problems participants were asked to first read the problem, then answer the five questions pertaining to the problem (which measured state motivation), re-read the problem, and then solve it. We did not restrict the time that participants were given to solve each problem, but they were aware that they would be given more tasks. Upon completion of the problem set participants went on to complete a series of unrelated tasks.

### Results

**Overall performance.** The incremental and insight problems were scored on a dichotomous right or wrong scale. To derive a subject's incremental score, the result for the two incremental problems was averaged together. Participants did more poorly than we expected on some of the six problems. For Problem Set One participants on average solved 1.52 of the 2 incremental problems correctly but only 16 percent solved the insight problem. For Problem Set Two participants on average solved 0.70 of the 2 incremental problems and 16 percent solved the insight problem. Note that unlike some other studies of insight problem solving (e.g., Schooler, et al., 1993) participants were not given another chance to attempt the problem if they handed in an incorrect solution.

We tested for any order effects on the problems as each set of three problems was presented in one of six possible orders. We found no evidence in either problem set that the order in which participants solved the problems affected

their performance: Problem Set One  $F(5, 146) = 1.35, p = .25$ ; Problem Set Two  $F(5, 133) = 0.98, p = .43$ .

Table 1: Correlations of the motivation factors with incremental and insight problem scores, and z-score test of the difference between the two correlations.

Problem Set One (n=152)	Incremental	Insight	z-score
Interest	.255 **	.000	2.16 $p = .030$
Challenge	.143 *	-.006	1.23 $p = .22$
Fear of Failure	.061	-.026	.076 $p = .96$
Success	.097	-.011	.89 $p = .37$
Problem Set Two (N=141)	Incremental	Insight	z-score
Interest	.240 **	-.011	2.26 $p = .024$
Challenge	.204 *	-.003	1.85 $p = .064$
Fear of Failure	-.039	.060	-.87 $p = .38$
Success	.169*	-.092	2.33 $p = .020$

\* $p < .05$  \*\* $p < .01$

**Initial Motivation.** As measured by the QCM, participants in both problem sets had reasonably high motivation. The means for the four motivation factors for participants in Problem Set One were as follows: Interest  $M = 4.02$  ( $SD = 1.07$ ), Challenge  $M = 4.41$  ( $SD = 0.88$ ), Success  $M = 5.19$  ( $SD = 0.92$ ), and Fear of failure  $M = 2.66$  ( $SD = 0.88$ ). For Problem Set Two the means were: Interest  $M = 4.02$  ( $SD = 1.05$ ), Challenge  $M = 4.36$  ( $SD = 0.93$ ), Success  $M = 5.36$  ( $SD = 0.83$ ), Fear of failure  $M = 2.65$  ( $SD = 1.02$ ). The two groups did not differ on any of these motivation scales (all  $p > .10$ ). Both groups thought the task moderately interesting and challenging, did not fear failure, and thought they would succeed.

The incremental problem solving scores and the insight problem solving scores were correlated with the four motivational factors of the QCM (Fear of failure, Challenge, Interest, and Success). These correlations are presented in Table 1. For both sets of problems it was found that both Interest and Challenge correlated significantly with incremental problem solving but not with insight problem solving. For each motivation factor we used a z-score conversion (see Olkin, 1967) to test the difference between the correlations of that factor with incremental and insight scores. Only for Interest was the correlation with incremental scores significantly higher than the correlation with insight scores, in both sets. Success correlated significantly with incremental problem solving only for set two, this finding was not replicated with set one. Fear of

failure did not significantly correlate with either incremental or insight problem solving for either set of problems. The difference between correlations for Success was significant for Problem Set Two, but we did not replicate this result with the other set. These findings show that motivation, in particular interest, consistently correlated with incremental problem solving but not insight problem solving.

**State Motivation.** In order to assess if participant's state motivation for each problem influenced problem solving, the three critical motivation questions presented on each of the problem sheets were averaged to create a state motivational score (see Vollmeyer & Rheinberg, 1998). The three critical items were: "This task will be fun", "I'm sure I will find the correct solution", and "It is clear to me how to proceed". Participants' motivation during the task was moderate (see Table 2). Each state motivation score was correlated with its corresponding problem. As Table 2 shows, only one correlation was found to be significant. In Problem Set One, one incremental problem correlated significantly with its state motivation,  $r(141) = .263, p < .01$ . All other correlations were found not to be significantly different from zero. Overall these findings indicate that motivation for each problem was not correlated with performance, regardless of problem type.

Table 2: Correlations of state motivation with each specific problem, together with the percent of subject correctly answering that problem and its mean state motivation (standard deviation in parenthesis).

Problem Set One	Percent correct	Mean (SD) of state motivation	State motivation correlation
Incremental Problem 1	63%	4.55 (1.23)	.263 **
Incremental Problem 2	89%	4.85 (1.18)	.098
Insight Problem	16%	4.15 (1.01)	.060
Problem Set Two	Percent correct	Mean (SD) of state motivation	State motivation correlation
Incremental Problem 1	14%	4.33 (1.23)	.057
Incremental Problem 2	55%	4.11 (1.37)	.058
Insight Problem	16%	4.00 (1.11)	.100

\*\* $p < .01$

## Conclusions

This study achieved our aim of demonstrating a differential relationship between motivation and different types of problems. We not only showed that motivation correlates with one type of problem solving, but that it does *not* correlate with another type. Thus we supported the claim that motivation affects problem solving, and made it hard to argue that such correlations are simply due to some general ability factor. Consistent with the suggestion of Vollmeyer and Rheinberg (1998) and Locke and Latham (1990), motivation only affected problems for which there was a process to be helped or to be disrupted.

The critical motivation factor was Interest, as predicted by previous research (Schiefele, 1996). Interest correlated significantly with incremental problem solving scores. This correlation was significantly higher than the correlation between motivation and insight problem solving scores. Note that although we only report a single study here, in effect the two groups represent a replication of this result. Given that the two groups of participants did different problems sets with differing degrees of success, there appears to be some generality to our findings.

Although the amount of variance in performance explained by motivation is statistically significant, it is small. This does not equate to saying that the influence of motivation on cognition must be correspondingly small. The measures we used were inherently noisy. The QCM is only a pencil-and-paper test of motivation and whether someone solves a particular problem on a particular day is a product of many factors. Further it should be noted that these sorts of problems are often considered to be stable tests of intelligence, so to find motivation influences on even these types of problems is particularly interesting. In future work we will measure ability so as to determine how much of the remaining variance in performance is accounted for by motivation once the variance due to ability has been removed.

We also measured participant's state motivation for each problem they solved. Out of the two problem sets we found only one problem, an incremental problem to be significantly correlated with its state motivation. Whereas this accords with our findings for initial motivation, it was not found consistently; therefore we cannot draw any conclusions. It is possible that the five-question state motivation measure was not sensitive enough or was just not appropriate for this type of task. The state motivation measure is also hard to interpret because it may not only anticipate the problem about to be solved, but also be a reaction to performance on the previous problems. Unlike initial motivation, which is measured before participants solve any of the problems, the direction of any causal arrow would be harder to determine for the state motivation questionnaire.

The main aim of this study was to find a differential effect of motivation on different types of problems, but as well as this we found a much more specific effect (on Interest) as we predicted we would. However, consistent with the idea that motivation affects performance via the mediating processes, we would have to concede that under appropriate conditions motivation may help insight

problem solving. Our conditions may have been particularly conducive to producing a motivation effect on incremental problem solving, but not insight problem solving. By not restricting time, we provided a way in which persistence could help incremental problem solving as the participant did not have to worry about how long it took to get to the solution. Not giving a time limit may have reduced the opportunity for persistence (due to motivation) to affect insight problem solving, as the participant could simply decide that there was no chance to get any further with the problem and just hand it to the experimenter. It is plausible, however, that giving a specific time period for solving problems might actually encourage motivated participants to persist with looking for a solution to insight problems. Therefore, in a situation such as this, motivation might correlate with insight problem solving and not necessarily with incremental problem solving. Note that this in no way weakens our primary aim, demonstrating a motivational effect on problem solving, as these arguments are predicated on the assumption that motivation affects the process of solving problems. The exact patterns of effects on problems solving under different conditions, is a matter for future research.

This was a preliminary study, so further research will be necessary to determine the exact nature of the different effects of motivation on insight and incremental problems. One potential problem with this study was that the insight problems used had a low rate of solution, therefore it would be useful to conduct future research on easier problems. Future research will also need to test our assumption that intellectual ability helps both insight and incremental problem solving. In this study, we assumed that ability affects insight and incremental problem solving equally. This assumption was critical to our argument that motivation helped problem solving rather than any relationship being due to a third-factor, such as ability.

**Implications.** The findings of this study, although somewhat preliminary, have several implications. They show that motivation can influence problem solving, and by extension other cognitive tasks. A practical implication of this is that cognitive scientists should be aware that different tasks might be influenced by motivation in different ways. These possible influences of motivation need, therefore, to be taken into account when designing studies and experiments, otherwise effects may be found simply due to influences of motivation. Most importantly the finding that insight and incremental problems are influenced differently by motivation can be used as a stepping stone to further disentangle motivation and its relationship to cognition.

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### Appendix

<b>Problem Set One</b> (order was random)
<i>Incremental Problem 1:</i> 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): <p style="margin-left: 40px;">To the left of the 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.</p> Can you assign the proper suit to each picture card?
<i>Incremental Problem 2:</i> Next week I am going to have lunch with my friend, visit the new art gallery, go to the Social Security office, and have my teeth checked at the dentist. My friend cannot meet me on Wednesday; the Social Security office is closed weekends; the dentist has office hours only on Tuesday, Friday, and Saturday; the art gallery is closed Tuesday, Thursday, and weekends. On which day can I do everything I have planned?
<i>Insight Problem:</i> A woman has 4 pieces of chain. Each piece is made up of 3 links. She wants to join the pieces into a single closed loop of chain. To open a link costs 2 cents and to close a link costs 3 cents. She only has 15 cents. How does she do it?
<b>Problem Set Two</b> (order was random)
<i>Incremental Problem 1:</i> The police were convinced that Alan, Ben, Chris, or Dan had committed a crime. Each of the suspects made a statement, but only one of the statements was true: <p style="margin-left: 40px;">Alan said, "I didn't do it."  Ben said, "Alan is lying."  Chris said, "Ben is lying."  Dan said, "Ben did it."</p> Who is telling the truth? Who committed the crime?
<i>Incremental Problem 2:</i> If the puzzle you solved before you solved this one was harder than the puzzle you solved after you solved the puzzle you solved before you solved this one, was the puzzle you solved before you solved this one harder than this one?
<i>Insight Problem:</i> A dealer in antique coins got an offer to buy a beautiful bronze coin. The coin had an emperor's head on one side and the date 544 B.C. stamped on the other. The dealer examined the coin, but instead of buying it, he called the police. Why?