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# The Effect of Incidental Hints When Problems Are Suspended Before, During, or After an Impasse

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Two studies examine how the time at which problem solving is suspended relative to an impasse affects the impact of incidental hints. An impasse is a point in problem solving at which a problem solver is not making progress and does not know how to proceed. In both studies, work on remote associates problems was suspended before an impasse was reached, at the time an impasse was reached, or after a period of continued work during an impasse. After problem solving was suspended on a set of problems, participants completed a lexical decision task before resuming work on the set of unsolved problems. For half of the problems suspended during each impasse state, solution words were presented as incidental hints in the lexical decision task. The proportion of initially unsolved problems that were solved after the intervening lexical decision task was greater when problem solving was suspended at the point an impasse was reached than when problem solving was suspended before an impasse or after a period of continued work during an impasse. These results suggest that suspending problem solving at the point of impasse may increase susceptibility to incidentally presented hints. The point of impasse may be an opportune time for hints because the problem has been explored but there has not been a large increase in fixation on failed solution attempts.

*Keywords:* problem solving, hints, fixation, impasses

Difficult problems often lead to an impasse, at which point the problem solver does not know how to proceed. Eventually a new idea about how to proceed may enable the problem solver to overcome the impasse and reach a solution. There are many possible sources for this new idea, including incidentally encountered information that is relevant to the solution. The idea that people are susceptible to solution-relevant information (i.e., hints) during problem solving and during breaks in problem solving is present in some of the earliest work on insight and is characteristic of the prepared mind view of insight (see, e.g., Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995). For example, Maier (1931) found that participants exposed to an incidentally presented hint during work on an insight problem solved the problem more often than did participants who did not receive the hint. Furthermore, the majority of participants who solved the problem after receiving this hint did not report any awareness of receiving the hint.

There have been a number of studies since Maier's (1931) study that have shown that people process incidentally encountered information relevant to their goals seemingly without awareness. Bowden (1997) found that unreportable processing of solution-relevant information contributes to the experience of insight. Hints presented as part of a task unrelated to the problem have been shown to aid problem solving, and this benefit is not merely due to the recency of seeing the hint (Moss, Kotovsky, & Cagan, 2007). More generally, goals that have been set but not completed have been shown to affect processing of incidentally encountered information in many domains, including memory recall (Goschke & Kuhl, 1993; Patalano & Seifert, 1994, 1997; Yaniv, Meyer, & Davidson, 1995; Zeigarnik, 1927/1938), problem solving (Christensen & Schunn, 2005; Shah & Kruglanski, 2002), and task switching (Rothermund, 2003). Because these results indicate that people process goal-relevant information at some level, possibly without awareness, it is important to examine how the state of the problem at the point at which work is suspended impacts the effect of incidental hints.

Although some studies of problem solving with hints have made the distinction between impasses and nonimpasses as states of problem solving (Christensen & Schunn, 2005; Patalano & Seifert, 1994; Seifert et al., 1995), none of these studies examined the relationship between incidental hints and the state at which problem solving was suspended. The goal of the work presented in this article is to examine this relationship. In particular, the experiments reported here are concerned with impasses. As a person works on a problem without success, it becomes harder to think of new ideas, and the problem solver may eventually reach an impasse, which is a point at which search has been conducted within

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one or more problem representations but progress toward a solution has stalled. One of the reasons for this difficulty is that failed ideas are highly accessible in memory due to their recency. The blocking effect that develops from such highly accessible yet useless ideas has been referred to as fixation (Smith & Blankenship, 1991). For incidental hints to influence problem solving, it may be necessary to have a well-developed representation of the problem as well as relatively low fixation on incorrect solution attempts.

## Impasses and Problem Representation

Any problem for which the initial representation leads to a problem space that does not contain the solution, for which search is difficult, or that is too large for the solution to be found quickly has the potential to lead to an impasse that must be overcome. Impasses have been characterized behaviorally by the cessation of problem-solving activity (Ohlsson, 1992). There are a number of reasons to think that an impasse is an important state of problem solving. In the case of analogical retrieval, it has been shown that failing on a problem is likely to lead to the retrieval of analogous failures along with the way the failures were overcome (Gick & McGarry, 1992). The idea that failure drives the search for new information is a common finding in problem solving (Lovett & Schunn, 1999; MacGregor, Ormerod, & Chronicle, 2001; Ormerod, MacGregor, & Chronicle, 2002). Research also indicates that representation change processes are engaged when there is a lack of success with the current representation (Kaplan & Simon, 1990; Knoblich, Ohlsson, Haider, & Rhenius, 1999; Ohlsson, 1984, 1992). Therefore, an impasse may be a point at which the problem solver is highly likely to be searching for new information in order to explore alternative representations of the problem.

The process of searching for a problem representation involves unreportable search processes that examine memory and the environment for cues that may help in formulating a new representation (Beeman & Bowden, 2000; Bowden & Jung-Beeman, 2003a; Bowers, Regehr, Balthazard, & Parker, 1990; Kaplan & Simon, 1990). The ability of these search processes to make use of a hint may be affected by the similarity between information active in memory and the content of the hint, and the finding that the current problem representation affects the use of hints has a long history (e.g., Kaplan & Simon, 1990; Maier, 1930).

An additional reason that impasses are important states is that memory is better for unsolved problems interrupted during an impasse than it is for other unsolved and solved problems (Patalano & Seifert, 1994). The increased accessibility for impasse problems has led to the proposal that problems at the point of impasse may be most susceptible to future exposures to solution-relevant information (Seifert et al., 1995).

## Impasses and Fixation

Fixation can be induced by priming incorrect associations, but it can also occur naturally as participants use their knowledge to generate potential solutions to the problem. In studies in which fixation was induced by priming incorrect associations, a break from problem solving decreased fixation so that future problem attempts were more successful (Smith & Blankenship, 1991; Vul & Pashler, 2007), but in cases in which fixation was due to long-term associations, such as those found in the development of expertise, a break did not successfully reduce fixation (Wiley, 1998). These results support the idea that fixation is a source of significant problem difficulty. Fixation may lead to impasses because repeated attempts to think of new ideas merely end up increasing the chances of retrieving old ideas, and therefore continuing to retrieve old ideas during an impasse will do nothing but increase the fixation on old ideas.

Self-generated fixation due to incorrect solution attempts may even interfere with the ability to associate new solution-relevant information with the problem representation. In a series of studies using riddle problems, it has been shown that earlier attempts at solving a riddle blocked the association of new solution-relevant information as assessed by recall (Perfetto, Bransford, & Franks, 1983), and this effect was stronger for self-generated solution attempts than it was for reading solution attempts generated by others (Perfetto, Yearwood, Franks, & Bransford, 1987). Therefore, in addition to fixation making it harder to think of new ideas, it may also make it harder to associate new information with an existing problem.

## Overview of Experiments

The main idea explored in this article is that an impasse is a point at which the problem solver has explored one or more problem representations, but it is also a point at which continued work on a problem may hurt the chances of solving it by strengthening fixation on previously generated ideas. The prediction to be tested in the following experiments is that abandoning a problem soon after an impasse is reached will maximize the impact of incidental hints. This prediction comes from the beneficial effects of having a sufficiently developed representation of the problem along with the negative effects of fixation due to the repeated retrieval of old ideas.

Some support for this prediction comes from an initial exploratory study that used concurrent verbal protocols to determine when an impasse was reached (Moss, 2006). Fixation and the development of the problem representation were measured using the number of unique solution attempts generated along with the amount of time taken to generate those attempts. The results supported the predicted effects of fixation and representation development described here. However, the statistical power of the study was relatively low, and one of the results was of marginal significance.

On the basis of that exploratory study, the first study presented here was designed to test whether incidental hints are more effective for problems suspended at the time an impasse is reached than for problems suspended after a time of continued work postimpasse (Hypothesis 1). Hypothesis 1 is based on the idea that fixation builds up rapidly during an impasse, and this fixation interferes with the effect of hints. The second study was designed to further test Hypothesis 1 as well as the prediction that incidental hints would be more effective for problems suspended at impasse than for problems that were interrupted early in problem solving (Hypothesis 2). Hypothesis 2 is based on the beneficial effects of developing a sufficient problem representation before work on the problem is suspended.

Compound remote associates problems are used in the studies in this article. Although these kinds of problems have been used in the Remote Associates Test (RAT) in the past as a measure of creative ability (Mednick, 1962), we use them simply because they are problems that can be solved quickly and they rely on general knowledge that most native English speakers possess. Each problem consists of three words, and the task is to find a fourth word that forms a compound word or common phrase with each of the other words (Bowden & Jung-Beeman, 2003b). An example of a participant's efforts to solve the RAT problem consisting of the words *hunter, gear,* and *hammer* is presented in Figure 1. The answer to this problem is *head,* which forms the words *headhunter, headgear,* and *hammerhead.*

RAT problems are relatively simple problems that rely on memory retrieval, and they are problematic for people because the cues provided have only a weak association with the target word. There has been some evidence that people can distinguish between problems for which there is an immediate insightlike recognition of the solution and problems for which there is strategic search and testing of possible solutions (Bowden & Jung-Beeman, 2003a). Participants may answer some problems quickly through automatic recognition and retrieval, but at some point they switch to a more methodical generate-and-test problem-solving procedure. The fact that this generate-and-test procedure relies on memory retrieval makes these problems particularly susceptible to fixation effects due to the repeated retrieval attempts made during problem solving and the fact that the problem words are poor retrieval cues for the solution word. Further discussion of the nature of the RAT problem-solving process can be found in Moss et al. (2007).

The studies presented here make use of a design in which participants work on a set of RAT problems, followed by a lexical decision task in which solution words are embedded for some of the problems that participants initially left unsolved. The solution words were used as a rather direct form of hint. After the lexical decision task, participants were then presented with a second opportunity to work on RAT problems they had not yet solved.

## Experiment 1

### Method

**Participants.** Forty-five undergraduates (17 female) at Carnegie Mellon University participated in the study as part of a course requirement. All of the participants were native English speakers and between the ages of 18 and 35 years.

**Materials.** The 28 RAT problems used were chosen from the normed set published by Bowden and Jung-Beeman (2003b) such that the expected mean proportion of participants solving them in 30 s was .51 with a range of .36–.67. None of the words in the RAT problems were associated with words in the other RAT problems. A pool of 107 words and 168 nonwords was generated for the lexical decision task such that none of the words were associated with any of the RAT problems, and the words were of a similar length and frequency as those for the RAT problem solutions. Word association was determined with word association norms (Nelson, McEvoy, & Schreiber, 1998).

**Design and procedure.** The experiment consisted of two blocks of RAT problems separated by an intervening lexical decision task. There were two within-subject factors. The first factor was the duration of problem solving after an impasse was indicated. Participants could proceed to the next problem after either 0 s (impasse-0 condition) or 45 s (impasse-45 condition). The second factor was whether the solution to the problem was presented as a hint or not. These factors were crossed such that hints were presented for half of the impasse-0 problems and half of the impasse-45 problems.

Participants were given instructions on how to complete both tasks, and they were told that the experiment would involve alternating between the two tasks. Participants were asked to solve word association problems by generating a word that could be placed either before or after each of the three words in the problem to form compound words or common phrases. The problems were presented as three words arranged in a vertical column in the center of the screen with an outlined box presented beneath the last word in which the participants typed their answer. If a participant entered an incorrect answer, the computer made an error sound and the answer box was cleared. The participant then had the remainder of the time limit to continue working on the problem. Feedback consisting of the word *Unsolved* or *Solved* was presented in the center of the screen for 2 s at the end of each problem, followed by the next RAT problem.

Participants were instructed to press the *Escape* key when they had reached an impasse. An impasse was defined as a point at which they felt that they were not making any progress on the problem. They were told that for some problems pressing the *Escape* key would allow them to immediately move on to the next problem but that for other problems they would need to continue working on the problem for a period of time. Participants were informed that they would have another opportunity to work on problems that they had left unsolved.

Participants were then instructed on how to give concurrent verbal protocols using the procedure and practice tasks found in the Appendix of Ericsson and Simon (1993). Verbalizations were audio-recorded for later analysis. They were told that they did not need to verbalize during the lexical decision task. After the protocol instruction, participants completed two practice RAT problems followed by 10 practice lexical decision trials. For the lexical decision task, participants were instructed to respond as quickly and accurately as possible.

Participants then completed the initial set of problems. When participants indicated that they were at an impasse, the computer randomly assigned the problem to either the impasse-0 or

| First Attempt | Second Attempt |
|---|---|
| a hammer | uh |
| a **deer** hunter | hammer |
| a **jack** hammer | a **jack** hammer |
| um | a |
| **rubber** hammer | **carpenter's** hammer |
| gear | a |
| **mountain** gear | mmm |
| **duck** hunter | hunter |
| duck gear | hunter |
| (types in *duck* as answer) | |
| um | |
| a | |
| there's a jack hammer | |
| there's a rubber hammer | |
| there's | |

*Figure 1.* Sample RAT problem-solving protocol showing fixation. The given problem was the words *hunter, hammer,* and *gear*, for which the answer was *head*. Candidate words are in bold, with repeated candidates shown in gray. RAT = Remote Associates Test.

impasse-45 condition. If the problem was assigned to impasse-0, then the next problem was presented. If the problem was assigned to impasse-45, then the problem remained on the screen for 45 s or until it was solved.

The lexical decision task consisted of 10 neutral words unrelated to the problems, solutions for half of the unsolved problems, and the number of nonwords necessary to ensure there was an equal number of words and nonwords. The first 10 trials of the lexical decision task were considered practice trials and consisted of five neutral words and five nonwords. The remaining items were presented in random order. Participants pressed one key on a keyboard to indicate a "word" response and another key for "nonword." Each trial began with a fixation cross presented in the center of the screen for 1,500 ms, followed by the stimulus, which remained on the screen until the response. A blank screen was presented for 500 ms between trials.

After the lexical decision task, the unsolved problems were presented in random order, with a time limit of 30 s each. The study was limited to a 1-hr session. Because the initial set of problems was untimed, in order to ensure completion of the study, we did not present all 28 problems to those participants who took too long on the first set of RAT problems. It was possible to program the experiment to start the lexical decision task on the basis of a calculation of how much time had elapsed and the number of problems that had been left unsolved. Only four participants did not see all 28 problems. These participants saw 7, 19, 20, and 22 of the 28 problems. Excluding the participant who only saw seven problems did not change the statistical significance of any of the results. At the end of the study, participants completed a questionnaire designed to determine whether they could report the relationship between the lexical decision task and the RAT problems.

## Results

One participant was excluded from all analyses because his mean response time to word stimuli in the lexical decision task was greater than 1 s. Because all manipulations were within-subject, all effects including interactions could be reduced to a paired contrast, and therefore effect sizes are reported as Cohen's $d$.

**Performance on RAT problems.** Improvement on previously unsolved RAT problems was measured as the proportion of unsolved problems that were solved on the second attempt for each condition. This proportion is reported for each condition in Table 1. Eight participants reported noticing the relationship between the tasks (i.e., noticers), and their data were analyzed separately. The remaining participants (i.e., nonnoticers) solved 56% of the RAT problems on the first attempt ($SE$ = 2%). The predicted interaction (Hypothesis 1) was present because the effect of the hints was greater in the impasse-0 condition than in the impasse-45 condition, $F(1, 35) = 4.47$, $p = .04$, $d = 0.71$. The difference in difficulty between impasse conditions approached significance, $F(1, 35) = 3.82$, $p = .06$, $d = 0.66$, and there was no main effect of hint presentation, $F(1, 35) = 1.90$, $p = .18$.

The noticers were analyzed separately from the rest of the participants because they may have employed a different problem-solving strategy, such as trying to recall words presented in the lexical decision task while solving the problems. Their data were consistent with such a strategy because they improved more on problems where there was a hint presented regardless of impasse condition, $F(1, 7) = 5.86$, $p = .046$, $d = 1.83$. For these participants, there was no effect of impasse condition, $F(1, 7) = 1.90$, $p = .21$, and no interaction between hint and impasse condition, $F(1, 7) = 2.62$, $p = .15$. They solved 51% of the problems on the first attempt ($SE$ = 6%).

**Fixation.** The verbal protocols were analyzed to determine whether there was indeed a drop in the number of new candidate solutions being generated by participants after an impasse was reached. Analysis of the protocols was limited by a technical problem with the audio recording equipment, which led to blank recordings for a number of the participants. Only 22 participants' protocols were included in this fixation analysis. The lack of recordings affected only the acquisition of the verbal protocol data, and because the problem was not apparent to the experimenter or participants, it did not affect participants' performance.

The number of unique candidate solutions was determined for each problem by examining the verbal protocols. For example, in the first column of Figure 1 there are five unique candidate solutions verbalized by the participant. The candidate generation rate was determined by dividing the number of unique candidates by the time spent on the problem (i.e., number of candidates per second). For impasse-45 problems, the candidate rate was examined both before and after the impasse.

As expected, the candidate generation rate for impasse-0 problems ($M$ = .08, $SE$ = .008) did not differ from the rate for impasse-45 problems ($M$ = .09, $SE$ = .014) before the impasse was reached, $t(21) < 1$. The combined candidate rate for both

Table 1
*Mean Proportion of RAT Problems Solved in Each Condition in Experiments 1 and 2*

| Experiment and participant type | Preimpasse | | Impasse-0 | | Impasse-45 | |
|---|---|---|---|---|---|---|
| | No hint | Hint | No hint | Hint | No hint | Hint |
| Experiment 1 | | | | | | |
| Nonnoticers | | | .13 (.03) | .27 (.05) | .13 (.04) | .10 (.03) |
| Noticers | | | .09 (.05) | .23 (.09) | .04 (.04) | .43 (.14) |
| Experiment 2 | | | | | | |
| Nonnoticers | .37 (.04) | .34 (.04) | .22 (.03) | .31 (.03) | .13 (.02) | .12 (.02) |
| Noticers | .29 (.06) | .40 (.07) | .22 (.05) | .26 (.05) | .13 (.04) | .19 (.06) |

*Note*. Standard errors are in parentheses. RAT = Remote Associates Test; impasse-0 = participant proceeded to the next problem immediately after reaching an impasse; impasse-45 = participant continued trying to solve a problem for 45 s after reaching an impasse.

conditions before the impasse was greater than the candidate rate after the impasse in impasse-45 problems ($M$ = .05, $SE$ = .01), $t(21) = 2.67$, $p$ = .01, $d$ = 1.17. This result supports the idea that problem progress stalled or at least slowed significantly after the point of impasse.

**Lexical decision.** Accuracy was 98% or better in each condition. Responses to words that took longer than 1,300 ms were excluded (3% of the data). The mean response times for correct responses to the words in the lexical decision task were analyzed. For the nonnoticers, there was no difference in response time for hints related to impasse-0 problems ($M$ = 573, $SE$ = 14) and hints related to impasse-45 problems ($M$ = 579, $SE$ = 18), $t(35) < 1$, so the hints were combined in the comparison to the unrelated words. These participants did not respond to hint words ($M$ = 577, $SE$ = 13) faster than neutral words unrelated to the RAT problems ($M$ = 592, $SE$ = 15), $t(35) = 1.01$, $p$ = .32. The lexical decision times for the noticers were also analyzed, but their results did not differ from those of the nonnoticers.

## Discussion

These results are in line with Hypothesis 1, which asserts that problems abandoned at the point of an impasse would benefit more from an incidental hint than would problems abandoned after a period of continued work after reaching an impasse. Forcing participants to work past an impasse eliminated the effect of the incidental hints. Even though the hint was presented after other problems had been worked on, the state at which problem solving had been suspended impacted the effect of the hint. This result means that the representation of the problem as well as how fixated that representation is affects the likelihood that information related to a problem is acquired and used.

Although the protocol results were somewhat limited due to technical problems, the decreased candidate generation rate after the point of impasse supports the idea that fixation accumulates at a high rate when people are forced to work past the point of impasse. This increased fixation is likely one of the primary reasons that incidental hints had a greater impact for problems abandoned at the point of impasse. Hypothesis 2 is that there is some benefit to developing a sufficient problem representation before an incidental hint is presented. This was tested in Experiment 2 by adding a preimpasse condition, during which participants were allowed only 10 s to work on a problem before it was taken away.

# Experiment 2

## Method

**Participants.** Ninety-eight undergraduate students (39 female) at Carnegie Mellon University and Mississippi State University participated in the study as part of a course requirement. All of the participants were native English speakers and between the ages of 18 and 35 years.

**Design and procedure.** The design and procedure were the same as in Experiment 1 except that a preimpasse condition was added. In the preimpasse condition, the RAT problems were presented for only 10 s. A total of 38 RAT problems were used, and for each participant 10 of these problems were randomly assigned to the preimpasse condition. As in Experiment 1, participants were instructed to work on a problem until reaching an impasse. They were also told that some problems would be taken away before they had declared an impasse. They could not tell which problems would be taken away early. Verbal protocols were not collected because more participants were included to increase statistical power.

## Results

Three participants were excluded for poor performance or for not following instructions (50% accuracy on lexical decision trials, average lexical decision response time over 9 s, and always reaching an impasse in less than 10 s). A technical problem allowed nine participants to see preimpasse problems for slightly longer than the 10-s time limit. Analyses were performed with and without these problems, and there was no difference in the results. The analyses reported here include these problems.

Because participants were recruited from two different universities, a location factor was initially included in all analyses. Although location had a significant effect on both problem performance and lexical decision times, it never interacted with any other factor. Participants at one location were on average slightly worse problem solvers and slower lexical decision makers. Because all effects of interest were within-subject, location was dropped as a factor in all analyses.

**Performance on RAT problems.** Twenty-three participants were able to report the relationship between the RAT and lexical decision tasks at the end of the study. Participants on average answered 36% of the preimpasse RAT problems on the first attempt ($SE$ = 2.6%) and 57% of the problems in the two impasse conditions on the first attempt ($SE$ = 1.8%).

The primary measure of interest was again the proportion of unsolved problems that were solved on the second attempt for each condition. These proportions are shown in Table 1. Given the specific a priori hypotheses being investigated, Hypotheses 1 and 2 were each tested with a planned comparison using a 2 (impasse timing condition) $\times$ 2 (hint condition) analysis of variance (ANOVA). Hypothesis 1 was examined by including the impasse-0 and impasse-45 conditions. The predicted interaction was present because the effect of the hint was greater in the impasse-0 condition than in the impasse-45 condition, $F(1, 71) = 4.08$, $p$ = .047, $d$ = 0.48. This interaction replicates the main result of Experiment 1 and supports Hypothesis 1. Impasse-0 problems were more likely to be answered than were impasse-45 problems, $F(1, 71) = 14.65$, $p < .001$, $d$ = 0.91. There was no main effect of hints, $F(1, 71) < 1$.

Hypothesis 2 was examined by including the preimpasse and impasse-0 conditions. The interaction predicted by Hypothesis 2 was present because the effect of hints was greater in the impasse-0 condition than in the preimpasse condition, $F(1, 71) = 5.66$, $p$ = .02, $d$ = 0.56. Preimpasse problems were more likely to be answered than were impasse-0 problems regardless of hint condition, $F(1, 71) = 8.14$, $p$ = .006, $d$ = 0.68. There was no main effect of seeing the hints, $F(1, 71) < 1$.

The participants who reported the relationship between the tasks may have employed a different problem-solving strategy than did other participants, such as trying to recall words presented in the lexical decision task while solving the problems. When impasse-0 problems were compared with preimpasse problems, there were main effects of impasse condition that approached significance, $F(1, 22) = 3.15$, $p = .09$, $d = 0.75$, and hints, $F(1, 22) = 2.86$, $p = .10$, $d = 0.72$. The interaction of hint and impasse condition was not significant, $F(1, 22) < 1$. When impasse-0 problems were compared to impasse-45 problems, there was an effect of impasse condition that approached significance, $F(1, 22) = 3.12$, $p = .09$, $d = 0.75$. The main effect of hint was not significant, $F(1, 22) = 1.41$, $p = .25$, and there was no interaction, $F(1, 22) < 1$. Although the means for the hint condition were higher in all impasse conditions, the effect of the hint was not significant.

**Lexical decision.** Accuracy was 95% or better in each condition. Responses to words that took less than 300 ms or longer than 1,300 ms were excluded (4% of the data). For the nonnoticers, the mean response times for correct responses to the words in the lexical decision task were analyzed. Response times to the hint words were analyzed with a three-level single factor ANOVA. There were no significant differences between response times to the hints corresponding to preimpasse ($M = 597$, $SE = 14$), impasse-0 ($M = 617$, $SE = 14$), and impasse-45 ($M = 622$, $SE = 17$) problems, $F(2, 142) = 1.28$, $p = .28$. The response times for hint words collapsed across impasse conditions did not differ from the response times for neutral words ($M = 606$, $SE = 11$), $F(1, 71) < 1$. The lexical decision times for the noticers were also analyzed, but their results did not differ from those for the nonnoticers.

## Discussion

The effect of an incidental hint was directly compared for three stages of problem solving: preimpasse, the point of impasse, and 45 s after the point of impasse. The results replicate those of Experiment 1 because hints were more effective for impasse-0 than for impasse-45 problems. It should be noted that the results of Experiment 1 were replicated even though verbal protocols were not used in Experiment 2. This result should alleviate any concern about whether the act of verbalizing influenced problem solving in that experiment.

The results also show that the hint was more effective for impasse-0 problems than for preimpasse problems. This provides support for Hypothesis 2. The advantage for impasse-0 over impasse-45 problems is attributed to the increase in fixation from continuing to generate previously rejected candidate solutions. It is unlikely that much fixation was built up in the 10 s of problem solving in the preimpasse condition, so the advantage for impasse-0 over preimpasse is likely due to the development or exploration of a problem representation. The advantage for problems at the point of impasse could be due to a balance between problem representation development and fixation whereby there is an advantage to receiving the hint after the problem space has been explored but before fixation develops.

# General Discussion

The results of the two studies show how the state at which a problem is suspended affects the impact of incidental hints encountered while problem solving is suspended. In particular, the results support both hypotheses being investigated. First, incidental hints had a greater impact on problems suspended at the point of impasse than they did on problems on which participants continued working after reaching an impasse. Second, incidental hints also had a greater effect on problems suspended at the point of impasse than on problems suspended before an impasse was reached.

One explanation for the first result is that working past an impasse may lead to an increase of fixation on old ideas that subsequently decreases the likelihood of using any incidentally encountered hints. If a RAT problem is not solved within the first few seconds of presentation, participants' protocols show that they start a generate-and-test search through memory. With a memory model like ACT-R (Anderson et al., 2004), fixation can be viewed as a buildup of baseline activation due to recent retrievals of candidate solution words. In this architecture, baseline activation increases each time an item is retrieved and then decays away according to a power function. Because retrieval probability is related to activation values, then the words most likely to be retrieved from memory with a generate-and-test solution method are those that have been retrieved in the recent past. In RAT problems, an impasse is reached when one is unable to retrieve any new candidate words. At this point, further work on the problem is likely to lead to retrieval of words that have already been retrieved and rejected. This line of reasoning explains why work during an impasse is likely to lead to increased fixation.

Because decay of activation is a power function in ACT-R, the most recently retrieved words will decay faster relative to words that have not been retrieved recently. Taking a break from the problem is likely to reduce some fixation due to highly active but incorrect candidate solutions, but fixation due to more long-term causes such as associations between words does not benefit from an incubation period, presumably because such associations do not decay with time (Smith & Blankenship, 1991; Vul & Pashler, 2007; Wiley, 1998). The fixation in Experiments 1 and 2 is more likely to be due to recency of retrieval rather than long-term associations, because we did not specifically design the problems to take advantage of highly associated but incorrect solutions, as Wiley (1998) did.

The lexical decision task is a break in problem solving during which fixation due to recency likely decayed somewhat. However, it is unlikely that this brief break in problem solving is enough to eliminate fixation. In fact, participants in a similar study with an intervening lexical decision task tended to repeat rejected candidates during a second solution attempt (Moss, 2006). An example of repeating rejected solution candidates can be seen in Figure 1. This line of reasoning leads to the implication that if an increase in fixation (or base-level activation) is the reason that hints help less after working during an impasse, then the hint must compete with existing fixation. This competition with existing fixation can be explained by existing mechanisms in ACT-R. The solution word receives a boost of activation from its retrieval during the lexical decision task when it is presented as a hint. Therefore the solution word is more likely to be retrieved in the future. However, retrieval of a particular item is a probability based on the activation values of all relevant items in memory, and therefore any existing fixation will decrease the impact of the hint.

This explanation only partially explains the impact of incidental hints, however. The boost in activation must be something more than just a recency effect, because even when recency is controlled for, seeing hints before beginning work on a problem is less effective than seeing them during a break in problem solving (Moss et al., 2007). Similarly, the increase in activation from the lexical decision task would also be expected to affect preimpasse problems if it were due to only recency of exposure. This competition with existing fixation built up during an impasse is one explanation for the result that incidental hints help more when a problem is suspended at an impasse rather than after continued work during an impasse, but it does not address the result from Experiment 2 that incidental hints are more effective for problems suspended at an impasse than for problems suspended preimpasse.

One possible explanation for this result from Experiment 2 is that a sufficient representation of the problem must be created and searched for the hint to be effective. People do not seem to generate complex problem representations for RAT problems. If one thinks about memory as a network of associated words or concepts, then RAT problem solving can be seen as a search in this network. However, these problems are still complex enough for representation change. On the basis of the protocols we collected, participants were often generating candidate solutions primarily based on one of the three problem words at a time. The other two problem words could have been influencing search, but participants seemed to focus on one at a time. If the problem word currently being used to generate candidates is *star*, then the space one is searching is different if one thinks about "star" as a celestial body made of hot gas rather than as a celebrity. In addition, the problem solver can also change the space being searched by switching to another one of the problem words. As a problem solver works on this problem, more meanings of each of the three problem words are used as search points.

It may be that working on the problem activates these concepts in memory when they are searched, and then these activated concepts influence the acquisition and use of the hint. Exactly how this may work is unclear at this point, but one possibility is that working on the problem partially activates the solution word, and the presentation in the lexical decision task further activates the word, bringing it above a retrieval threshold. It should be noted that this mechanism relies on the activation of words in memory, as does our account of fixation. Therefore it may be that there is a similar mechanism underlying both effects of exploration and of fixation.

Another relevant issue concerning representation is the recognition of the need to search for a new one. Research has shown that failure within a representation drives the search for a new one and influences how likely people are to explore new ideas that may be related to the problem (Kaplan & Simon, 1990; Lovett & Schunn, 1999). Repeated failure may actually make people more likely to be affected by incidental hints, which could also help to explain why the hints helped more in the impasse-0 condition than in the preimpasse condition in Experiment 2.

The idea that hints presented during a break in problem solving may help, especially during an impasse, is not new (Kaplan, 1989; Seifert et al., 1995). The results presented in this article build on this prior research to show that the state of the problem representation as well as fixation on prior ideas may be equally important for assessing the impact of encountering problem-relevant information. These results imply that the best time to suspend problem solving to maximize the effect of encountering relevant information is at the point of impasse.

## Limitations

There are a few limitations of the current experiments that need to be addressed by future work. The first is that there appears to be a difference between people who caught on to the relationship between the two tasks and those who did not. The awareness of this relationship was assessed by a questionnaire, on which participants were asked to report what the relationship was. There is no reason to suspect that participants would not report the relationship, had they been able to do so; however, future work should examine alternative measures of awareness.

A second limitation is that there was an overall difference in problem solution rate for preimpasse, impasse-0, and impasse-45 problems. In particular, impasse-45 problems are those that remained unsolved after an additional 45 s of work postimpasse. It was the case that some participants answered problems during this postimpasse time period. In Experiment 1, a total of 28 problems in the impasse-45 condition (12.5% of the problems in the past-impasse condition) were answered during this time, and in Experiment 2, a total of 67 problems in the impasse-45 condition (10.5% of all problems in this condition) were solved during this time. According to published norms (Bowden & Jung-Beeman, 2003b), those problems that remained unsolved in the impasse-45 condition were no more difficult ($M$ = .51) than the problems that were solved in the 45 s ($M$ = .50). However, norms do not account for the fact that problem difficulty is often based on the interaction of a particular person and a particular problem.

This main effect of difficulty across conditions is a challenge for future work because problem difficulty is often measured by time to solve. Problems that have been worked on for more time after an impasse has occurred are then by definition more difficult problems. It will be challenging to pull apart time spent on a problem from problem difficulty. In any case, this difficulty effect is unlikely to account for the results presented here. First, problems were randomly selected to be in the hint or no-hint conditions. Any problems that would have been solved by spending more time working on the problem would have influenced the means for these two conditions equally, resulting in a net zero change in the effect of the hint. Second, calculations were done to assess what impact those problems that were answered during the 45 s after an impasse could have had on the effect of the hint in the impasse-45 condition, and the effect was negligible. Of course, one argument that could still be made is that the hint had no effect because these were harder problems. However, it seems at least equally plausible that seeing the solution should in fact have a greater impact for the most difficult problems, especially for simple problems such as the RAT problems used here.

Even with these limitations, the results presented here have implications for problem solving in terms of what happens at an impasse and how an impasse may be overcome. Developing a representation of a problem and exploring that representation is necessary for problem solving. However, when the problem remains unsolved and new ideas are subsequently harder to come up with, then fixation on previous unsuccessful ideas increases. This increase in fixation not only makes finding the solution harder but also decreases the chance that new information encountered during a break in problem solving will become incorporated into further work on the problem. Thus, there appears to be an optimal time to suspend problem solving that occurs around what has traditionally been called an impasse. This is a time where encountering new information may be the most beneficial.

In the work presented here, the hint was always the one-word solution to the problem. Given that others have shown effects of incidentally encountered information in more complex problems (Christensen & Schunn, 2005; Gick & McGarry, 1992; Tseng, Moss, Cagan, & Kotovsky, 2008), then it will be interesting to see whether similar effects of problem representation and fixation during impasses can be found in these more complex problems. In addition, others have not found an effect of incidental hints when the task in which hints were embedded emphasized processing the letters of the hint words rather than the word as a whole (Dodds, Smith, & Ward, 2002). This result could mean that the type of processing that the hint undergoes may also be an important factor. Future work along these lines using more complex problems and other forms of hints should provide insight into a number of areas of cognition, such as insight, incubation, and perhaps even knowledge transfer. In addition, there may be some practical benefits to knowing when people are most susceptible to receiving hints, such as in educational settings or in the design of problem-solving aids.

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