Partly versus Completely Out of Your Mind: Effects of Incubation and Distraction on Resolving Fixation

ABSTRACT

Incubation has long been proposed as a mechanism in creative problem solving (Wallas, 1926). A new trial-by-trial method for observing incubation effects was used to compare the forgetting fixation hypothesis with the conscious work hypothesis. Two experiments examined the effects of incubation on initially unsolved Remote Associates Test (RAT) problems. Following exposure to misleading clues designed to induce initial fixation on RAT problems, versus no clues, participants were retested on problems either immediately after their first attempt (no-incubation), or after a 40-second incubation period. Resolution of initially unsolved RAT problems (fixated versus non-fixated) was examined as a function of complete interruption (Experiment 1) or partial distraction (Experiment 2). An incubation effect, that is, better resolution of initially unsolved problems retested after a delay rather than retesting immediately, was seen only in Experiment 1, in which unsolved problems were completely removed from sight. Furthermore, an incubation effect was found only for initially fixated problems, and not for problems that were not accompanied by misleading clues. The results are consistent with the forgetting fixation hypothesis (Smith & Blankenship, 1989), which states that putting unsolved problems completely out of mind allows initial fixation to dissipate, and the results indicate that the opportunity for some conscious work during incubation periods may not be optimal for resolving fixation.

INTRODUCTION

Solving problems that require a person to be creative is not easy. In contrast to typical problem solving, creative problem solving involves approaching a problem without knowledge of how you are going to move from the beginning to the goal state. If a problem-solver employs typical thinking when attempting to solve a creative problem, typical thinking can sometimes lead the problem-solver to become fixated on an incorrect solution path. However, incubation intervals offer
a promising remedy to the problem of creative problem solving. Incubation effects are cases in which putting a problem aside, rather than continuing work on it, can lead to an insightful solution (Wallas, 1926; Woodworth & Schlosberg, 1954). Incubation can be observed in real-world settings in problem solving (e.g., returning to a deferred problem on an exam), in memory retrieval (e.g., remembering a temporarily forgotten name), and in historically significant creative insight (e.g., Kary Mullis thinking of the Nobel prize-winning idea of the polymerase chain reaction while driving his car). By its very nature, the concept of incubation is counterintuitive. If people want to succeed in solving problems, retrieving memories, or thinking creatively, it makes sense that they would be better off by continuously working towards achieving their goal rather than by taking breaks.

Despite its occurrence in real world settings, incubation has not always been observed in experimental settings. In the early stages of incubation research, few published experiments provided evidence for incubation (C. Patrick, 1938; Silviera, 1971), and those few were never reported to be replicable. Other studies failed to find incubation effects (e.g., Dominowski & Jenrick, 1972; Gall & Mendelsohn, 1967; Olton, 1979; Olton & Johnson, 1976). One review of published studies concluded that incubation may not exist (Olton, 1979; Olton & Johnson, 1976). More recently, however, numerous cases of incubation effects have been reported (Both, Needham, & Wood, 2004; Browne & Cruse, 1988; Christensen & Schunn, 2005; Goldman, Wolters, & Winograd, 1992; Houtz & Frankel, 1992; Norlander & Gustafson, 1996; Segal, 2004; Smith & Blankenship, 1989, 1991).

The inconsistencies of the prior incubation findings might be attributed to the methodology in whether or not fixation was induced (Smith & Blankenship, 1989, 1991; Vul & Pashler, 2007). Smith and Blankenship's methodology entailed inducing fixation on the initial trials of critical problems, followed either by a retest given immediately, or given after a delay. Smith and Blankenship's methods were developed to test the forgetting fixation hypothesis, which states that incubation effects can be observed to the extent that the incubation period permits one to forget inappropriate responses that come to mind initially, which block correct solutions or key ideas from coming to mind. According to the theory, fixation occurs when competing associates (i.e., blockers) become activated. When fixation on blockers dissipates, more appropriate concepts needed for solving a problem can be accessed. This theory predicts that the better an incubation task is at causing one to forget the fixation, the more likely resolution will occur. Smith and Blankenship (1991) observed incubation effects when fixation was initially induced. Furthermore, Smith and Blankenship (1989) found that forgetting of experimentally provided blockers and increased resolution of initially unsolved problems both occurred as a function of longer incubation intervals. The forgetting fixation hypothesis has been supported not only by findings of incubation following initial experimentally induced fixation in problem solving (Smith & Blankenship, 1989, 1991), but also by findings of incubated reminiscence (memory recovery) effects (Smith & Vela, 1991) that follow initial output interference, a memory blocking phenomenon.
The conscious work hypothesis, in contrast to the forgetting fixation hypothesis, states that during incubation, the mind works at constructing solutions in incremental steps (e.g., Browne & Cruse, 1986; Smith, 1995). According to the conscious work hypothesis, incubation occurs when one is consciously engaged in solving a problem despite not having the problem physically present (Browne & Cruse, 1986; Gall & Mendelsohn, 1967; Weisberg & Alba, 1981). For example, Browne and Cruse (1988) found that participants who relaxed during an incubation interval resolved a difficult geometry problem by using brief periods of conscious work during incubation. Conscious work may be augmented by chance encounters with hints related to the solutions of initially unsolved problems during incubation intervals (e.g., Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995), another prediction consistent with Browne and Cruse’s findings.

The forgetting fixation and conscious work hypotheses are not necessarily mutually exclusive. That is, both forgetting fixation and conscious work may occur during incubation intervals, and both may contribute to the resolution of initially unsolved problems. Of the two, however, only the forgetting fixation hypothesis depends upon fixation or blocks as the cause of one’s initial failure to solve a problem; the conscious work hypothesis does not depend on initial fixation. In the present experiments, we tested whether forgetting fixation or the opportunity for conscious work is more likely to lead to incubation effects when fixation initially impedes problem solving.

The present study tested predictions of the forgetting fixation hypothesis vs. the conscious work hypothesis, using Remote Associate Test (RAT) problems to observe incubation effects. RAT problems were originally designed as measures of creativity (Mednick, 1962). These problems require participants to think of a single word that can form expressions with all three words of the problem. For example, the word “pit” solves the RAT problem “ARM COAL STOP,” because it can be used to form the expressions ARM-pit, COAL-pit, and pit-STOP. RAT problems have been successfully used in incubation studies (Jung-Beeman et al., 2004; A. S. Patrick, 1986; Smith & Blankenship, 1991).

In the present study fixation was induced by providing a misleading cue prior to each critical RAT problem. The present study used a trial-by-trial paradigm for studying incubation effects, inducing fixation on each critical trial, and observing incubation for a single RAT problem at a time. Previous studies of incubation that employed multiple problems manipulated incubation by either retesting each problem immediately in the no incubation condition, versus giving participants a first attempt on all problems, followed by an incubation interval, and then a second attempt on all problems (Peterson, 1974; Smith & Blankenship, 1989, 1991). Because mental operations were not tightly controlled during the incubation periods in these experiments, it is not clear whether the delayed retesting in those studies relieved fixation, furnished verbal hints in the form of other RAT problems, or provided time for extra conscious work on initially unsolved problems. In the present study, each incubation trial consisted of a fixation task, an initial
attempt to solve a RAT problem, a delay involving a vigilance task, and then a second attempt to solve the RAT problem. Thus, each trial was disjoint, and the cause of any incubation effects could be more directly attributed to specific events occurring within a given trial.

The present experiments examined the effects of withdrawing attention from fixated problems during incubation intervals. During each incubation interval a digit-monitoring task was given in which participants counted occurrences of a pattern of numbers seen on a screen. In Experiment 1 the incubation interval involved complete interruption; RAT problems were removed from the viewing screen during incubation/digit-monitoring, making continued conscious work on unsolved RAT problems quite difficult. Thus, the interruption in Experiment 1 involved true incubation effects, in which problems are put aside completely. In Experiment 2 the incubation interval involved distraction; unsolved RAT problems remained on-screen during the digit-monitoring tasks, allowing, and even encouraging participants to continue working on initially unsolved RAT problems during incubation periods. Thus, participants did not truly put unsolved problems completely aside; rather, participants were distracted from concentrating attention on unsolved RAT problems in Experiment 2.

The conscious work hypothesis predicted that an incubation interval involving partial distraction should produce greater resolution of initially unsolved RAT problems, as compared with an immediate retest (no incubation control) condition, because the continued presence during the break of an initially unsolved RAT problem should have allowed some conscious work to continue. The conscious work hypothesis predicted that a complete withdrawal of attention from unsolved RAT problems during the incubation period, which occurred in Experiment 1 when unsolved problems were removed from sight during the break, should have produced smaller incubation effects, if any incubation effects at all. These predictions of the conscious work hypothesis were made not only for experimentally fixated problems, but also for non-fixated problems. In all cases, having an opportunity to work on unsolved problems, as in Experiment 2, should benefit resolution, whereas conscious work should be impeded for both types of problems during the incubation periods in Experiment 1.

The forgetting fixation hypothesis, in contrast, predicted the opposite of the conscious work hypothesis, specifically, that leaving initially unsolved RAT problems on the screen (Experiment 2) would maintain the experimentally-induced fixation, thereby impeding resolution of those problems. According to the forgetting fixation hypothesis, a complete withdrawal of attention during incubation tasks (Experiment 1) should yield incubation effects, as seen by greater resolution of initially fixated problems in the delayed retest condition relative to the immediate retest condition. Problems that were not experimentally fixated were not predicted by the forgetting fixation hypothesis to show incubation effects, because there should have been little fixation to be forgotten in those cases.
EXPERIMENT 1

Participants saw a series of trials (see Table 1) in which they were given first a two-word phrase task, used on some trials to induce fixation, followed by an initial attempt on a RAT problem. In the incubation condition, the initial attempt at a RAT problem was followed by an incubation period during which participants monitored the screen for digit patterns. The RAT problem for that trial did not remain on the screen during digit-monitoring in Experiment 1. In the no incubation control condition a 1-second pause was given rather than the 40-seconds of digit-monitoring. Each trial concluded with a second attempt on the RAT problem.

<table>
<thead>
<tr>
<th>Test</th>
<th>Stimuli</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helpful Trial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two Word Phrase</td>
<td>Star</td>
<td>Movie, Dust</td>
</tr>
<tr>
<td>Task</td>
<td>Falling</td>
<td>Movie, Dust</td>
</tr>
<tr>
<td>Remote Associate</td>
<td></td>
<td>Movie star, Star</td>
</tr>
<tr>
<td>Test</td>
<td></td>
<td>dust</td>
</tr>
<tr>
<td>Unrelated Trial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two Word Phrase</td>
<td>Hop</td>
<td>Door, Bell</td>
</tr>
<tr>
<td>Task</td>
<td>Goat</td>
<td>Pass, Range</td>
</tr>
<tr>
<td>Remote Associate</td>
<td></td>
<td>Door hop, Doorbell</td>
</tr>
<tr>
<td>Test</td>
<td></td>
<td>Mountain</td>
</tr>
<tr>
<td>Blocking Trial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two Word Phrase</td>
<td>Cat</td>
<td>Board, Black</td>
</tr>
<tr>
<td>Task</td>
<td></td>
<td>Blackboard, Black</td>
</tr>
<tr>
<td>Remote Associate</td>
<td></td>
<td>Cat</td>
</tr>
<tr>
<td>Test</td>
<td></td>
<td>Sleep, Board</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Walk</td>
</tr>
</tbody>
</table>

On blocking trials, initial fixation was induced on a RAT problem by presenting an incorrect solution via a two-word phrase task immediately preceding the RAT problem, whereas on unrelated trials, the words on the two-word phrase task were unrelated to the subsequent RAT problem (see Table 1). On a third of the trials, the two-word phrase task contained the solution to the accompanying RAT problem. These helpful hints were given on some problems to encourage participants to consider the words on the accompanying two-word phrase task when trying to solve all of the RAT problems, a procedure intended to increase the likelihood that fixation would be successfully induced on blocking trials.

Resolution was calculated as the proportion of RAT problems not solved initially, but that were later resolved when retested. An incubation effect could be evidenced by a greater resolution rate for the incubation condition (delayed re-test) than for the no incubation condition (immediate re-test).

The type of digit-monitoring task given during the incubation period was also manipulated. Participants monitored the visually presented sequences of digits for spans of either two consecutive odd digits, three consecutive odd digits, or five consecutive odd digits as their incubation task. This manipulation was conducted in order to manipulate how much attention is withdrawn from the RAT.
problem during the incubation interval. According to the conscious work hypothesis, incubation effects will be observable when the problem-solver is free to think about the RAT. In contrast, the forgetting fixation hypothesis predicts that incubation effects are optimal when the incubation interval forces the problem-solver to forget about the RAT. Thus, the digit-monitoring task attempted to withdraw a low, medium, or high amount of attention from the RAT problem. Error rates for digit-monitoring (i.e., the proportion of trials in which a participant miscounted the frequency of target digit patterns) were analyzed, computing rates separately for cases in which a RAT problem was initially solved versus cases in which the problem was not initially solved. This analysis was an indicator of how distracting the incubation task was and how much attention the participant might continue to give to unsolved RAT problems during incubation.

The forgetting fixation hypothesis predicted that removing the presence of RAT problems during digit monitoring in Experiment 1 would reduce the effects of the induced fixation, thereby leading to incubation effects for experimentally blocked RAT problems. Incubation effects were not predicted by the forgetting fixation hypothesis to be observed for RAT problems accompanied by unrelated words. In contrast, the conscious work hypothesis predicted that completely removing initially unsolved problems from mind during incubation intervals would prevent incubation effects from occurring, a prediction made both for items accompanied by blockers and for those accompanied by unrelated words.

METHOD

Participants. Participants for this study came from an introductory psychology course and received credit towards course completion. These students had the option of signing up for the present experiment or other experiments being offered in the psychology department. Sessions for the experiment ranged from 1-6 participants at a time. A total of 88 students participated in this experiment and were randomly assigned to one of the three conditions.

Materials. Three types of tasks were given to participants: a two-word phrase task, a RAT problem, and a digit-monitoring task. The RAT is a word association task that contains three words. These RAT problems were compiled from prior studies (Smith, Sifonis, & Tindell, 1998) or by experimenter-generation (see Appendix A for a complete list).

The two-word phrase tasks (Appendix A) also contained three words each and were constructed either from the words used in the corresponding RAT problems (see Table 2) or from experimenter generation. In the two-word phrase task, participants were presented with three words (e.g., FLAG VAULT POLE) on the screen and asked to form two compound words or 2 two-word phrases using only those three words provided. For example, “FLAG POLE” and “POLE VAULT” could be formed from the displayed words.
For RAT problems participants were asked to come up with a single word that could be used to make a compound word or two-word phrase with all three of the problem words (e.g., ARM COAL STOP) on the screen. For example, the solution "pit" makes a compound word or two-word phrase with each of the problem words, ARMPIT, COAL PIT, and PIT STOP.

Participants were given a response form for the experiment. For each trial, blanks were provided for participants to write their first RAT attempt, the number of strings of odd-digits they witnessed, and their second RAT attempt.

The digit-monitoring task contained a list of 40 digits ranging in value from 1-9. Each list contained random numbers along with strings of two consecutive odd numbers, three consecutive odd numbers, or five consecutive odd numbers. A total of 84 lists were created. The stimuli were presented via Microsoft PowerPoint 2000 on a 20" computer monitor.

Design & Procedure. In the incubation condition, each trial contained first a two-word phrase task, then a RAT problem, then a digit-monitoring task, and finally, a retest of the RAT problem (see Figure 1). Trials in the no incubation condition contained only two-word phrase tasks and RAT problems.

In all conditions, participants were given 20 seconds to complete each two-word phrase task and 15 seconds for the initial RAT attempt. In the digit-monitoring task, participants were asked to monitor for strings of consecutive odd digits. Participants counted the number of occurrences of either two consecutive odd numbers, three consecutive odd numbers, or five consecutive odd numbers (dependent upon condition)\(^1\). Digits flashed on the screen at a rate of one per second for 40 seconds. At the end of this period, participants were given 7 seconds to write down the number of targeted sequences they monitored, as well as the answer to the RAT problem if they solved it during the digit presentation. Participants in the no incubation condition were given 20 seconds for the two-word phrase task, 15 seconds of the initial RAT presentation, a 1-second pause (a blank screen), and 7 seconds of a second RAT problem presentation.

Twenty-eight trials were constructed for the present study. For Experiment 1, 24 trials were used. Of these trials, 10 were classified as blocking, five as unrelated, and five as helpful. The other four trials were used as example trials (one helpful, one blocking, and two unrelated). These trials differed by the words used in the accompanying two-word phrase tasks (see Table 1). The blocking trials contained a blocker word in the two-word phrase task that would be associated with only two of the three words of that trial's RAT problem. The intention was for participants to become fixated on the incorrect solution words (blockers). For example, after completing a two-word phrase task (e.g., CAT BOARD BLACK; solution: "Blackboard, Black cat"), the participant may have been fixated on the blocker word "black" when completing the subsequent RAT problem (e.g., CAT

\(^1\) No differences in digit-monitoring error rates as a function of number of consecutive odd digits were found in either experiment; therefore, participants in all three digit-monitoring tasks were combined into a single incubation condition.
FIGURE 1. Trial-by-trial method used for conditions in Experiments 1 and 2.

Low, Medium, High
Two-Word Phrase Task (20s)

Initial RAT Attempt (15s)

Digit-monitoring* (40s)

Second RAT Attempt (7s)

No Incubation
Two-Word Phrase Task (20s)

Initial RAT Attempt (15s)

Blank Screen (1s)

Second RAT Attempt (7s)

* RAT problems remained on-screen in Experiment 2, but were not present in Experiment 1.
Incubation and Distraction

SLEEP BOARD; solution: "walk"). The unrelated trials contained words in the two-word phrase task that were completely unrelated to the corresponding RAT problem on that trial. For the six helpful trials, non-critical problems were accompanied by helpful hints in the two-word phrase tasks. For example, a two-word phrase task of STAR MOVIE DUST, included the solution to the subsequent RAT problem (FALLING MOVIE DUST), "star." The purpose of using helpful trials was for participants to gain experience in using words from the two-word phrase task in solving the RAT, thus increasing the likelihood of fixation in the blocking trials. While no instructions were provided to participants that a RAT's solution could be found in the two-word phrase task, it is assumed that through experience and one of the example trials, participants used words in the two-word phrase task as initial solution attempts on the RAT. The order of the 28 trials was randomly created; however, every participant was presented the trials in the same order.

Experiment 1 was constructed using a 3 (digit-monitoring level — low, medium, high) X 3 (trial type — blocking, unrelated, helpful) design. Digit-monitoring was manipulated between-subjects and refers to whether participants were asked to monitor for two (low), three (medium), or five (high) odd-digit strings. Trial type was manipulated within-subjects and refers to whether the trial's two-word phrase task was intended to induce fixation (blocking), aid solution (helpful), or have no relation to that trial's RAT problem (unrelated). For analyses, helpful trials were not included (helpful trials were included in the procedure, not because of theoretical predictions, but rather to encourage participants to try using words from the two-word phrase task to solve RAT problems). The fourth condition (no incubation) contained no digit-monitoring, but did include all three trial types.

RESULTS

A significance level of $p < .05$ was used on all statistical tests for both Experiments 1 and 2. Three dependent measures of interest were calculated for these experiments. The proportion of RAT problems solved initially was calculated by dividing the number of RAT trials solved initially by the number of trials provided to participants. For example, if a participant solved two of the six unrelated trials, then the proportion of unrelated trials solved initially would be 0.33. Resolution score, an indicator of incubation effects, was also calculated. This was done by taking the number of RAT problems that were initially unsolved but solved after the delay, and dividing this number by the number of trials that were not solved initially. For example, if a participant solved only two of the six unrelated trials on their initial attempt, but then solved one of the four unsolved problems on their second attempt, then the resolution score would be 0.25. Thus, if a participant solved a problem initially, then it could not be resolved and was not included in the resolution analysis. The last dependent measure of interest was digit-monitoring errors. This refers to the number of trials in which the participant did not indicate the correct number of occurrences of two, three, or five odd digit strings.
A one-way ANOVA analyzed the effects of the three digit-monitoring tasks (two, three, or five consecutive odd digits) using the digit-monitoring error rate as the dependent variable. The proportion of trials resulting in a digit-monitoring error was not affected by the number of monitored digits \(F(2, 63) = 2.26, \text{MSE} = 0.02\). Because the manipulation of digit-monitoring did not result in a varied level of difficulty (as measured by digit-monitoring error rates), all three digit-monitoring task conditions were combined for analyses of the delayed retest condition.

A 2 (retest—immediate vs. delay) x 2 (trial type—blocking vs. unrelated) ANOVA was used to analyze resolution scores. There was a main effect of trial type \(F(1, 87) = 9.75, \text{MSE} = 313.79\). Resolution was greater in unrelated trials than in blocking trials (Table 2). There was no main effect of retest \(F(1, 87) = 1.00, \text{MSE} = 409.44\). Although there was not a significant interaction \(F(1, 87) = 0.63, \text{MSE} = 313.79\), we moved onto a priori comparisons. To test the predictions of the competing hypotheses regarding incubation effects, two planned comparisons were calculated comparing resolution scores. In the case of blocking trials, resolution was significantly greater in the delayed re-test condition than the immediate re-test condition \(t(58) = 1.93, p = .03\). There was no difference between the two conditions in resolution scores for unrelated trials \(t(87) = 0.17, p = .86\).

**Table 2.** Mean resolution rates for RAT problems in blocking trials of Experiment 1 as a function of incubation condition and type of words accompanying RAT problems.

<table>
<thead>
<tr>
<th>Type of Words with RAT Problems</th>
<th>Incubation (delayed)</th>
<th>No Incubation (immediate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocking</td>
<td>.10 (.01)</td>
<td>.05 (.02)</td>
</tr>
<tr>
<td>Unrelated</td>
<td>.17 (.03)</td>
<td>.16 (.05)</td>
</tr>
</tbody>
</table>

Standard errors of the mean are shown in parentheses.

A paired samples t-test was computed to examine digit monitoring error rates as a function of problem status, that is, trials in which RAT problems were solved vs. not solved on initial attempts. One participant was removed for this analysis due to not solving a single trial initially. There was no significant effect of problem status \(t(64) = 1.29, p = .20\); the error rate for trials in which RAT problems were initially solved \((M = .12, SE = .02)\) was not significantly different from the rate on trials in which problems were not initially solved \((M = .15, SE = .02)\).

A 2 (retest—delayed vs. immediate) x 2 (trial type—blocking vs. unrelated) ANOVA was also computed to analyze the proportion of trials solved initially. There was a main effect of trial type \(F(1, 89) = 10.99, \text{MSE} = 26.27\). RAT problems in unrelated trials \((M = .39, SE = .03)\) were solved at a higher rate in the initial presentation than RAT problems in blocking trials \((M = .30, SE = .02)\). There was not a significant effect of retest \(F(1, 89) = .24, \text{MSE} = 1.57\) or an interaction \(F(1, 89) = .18, \text{MSE} = 0.43\).
DISCUSSION

In the present experiments, an incubation effect was operationally defined as a case in which the resolution rate was greater after a delayed retest, as compared to an immediate retest. Experiment 1, using a trial-by-trial paradigm, demonstrated a significant incubation effect for blocking trials, but not for trials in which RAT problems were accompanied by unrelated words. That is, when a participant came to an impasse due to fixation, resolution of unsolved problems was achieved by taking participants' minds completely off of initially blocked RAT problems with a digit-monitoring task. There was no significant benefit of incubation intervals in terms of resolving RAT problems that were not initially accompanied by blockers. These results are consistent with the forgetting fixation hypothesis of incubation, which states that fixation can be escaped if attention is completely withdrawn from fixed problems. Although the results do not show that forgetting fixation is a necessary condition for observing incubation effects, they do indicate that forgetting fixation is a sufficient cause of incubation effects.

An interesting finding was that there were greater resolution rates for unrelated trials than blocking trials. On this surface, this may be interpreted as counter to the predictions of the forgetting fixation hypothesis. However, these increased rates are due to higher initial solution rates (increasing the proportion of RATs solved initially increases the resolution rates). Because of this and the aforementioned observation of an incubation effect only in blocking trials, we can conclude that Experiment 1's findings do support the forgetting fixation hypothesis.

It may be that the methods used for observing incubation in previous studies of RAT problems (e.g., Smith & Blankenship, 1991) provided verbal hints in the form of other RAT problems, and/or provided opportunities for extra conscious work on initially unsolved problems. Such opportunities were not available in the trial-by-trial method used in the present study. Clearly, verbal hints and opportunities for extra conscious work were not necessary for the observation of an incubation effect in Experiment 1. The incubation effect may have occurred in Experiment 1 because conscious work on initially blocked problems was prevented by the digit-monitoring task. Conscious work on a problem would prevent participants from forgetting the initial fixation induced by blocker words. Alternatively, it may be that a partial withdrawal of attention from experimentally fixated RAT problems, as compared with complete withdrawal of attention, might lead to even greater incubation effects than were found in Experiment 1, because some degree of conscious work might be possible, which could enhance incubation effects. These two possibilities were tested in Experiment 2.

EXPERIMENT 2

In Experiment 1, RAT problems were removed from view during incubation intervals. This procedure was effective for taking participants' thoughts completely away from initially unsolved RAT problems, as evidenced by the lack of a significant difference in digit-monitoring errors between trials in which problems were solved vs. those in which problems were initially unsolved. In Experiment 2, in contrast, RAT problems were continuously displayed below the digits during
incubation intervals so that participants could continue to work on solving the problem while they monitored the digits. Thus, Experiment 2's period between initial and second RAT solution attempts was more of a distraction interval than an incubation interval. Competition between problem solving and digit-monitoring for attentional resources was expected to be observable in the form of increased digit-monitoring errors on trials in which RAT problems were initially unsolved, as compared with trials in which problems were initially solved. Such a pattern would indicate that, although focused on the digit-monitoring task, participants were nonetheless allocating some attentional resources to solving the on-screen RAT problems.

The conscious work hypothesis predicted that an incubation effect would occur when using these distraction intervals. That is, because some conscious work is possible when participants are only slightly distracted, that conscious work could help participants resolve initially unsolved problems. The forgetting fixation hypothesis, however, predicted that maintaining some level of attention to initially unsolved RAT problems should sustain fixation, thereby minimizing or preventing incubation effects from occurring.

METHOD

Participants. Participants for this study came from an introductory psychology course and received credit towards course completion. These students were given the option of signing up for this experiment or other experiments being offered in the psychology department. Sessions for the experiment ranged from 1-6 participants at a time. A total of 90 students participated in this experiment and were randomly assigned to the incubation and no incubation conditions.

Materials. The same materials from Experiment 1 were used in Experiment 2.

Design & Procedure. The same design and procedure from Experiment 1 was used in Experiment 2. The only exception was that RAT problems were displayed during the digit-monitoring task on each trial. Twenty-eight trials were constructed for this experiment. Of these, 12 were classified as blocking, six as helpful, and six as unrelated. The remaining four trials were used as examples (one blocking, one helpful, and two unrelated) to aid in participants' understanding of the experimental tasks. The reason four additional trials were included was because it was determined that we could increase the number of observations without having the length of the experiment sessions exceed 1 hour.

RESULTS

A one-way ANOVA analyzed the effects of the three digit-monitoring tasks (two, three, or five consecutive odd digits) using the digit-monitoring error rate as the dependent variable. The proportion of trials resulting in a digit-monitoring error was not affected by the number of monitored digits \( F(2, 60) = 0.38, MSE = 0.03 \). Therefore, as in Experiment 1, all three levels of digit-monitoring tasks were combined for analyses of the delayed retest condition.
Incubation and Distraction

As in the previous experiment, in an attempt to investigate incubation effects, resolution scores were analyzed (Table 3). A 2 (retest — immediate vs. delay) X 2 (trial type — blocking vs. unrelated) ANOVA was used to analyze resolution scores. There was no main effect of trial type \( F(1,87) = 1.20, MSE = 234.91 \) or retest \( F(1,87) = 0.08, MSE = 264.47 \). Although there was not a significant interaction \( F(1,87) = 0.56, MSE = 234.91 \), we moved onto a priori comparisons. Planned comparisons indicated that resolution was not significantly greater for delayed retested problems than for immediately retested ones either in the blocking trials \( t(88) = 1.12, p = .26 \), or in the unrelated trials \( t(87) = 0.24, p = .81 \) (Table 4). Care should be given when interpreting these resolution results given the low amount of observed power (.19). This appears to be due to a very low effect size (.08), which would have required over 1,000 participants to reach an observed power of .95.

**Table 3.** Mean resolution rates for RAT problems in blocking trials of Experiment 2 as a function of incubation condition and type of words accompanying RAT problems.

<table>
<thead>
<tr>
<th>Type of Words with RAT Problems</th>
<th>Incubation (delayed)</th>
<th>No Incubation (immediate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocking</td>
<td>.06 (.01)</td>
<td>.08 (.02)</td>
</tr>
<tr>
<td>Unrelated</td>
<td>.10 (.03)</td>
<td>.09 (.03)</td>
</tr>
</tbody>
</table>

Standard errors of the mean are shown in parentheses.

A paired samples t-test showed that digit monitoring error rates significantly varied as a function of problem status, that is, trials in which problems were solved vs. not solved on initial attempts \( t(62) = 3.32, p < .01 \). The proportion of initially unsolved trials that resulted in a digit monitoring error \( M = .24, SE = .02 \) was nearly twice that of initially solved trials resulting in a digit monitoring error \( M = .14, SE = .03 \).

A 2 (retest — delayed vs. immediate) X 2 (trial type — blocking vs. unrelated) ANOVA was also computed to analyze the proportion of trials solved initially. There was a main effect of trial type \( F(1,88) = 11.95, MSE = 27.80 \). RAT problems in unrelated trials \( M = .36, SE = .03 \) were solved at a higher rate in the initial presentation than RAT problems in blocking trials \( M = .27, SE = .01 \). There was not a significant effect of retest \( F(1,88) = 2.54, MSE = 9.30 \) or an interaction \( F(1,89) = .35, MSE = 0.82 \).

**DISCUSSION**

No incubation effects were found in Experiment 2; that is, initially unsolved RAT problems were not resolved better if retesting occurred after a 40-second period of distraction rather than when retesting occurred immediately after the initial attempt. The lack of an incubation effect was surprising, because
incubation effects have been reported numerous times with RAT problems (Jung-Beeman et al., 2004; A. S. Patrick, 1986; Smith & Blankenship, 1991), and were found in Experiment 1 of the present study.

During the 40-second distraction period, participants in Experiment 2 had some opportunity to continue conscious work on initially unsolved RAT problems. The fact that digit-monitoring errors nearly doubled for incubation intervals in which problems were initially unsolved, relative to intervals following initially solved problems, indicates that participants did give some attention to unsolved problems during the incubation tasks. Therefore, the results of Experiment 2 contradict predictions of the conscious work hypothesis, that opportunities for conscious work during incubation intervals can relieve fixation, thereby leading to incubation effects.

GENERAL DISCUSSION

The results of the present experiments show that incubation effects in creative problem solving can be observed with a trial-by-trial method in which each problem is independently manipulated and observed. On each trial in the present study, fixation was experimentally controlled, and attention was experimentally diverted (or not diverted) before the retest of each problem. In the incubation conditions of Experiment 1, in which attention was completely diverted from work on initially unsolved RAT problems, an incubation effect was observed for problems that had been experimentally fixated, but not for problems that were not fixated. In Experiment 2, which differed from Experiment 1 only in that initially unsolved RAT problems remained on the screen during the incubation interval, no incubation effect was observed. These findings were predicted by the forgetting fixation hypothesis (e.g., Smith & Blankenship, 1989, 1991), which states that incubation effects can be observed if a period of time away from fixated problems allows fixation effects to weaken. The findings are inconsistent with predictions derived from the conscious work hypothesis, because a greater opportunity for conscious work during the incubation period eliminated the incubation effect. The findings do not show that conscious work cannot produce an incubation effect; rather, they show that completely taking one's mind off of a fixated RAT problem facilitates resolution better than does partial withdrawal of attention from the unsolved problem.

Digit monitoring error rates showed clearly that in Experiment 2, when RAT problems remained on the screen during the digit-monitoring task, significantly more attention was withdrawn from monitoring when RAT problems were initially unsolved than when the problems were solved initially. In Experiment 2 the number of digit monitoring errors nearly doubled when problems had been initially unsolved, rather than solved on the first pass. These results confirm the idea that participants did not take their minds completely off of initially unsolved RAT problems during the distraction periods in Experiment 2. In contrast, in Experiment 1, when RAT problems were removed from view during digit monitoring, there were no differences in the digit monitoring error rates for trials in which RAT problems
had been initially solved versus trials when problems were initially unsolved. These results indicate that participants’ attention was more completely withdrawn from initially fixated RAT problems in Experiment 1 than in Experiment 2.

Because the present experiments controlled participants’ attention more tightly than was done in previous studies on incubation effects (e.g., Smith & Blankenship, 1989, 1991), we were better able to rule out alternative interpretations of the incubation effects in those studies. Those previous studies retested initially unsolved problems after incubation periods in which many other problems had been seen. Those procedures not only allowed participants to consciously work on unsolved problems during incubation, but also may have inadvertently provided hints to the unsolved problems if solution words had been triggered due to associations to intervening problems. Some studies have shown that hints provided during incubation periods can trigger incubation effects (e.g., Dodds, Ward, & Smith, 2003; Dominowski & Jenrick, 1972; Yaniv & Meyer, 1987). Thus, the results of the present experiments demonstrate that neither hints nor conscious work are necessary for incubation effects to be observed.

Although the present experiments show that for resolving fixated problems, completely diverting attention away from the problems is better than only partly diverting attention, they clearly do not rule out the usefulness of hints and conscious work for resolving initially unsolved problems. The present experiments demonstrated incubation effects only for experimentally fixated problems; initially unsolved RAT problems that were preceded by unrelated words did not show incubation effects, as in Smith and Blankenship’s (1991) study. Hints and conscious work may play a greater role in incubation effects that do not involve fixated problems. Ongoing experiments are examining this possibility.

The present study has demonstrated a new methodology that is effective for studying incubation effects in creative problem solving. It has also shown that concurrent tasks are not sufficient for producing incubation effects. To be effective for causing forgetting of fixation, and concomitantly causing incubation effects, the incubation task must be one that keeps fixated problems completely off the minds of participants. In support of the forgetting fixation hypothesis, these effects appear to only occur when the primary problem has become fixated.

REFERENCES


Nicholas Kohn, Dept. of Psychology, Mail Stop 4235, Texas A&M University, College Station, TX 77843-4235, nkohn@tamu.edu

117
### APPENDIX A.

**RAT PROBLEMS, SOLUTIONS, BLOCKERS, AND TWO-WORD PHRASE STIMULI USED IN THE PRESENT STUDY.**

<table>
<thead>
<tr>
<th>Trial Type</th>
<th>RAT Problem</th>
<th>Solution</th>
<th>Blocker</th>
<th>Two Word Phrase Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocking</td>
<td>Salad</td>
<td>Head</td>
<td>Goose</td>
<td>Egg</td>
</tr>
<tr>
<td>Help</td>
<td>Widow</td>
<td>Bite</td>
<td>Monkey</td>
<td>Spider</td>
</tr>
<tr>
<td>Help</td>
<td>Picture</td>
<td>Window</td>
<td>Door</td>
<td>Frame</td>
</tr>
<tr>
<td>Blocking</td>
<td>Top</td>
<td>Shoe</td>
<td>Car</td>
<td>Box</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Worm</td>
<td>End</td>
<td>Shop</td>
<td>Book</td>
</tr>
<tr>
<td>Blocking</td>
<td>Hot</td>
<td>Catcher</td>
<td>License</td>
<td>Dog</td>
</tr>
<tr>
<td>Blocking</td>
<td>Arm</td>
<td>Coal</td>
<td>Stop</td>
<td>Pit</td>
</tr>
<tr>
<td>Unrelated</td>
<td>News</td>
<td>Plate</td>
<td>Clip</td>
<td>Paper</td>
</tr>
<tr>
<td>Blocking</td>
<td>Ship</td>
<td>Suit</td>
<td>Parking</td>
<td>Space</td>
</tr>
<tr>
<td>Helpful</td>
<td>River</td>
<td>Note</td>
<td>Blood</td>
<td>Bank</td>
</tr>
<tr>
<td>Helpful</td>
<td>Sick</td>
<td>Swell</td>
<td>Mist</td>
<td>Sea</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Light</td>
<td>Main</td>
<td>Sweeper</td>
<td>Street</td>
</tr>
<tr>
<td>Blocking</td>
<td>Apple</td>
<td>House</td>
<td>Family</td>
<td>Tree</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Manners</td>
<td>Round</td>
<td>Tennis</td>
<td>Table</td>
</tr>
<tr>
<td>Blocking</td>
<td>Storm</td>
<td>White</td>
<td>Ball</td>
<td>Snow</td>
</tr>
<tr>
<td>Helpful</td>
<td>Falling</td>
<td>Movie</td>
<td>Dust</td>
<td>Star</td>
</tr>
<tr>
<td>Blocking</td>
<td>Water</td>
<td>Cube</td>
<td>Skate</td>
<td>Ice</td>
</tr>
<tr>
<td>Blocking</td>
<td>Electric</td>
<td>High</td>
<td>Easy</td>
<td>Chair</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Goat</td>
<td>Pass</td>
<td>Range</td>
<td>Mountain</td>
</tr>
<tr>
<td>Blocking</td>
<td>Deck</td>
<td>Recorder</td>
<td>Scotch</td>
<td>Tape</td>
</tr>
<tr>
<td>Unrelated</td>
<td>Water</td>
<td>Tobacco</td>
<td>Stove</td>
<td>Pipe</td>
</tr>
<tr>
<td>Helpful</td>
<td>Sandwich</td>
<td>Golf</td>
<td>Foot</td>
<td>Club</td>
</tr>
<tr>
<td>Blocking</td>
<td>Bed</td>
<td>Duster</td>
<td>Weight</td>
<td>Feather</td>
</tr>
<tr>
<td>Blocking</td>
<td>Cat</td>
<td>Sleep</td>
<td>Board</td>
<td>Walk</td>
</tr>
</tbody>
</table>