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Incubation and the persistence of fixation in problem solving

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Extra work on unsolved problems may lead to more improvement if the new work is delayed rather than undertaken immediately after initial solution attempts. Such a result constitutes incubation in problem solving. "Unconscious work" on a problem, commonly assumed to be responsible for incubation effects, may not be necessary to observe the phenomenon. We hypothesize that fixation, a block to successful problem solving, may develop during initial solution attempts and persist, interfering with immediate extra work more than with delayed extra work. Five experiments are reported in which fixation was induced to prevent optimal performance on the initial test of Remote Associates Test (RAT) problems (e.g., Mednick, 1962). After the fixation manipulation in three of the experiments, the effects of incubation intervals were examined by retesting the fixated problems. Both fixation (poorer initial problem-solving performance) and incubation (more improvement after a delayed retest than an immediate retest) were found in all the experiments which tested for the effects. In Experiments 1, 2, and 3, misleading distractors were presented alongside the RAT problems during the initial test of the problems to cause fixation. In Experiment 4, a block of paired associates—pairing the RAT words with the misleading distractors prior to problem solving—successfully induced fixation, indicating that the distractors affected memory retrieval. In Experiment 5, a trial-by-trial technique allowed fixation and incubation to be induced and tested separately for each item. All of our findings of incubation effects appear to have depended upon the initial induction of fixation. Although the experiments may not be representative of all naturally occurring cases of incubation, they provide a methodology for the study of fixation and incubation effects in problem solving in the laboratory.

When initial attempts at solving a problem fail, the problem may be temporarily put aside, during which time a little-understood stage of problem solving known as *incubation* may occur. A period of incubation may result in insight, in which the problem solver becomes suddenly and unpredictably aware of the solution to a problem. The time in which the unsolved problem has been put aside refers to the *incubation period* or *incubation time*; if insight occurs during this time, the result is referred to as an *incubation effect.* Although the idea of incubation

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effects has appeal to common personal experience, it has not enjoyed great empirical support in controlled laboratory studies of problem solving. Commonly cited discussions of incubation effects often appear in the literature not as reports of empirical studies, but rather as textbook discussions (Anderson, 1975; Posner, 1973; Woodworth & Schlosberg, 1954).

Several empirical studies have tested incubation effects in problem solving (Dominowski & Jenrick, 1972; Driestadt, 1969; Fulgosi & Guilford, 1968; Gall & Mendelsohn, 1967; Gick & Holyoak, 1980; Murray & Denny, 1969; Olton & Johnson, 1976; Patrick, 1986; Smith & Blankenship, 1989). A few of these experiments found incubation effects (Dreistadt, 1969, one experiment; Fulgosi & Guilford, 1968, one experiment; Murray & Denny, 1969, one experiment; Patrick, 1986, one experiment; Smith & Blankenship, 1989, four experiments). Of these studies, the only replicated findings of incubation effects are those reported by Smith and Blankenship, which employed a paradigm similar to that used in the present experiments. Of the remaining experiments, findings of incubation have been unreliable. Neither Dominowski and Jenrick (1972), Olton and Johnson (1976), Gall and Mendelsohn (1967), nor Gick and Holyoak (1980) found any incubation effects. Fulgosi and Guilford (1968) found an incubation effect after a 20-min but not after a 10-min interruption. Olton and Johnson (1976) reported failures to replicate effects by Fulgosi and Guilford (1968), Dreistadt (1969), and Silveira (1971, cited in Olton & Johnson, 1976). Murray and Denny (1969) reported a single effect, restricted to high ability subjects, and Patrick's (1986) one finding of an effect occurred only for low ability subjects. In sum, these studies provide neither a strong base of empirical support for the putative phenomenon of incubation nor a reliable means of observing the phenomenon in the laboratory. Clearly, a reliable method for observing and studying incubation effects in the laboratory is needed if we are to extend our knowledge beyond anecdotal accounts and speculation.

Perhaps one of the greatest obstacles to research on incubation effects is an adherence to the common assumption that incubation must be the result of unconscious problem solving. Authors writing about incubation routinely cite the introspections of the French mathematician Henri Poincaré. Poincaré's self-described insights into the nature of a set of mathematical functions claimed that "the role of this unconscious work in mathematical invention appears to me incontestable" (quoted in Perkins, 1981, p. 49). Unfortunately, consensual ways of observing and inducing such putative unconscious processes are not known. Even if such processes could be studied empirically, it is not clear that all incubation effects result from the

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same causes. Furthermore, there are several alternative explanations to the unconscious work hypothesis, many of which are at least as plausible, and which have some empirical basis. These alternatives will be treated in greater depth in the general discussion of the present paper. Although we hope eventually to discover the efficacy of the various alternative explanations, in the present study we have set as our goal the reliable induction and observation of incubation effects in a controlled setting.

The key to observing incubation effects in the laboratory, we believe, is to temporarily thwart solutions to otherwise tractable problems. Problems that are solved immediately require no incubation, and intractable problems which cannot be solved even with unlimited time will not be influenced by incubation time. A preliminary block to problem solving, which we will refer to as *fixation,* was described by Woodworth and Schlosberg (1954) in their discussion of incubation: "When the thinker makes a false start, he slides insensibly into a groove and may not be able to escape at the moment" (p. 841). The inescapability of fixated thinking in initial problem-solving attempts thus creates the possibility of an incubation effect, or successful problem solving following some time away from the problem. According to Woodworth and Schlosberg, "[T]he incubation period simply allows time for an erroneous set to die out and leave the thinker free to take a fresh look at his problem" (p. 841). This "set-breaking" view of incubation effects has also been noted by Posner (1973) and Anderson (1975).

One of the most creative and extensive treatments of fixation as mental set has been carried out by Luchins and Luchins (e.g., 1959, 1970). The paradigm induced *Einstellung,* or mental set, by presenting several problems in sequence, all of which could be solved using a specific algorithm. After this mental set induction, subjects received a critical problem which could be solved with a very simple and obvious solution, or with the *Einstellung* solution. Very few subjects saw the simple solution, relying instead on the previously encountered mental set. Such was often the case even when the critical problem could not be solved with the *Einstellung* solution. Thus, the immediately preceding experience with the set solution caused fixation, a block to successful problem solving.

Another approach to the issue of fixation has been studies of *functional fixedness* (e.g., Duncker, 1945; Maier, 1931), an inability that many subjects have in thinking of unusual uses for familiar objects. In the now famous two-string problem, subjects have difficulty in thinking of using pliers or an electronic device as a pendulum to solve a problem.

Because subjects' fixating experiences occurred prior to their participation in the experiment, functional fixedness may be seen as more long-lasting than the mental set induced after a few moments in the *Einstellung* studies. On the other hand, functional fixedness has been shown to be manipulable within an experimental session (e.g., Adamson, 1952; Adamson & Taylor, 1954). After performing a task in which either a switch or a relay was used in completing an electric circuit, subjects were given the choice of using one of the two objects as the pendulum in the two-string problem. Subjects have been found to avoid using the object recently involved in the circuitry problem, whether it was the switch or the relay (e.g., Birch & Rabinowitz, 1951). Subjects apparently had difficulty thinking of an object as a pendulum if it had just been used as a piece of electronic equipment, indicating that functional fixedness can be situationally induced. Furthermore, Adamson and Taylor (1954) found that the likelihood that the fixation procedure caused this effect to be observed was a negative function of the time between the circuit problem (the fixation procedure) and the two-string problem, observing performance after a delay of 30 min, 1 hr, 1 day, or 1 week.

A more recent approach to fixation has been taken by Jones (1989) and Jones and Langford (1987), working with the tip-of-the-tongue (TOT) phenomenon. They found that cases of TOT experiences increased if interlopers (words which sound or mean something like the target word) were read to subjects along with the definitions of rare words used to induce TOT states. The interlopers apparently blocked access to the correct targets, thus inducing a kind of fixation in memory retrieval. This accessibility approach to fixation will be considered more extensively in a later discussion.

The present set of experiments was partly intended to study and control fixation, the first part of this hypothetical pattern of cognition which leads to incubation. Inducing fixation during initial problem solving might more consistently provide the opportunity to observe incubation, which should occur as the initial induced fixation dissipates. The present studies were concerned with finding materials and techniques for inducing both fixation and incubation in problem solving.

The problems used in the present experiments were Remote Associate Test (RAT) items (e.g., Mednick, 1962). Each problem consisted of three words (e.g., ARM COAL PEACH). The solution is a single word which forms a common word or phrase with each of the three RAT test words. For example, the solution "Pit" makes the common word or phrase ARMPIT, COAL PIT, and PEACH PIT. In the present experiments, problem solving was fixated by priming information

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inappropriate to correct solutions of problems. For example, associating ARM with LEG, COAL with FURNACE, and PEACH with PEAR should have primed inappropriate information. The primed inappropriate information should have been more accessible than the correct target information, thus making each problem more difficult to solve.

The present experiments were also concerned with incubation effects. Incubation effects were tested in the present experiments by retesting unsolved RAT problems either immediately or after a period of incubation. Demanding tasks were inserted in the incubation intervals so that subjects would not continue to work on unsolved problems during the period of incubation. An incubation effect is herein defined as greater improvement in solving initially unsolved problems when retesting occurs after a delay rather than immediately following the initial test.

In a study by Patrick (1986), RAT problems were used to examine the role of ability in incubation effects. A prior study by Murray and Denny (1969) had found incubation effects only for "low ability" subjects, ability being measured by a Gestalt Transformation Test. Patrick used subjects' performance on an initial test of the RAT problems to assess ability more directly. He found that incubation effects were limited to high ability subjects (i.e., those scoring above the median on the initial test), in contrast to Murray and Denny's finding. Therefore, the importance of subjects' ability in findings of incubation effects was assessed in the present experiments.

EXPERIMENT 1

In Experiment 1, fixation was induced by presenting misleading associates in italics on the page alongside each of the three RAT words. Subjects were told that the words in italics were examples of associates of the RAT words. No associates were presented in the nonfixation control group. It was hypothesized that performance on fixation problems (i.e., problems with inappropriate priming) would be worse than performance on nonfixation problems. This method is conceptually similar to color-word and picture-word (Stroop) interference paradigms (e.g., Klein, 1964; Lupker, 1979). In both cases, performance may be thwarted or delayed by accompanying stimuli which tend to elicit retrieval of responses which are similar to the correct response, but which are also incorrect.

Incubation periods were manipulated by inserting demanding interpolated activities between an initial and later attempt at solving an RAT problem. All groups should show overall improvement in prob-

lem solving at the retest, because extra work should provide extra solutions. The experimental finding of incubation concerns the amount of improvement seen in an immediate retest compared with a delayed (incubated) retest. An incubation effect is observed when incubation time yields greater problem-solving improvements at the retest relative to improvements in the no-incubation condition.

It was predicted that incubation effects would be found for fixation groups. Although induced fixation may persist through an immediate retest, continuing to thwart solutions, it should be more likely to dissipate before a delayed retest, allowing greater improvements. Without induced fixation, the nonfixation group should have less of a block from which to recover at retest. Thus, it was predicted that retest improvements for the nonfixation group would not significantly differ for incubation versus no-incubation conditions.

METHOD

Subjects

Participants were 39 students who volunteered to fulfill part of an introductory psychology course requirement. Subjects were randomly assigned to treatment groups: 10 in the fixation/incubation group; 11 in the fixation/no-incubation group; 10 in the nonfixation/incubation group; and 8 in the nonfixation/no-incubation group.

Materials

The 20 Remote Associates Test (RAT) items used as experimental problems are shown in the Appendix. Each RAT item contains three words. The solution to a RAT problem is a word which is an associate of each of the three test words on a given item. The example explained to subjects was WASHER, SHOPPING, PICTURE (correct answer is "window").

A related associate (not a correct solution) was printed in parentheses in italics next to each RAT word. The misleading associates are also shown in the Appendix. Subjects were told that the distractors were examples of the kind of associates that are correct solutions.

Design

Half of the treatment groups (fixation) were given simultaneous fixation with the RAT items and half were not (nonfixation). The RAT retest was given after no interval for half of the groups (no incubation), and after a 5-min incubation period for the other half (incubation). Thus, a 2 (Fixation) × 2 (Incubation) between-subjects design was used.

Procedure

The 20 RAT items were each given twice (RAT-1 and retest). In the fixation conditions, incorrect associates were presented simultaneously with

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appeared on each of five pages in t
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RESULTS

Fixation

Nonfixation subjects solved
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Incubation

The proportion of problems
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RAT items. Four RAT problems (with or without misleading associates) appeared on each of five pages in the experimental test booklets, and subjects were allowed 2 min/page.

For the groups given a period of incubation, a science fiction short story was given to subjects to study for 5 min (ostensibly, for a later test) following RAT-1. The incubation groups were not informed of the subsequent retest. The no-incubation groups were given the retest immediately after the last page of RAT-1.

Booklets with the same 20 RAT problems in the original order were issued to subjects for the retest, either after no interval, or after the 5-min short story. No associates were presented at the retest. Subjects were allowed 4 min for each page of 4 problems on the retest.

RESULTS

Fixation

Nonfixation subjects solved more than twice as many problems as fixation subjects on the initial test (Table 1). A t test was computed comparing fixation and nonfixation groups, using proportion correct on the first test (RAT-1) as the dependent measure. Fixation significantly[1] decreased performance on RAT-1, $t(37) = 3.69$.

Incubation

The proportion of problems not solved on the initial test that were solved at retest defined the improvement score. An incubation effect was found for the fixation groups. At retest, incubation subjects who had been fixated solved .41 of the initially unsolved problems, whereas the fixated no-incubation subjects solved only .19 of the unsolved items (Table 2). The effect of incubation was significant for the fixated group, $t(19) = 3.88$.

No incubation effect was found for nonfixation subjects. Incubation subjects in the nonfixation condition solved .32 of the unsolved problems, compared with .22 improvement for the nonfixation/no-incubation condition (Table 2). The effect of incubation was not significant for the nonfixation group, $t(16) = 1.23$.

Table 1. Mean proportions correct on RAT-1 in Experiment 1 for fixation and nonfixation groups

Group		
Fixation	Nonfixation	Fixation effect
.10	.25	.15

Note. There were 20 problems on RAT-1. Fixation effect = (nonfixation RAT-1 proportion correct) − (fixation RAT-1 proportion correct).

Table 2. Mean improvement in Experiment 1 for incubation vs. no-incubation groups

Condition	Group		Incubation effect
	Incubation	No incubation	
Fixation	.41	.19	.22
Nonfixation	.32	.22	.10

Note. Improvement = (no. newly solved at retest)/(20 − no. solved on RAT-1). Incubation effect = (incubation improvement) − (no-incubation improvement).

An ANOVA tested incubation effects as a function of ability, as defined by RAT-1 performance. Subjects were divided into three groups according to the number correctly solved on the initial RAT: above the median, at the median, and below the median. Because there was a main effect of fixation, the medians for the fixation and nonfixation groups were computed independently such that, for example, high-scoring fixation subjects were classified with high-scoring nonfixation subjects in the high ability group.

The 2 × 3 (Incubation × Ability) ANOVA used improvement (i.e., the proportion of initially unsolved problems that were solved at the retest) as the dependent measure. Ability was low, median, or high. There was a significant Ability × Incubation interaction, $F(2, 33) = 3.88$, $MS_e = .02$. Participants who scored low or at the median had greater incubation effects than those with high ability (findings for Experiments 1, 2, and 5 appear in Table 9).

DISCUSSION

A clear, robust effect of fixation was observed as a result of the distractors presented with the RAT problems in Experiment 1. Subjects in the nonfixation condition solved more than twice the number of problems solved by the fixation subjects on the initial RAT. This fixation resulted not from the repeated use of an algorithm, as in the water-jar problem series of Luchins and Luchins (1959), nor was it caused by long-term preexperimentally induced fixation, as in Maier's (1931) 2-string (functional fixedness) problem. Rather, the fixation effect appeared to be caused by presenting misleading distractors that were related to the target solution.

Incubation effects were also observed in Experiment 1. The effect of incubation was significant in the condition in which subjects were first given a fixation treatment, but not in the nonfixation condition. Thus, support was evidenced for the idea that incubation may result

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EXPERIMENT 2

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METHOD

Subjects

Participants were 79 students w
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and 9 in the nonfixation/no hints

Materials

Of the 20 RAT problems listed
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.19	.22
.22	.10

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from the dissipation of fixation, a problem-solving block. This is not to say that there are no other possible causes of incubation effects. Rather, we claim to have demonstrated one way to observe incubation in the laboratory.

Ability, as measured by performance on the initial RAT, was related to incubation effects in Experiment 1. The finding of greater incubation for low ability subjects contradicts the findings of Patrick (1986), whose incubation effects with RAT problems were limited to high ability subjects.

EXPERIMENT 2

Experiment 1 showed that problem solving can be diverted away from appropriate solutions. In Experiment 2 we tried to maximize the effects of fixation using a method of presenting the misleading associates in a way that made them essentially unavoidable. The RAT problems were presented individually on a computer screen while misleading associates were flashed on the screen and a voice synthesizer spoke the misleading associates aloud.

Experiment 2 also tested the usefulness of a solution time metric in measuring fixation. It was hypothesized that even when a problem is solved, fixation might prolong the problem-solving process. Therefore, solutions as well as solution times were recorded in Experiment 2. In some treatment conditions, the first two letters of the correct answer were provided for the subject, making the problems very easy. It was expected that the problems with hints would be easy to solve, but that it would require more time to find solutions in the fixation condition. Because the two-letter hints were expected to keep performance near the ceiling for the initial RAT, we expected that incubation would be observed only in the no-hints condition. As in Experiment 1, it was predicted that incubation effects would occur following fixation, but not in the condition with no initial fixation.

METHOD

Subjects

Participants were 79 students who volunteered to fulfill part of an introductory psychology course requirement. Subjects were randomly assigned to treatment groups: 10 in seven of the eight experimental treatment groups, and 9 in the nonfixation/no hints/incubation group.

Materials

Of the 20 RAT problems listed in the Appendix, 10 were used in Experiment 2. The RAT words were presented in all uppercase letters with

the three words arranged vertically on the screen of an Amiga 1000 computer. In the conditions in which hints were presented simultaneously with the three RAT words, 2-letter hints (the first two letters of the correct solution) were shown near the bottom of the screen. In the conditions in which fixation was induced, each distractor appeared on the screen next to its related RAT word. The misleading distractors, printed in lowercase letters, flashed on and off at a 1-s rate, and a voice synthesizer spoke aloud each RAT word-distractor pair. A message, which remained at the top of the screen during all of the RAT problems, stated that the solutions were for only the words printed in uppercase letters. On the retest, all problems appeared with 2-letter hints. The incubation material consisted of the same story used in the incubation task in Experiment 1. The story was printed on the screen such that subjects could page forward through the story using the return key on the Amiga keyboard.

Design

On the initial RAT (RAT-1), subjects received either hints or no hints, and fixation (i.e., misleading distractors) or no fixation. The retest occurred either immediately after the last problem of RAT-1 or after a period of incubation.

Procedure

Subjects participated individually. After being familiarized with the computer screen and keyboard, subjects were given instructions about the RAT problems and, if appropriate, the hints and distractors (referred to by the experimenter as "associates"). As in Experiment 1, subjects were told that the distractors were examples of the kind of associates that are the correct solution. Subjects were shown the example problem along with the solution; they were instructed to type the solution on the keyboard and then to press the return key. Subjects were requested to type their answers as quickly as possible because it was a timed test. The time from the presentation of a RAT problem until the first keystroke was recorded for each trial. The specific keystrokes were also recorded. The subject had 1 min to respond, after which the next problem appeared.

In the no-incubation condition, an instruction to press the return key appeared on the screen immediately after the 10th problem. The first problem, with a 2-letter hint, appeared on the screen 2 s after the key was pressed (the first retested item). The remaining RAT items were also retested in the same order and manner as the first presentations. In the incubation condition, an instruction to read a story carefully appeared after the 10th RAT problem. To advance through the story on the screen, subjects pressed the return key; 5 min was allowed to read the story. After 5 min, the 10 RAT problems were retested as in the no-incubation condition.

RESULTS

Fixation

A 2 × 2 (Fixation × Hints) ANOVA was computed using number correct on RAT-1 as the dependent measure. There was a significant

effect of fixation, $F(1, 73) =$ solved more problems on RAT There was also a significant e $= 2.69$, indicating that perfor subjects were given the 2-lett

Another 2 × 2 (Fixation solution response time (RT) There was a significant effect 23.48, indicating that the pres problems considerably delaye ation condition (Table 3). The $73) = 30.98$, $MS_e = 23.48$, a hints.

Incubation

Two 2 × 2 (Incubation × the dependent measure were c and one for the nonfixation c

For the fixation condition, th on improvement, $F(1, 34) =$ improvement in the incubatio (Table 4). There was also an superior performance in the c the nonfixation condition, the $F < 1.0$, or of hints, $F(1, 30)$

A 2 × 2 (Incubation × Ab provement as the dependent

Table 3. Mean proportions corr Experiment 2 for fixation and n

Condition	Non
Hints	
Proportion correct	
RT (s)	
No hints	
Proportion correct	
RT (s)	1

Note. There were 10 problems on fixation effect = [(nonfixation RA 1 proportion correct)] × 10. For RAT-1 RT) − (nonfixation RAT-

on the screen of an Amiga 1000 com-
ints were presented simultaneously with
its (the first two letters of the correct
tom of the screen. In the conditions in
stractor appeared on the screen next to
ing distractors, printed in lowercase let-
te, and a voice synthesizer spoke aloud
message, which remained at the top of
problems, stated that the solutions were
case letters. On the retest, all problems
cubation material consisted of the same
n Experiment 1. The story was printed
ld page forward through the story using
ard.

jects received either hints or no hints,
tors) or no fixation. The retest occurred
roblem of RAT-1 or after a period of

After being familiarized with the com-
were given instructions about the RAT
ints and distractors (referred to by the
n Experiment 1, subjects were told that
e kind of associates that are the correct
ample problem along with the solution;
ution on the keyboard and then to press
sted to type their answers as quickly as
. The time from the presentation of a
roke was recorded for each trial. The
led. The subject had 1 min to respond,
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an instruction to press the return key
after the 10th problem. The first prob-
n the screen 2 s after the key was pressed
ing RAT items were also retested in the
t presentations. In the incubation con-
carefully appeared after the 10th RAT
tory on the screen, subjects pressed the
ad the story. After 5 min, the 10 RAT
-incubation condition.

NOVA was computed using number
ent measure. There was a significant

effect of fixation, $F(1, 73) = 6.27$, $MS_e = 2.69$; nonfixation subjects solved more problems on RAT-1 than did fixation subjects (Table 3). There was also a significant effect of hints, $F(1, 73) = 159.36$, $MS_e = 2.69$, indicating that performance on RAT-1 was far superior when subjects were given the 2-letter hints.

Another 2 × 2 (Fixation × Hints) ANOVA was computed using solution response time (RT) on RAT-1 as the dependent measure. There was a significant effect of fixation, $F(1, 73) = 18.96$, $MS_e = 23.48$, indicating that the presentation of the distractors with the RAT problems considerably delayed solution times relative to the nonfixation condition (Table 3). The effect of hints was also significant, $F(1, 73) = 30.98$, $MS_e = 23.48$, again showing faster soluton times with hints.

Incubation

Two 2 × 2 (Incubation × Hints) ANOVAs using improvement as the dependent measure were computed, one for the fixation condition, and one for the nonfixation condition.

For the fixation condition, there was a significant effect of incubation on improvement, $F(1, 34) = 4.63$, $MS_e = .09$, indicating greater improvement in the incubation than in the no-incubation condition (Table 4). There was also an effect of hints, $F(1, 34) = 7.93$, with superior performance in the condition in which hints were given. For the nonfixation condition, there was no effect either of incubation, $F < 1.0$, or of hints, $F(1, 30) = 2.63$, $MS_e = .12$.

A 2 × 2 (Incubation × Ability) ANOVA was computed using improvement as the dependent measure. Ability was low, median, or

Table 3. Mean proportions correct and response times (RTs) on RAT-1 in Experiment 2 for fixation and nonfixation groups

	Group		
Condition	Nonfixation	Fixation	Fixation effect
Hints			
Proportion correct	.86	.75	.11
RT (s)	7.68	14.19	6.51
No hints			
Proportion correct	.37	.29	.08
RT (s)	15.53	18.67	3.14

Note. There were 10 problems on RAT-1. For the proportion correct score, fixation effect = [(nonfixation RAT-1 proportion correct) − (fixation RAT-1 proportion correct)] × 10. For the RT score, fixation effect = (fixation RAT-1 RT) − (nonfixation RAT-1 RT).

Table 4. Mean improvement scores in Experiment 2 as a function of hints and fixation

Condition	Group		Incubation effect
	Incubation	No incubation	
Fixation			
Hints	.57	.27	.30
No hints	.21	.08	.13
Nonfixation			
Hints	.36	.38	−.02
No hints	.16	.20	−.04

Note. Improvement = (no. newly solved at retest)/(10 − no. solved on RAT-1). Incubation effect = incubation improvement − no incubation improvement.

high for subjects scoring below, at, or above the median on RAT-1. Separate medians were used for the hints + fixation; hints + nonfixation; no hints + fixation; and no hints + nonfixation conditions. Although somewhat greater incubation effects were found for the low group than for the high and median groups (Table 9), the Incubation × Ability interaction did not approach significance, $F < 1.0$.

DISCUSSION

The fixation manipulation in Experiment 2, with flashing and spoken-aloud distractors, was clearly an effective detriment to problem solving. The solution time measure was even more sensitive to fixation manipulations than was the accuracy measure. This effect was particularly noteworthy in the condition in which 2-letter hints were provided on RAT-1; more than an additional 6 s of solution time was needed for the fixation group, compared with the nonfixation group, even though good hints were provided on RAT-1.

Incubation was found only in the group that was initially fixated on RAT-1. This finding of an incubation effect following fixation is similar to the incubation effect in Experiment 1, which was also found only in the fixation condition.

Incubation effects appeared to be somewhat greater for low ability subjects, although the interaction was not significant. As in Experiment 1, however, it is clear that high ability subjects did not show the greatest incubation effects, in contrast to Patrick's (1986) study.

EXPERIMENT 3

Misleading associates were
problems in Experiments 1 an
cedure is that it cannot be kno
effects were caused by the pres
was caused by the relatedness o
In Experiment 3, the fixation
the relatedness of the distract
were either related or unrelate
In Experiment 3, as in Exper
presented simultaneously with
of the distractors was a sourc
Experiments 1 and 2, then p
related or unrelated, should be
relatedness of the distractors is
cause worse performance on R
tors. It is also possible that bot

METHOD

Subjects

Participants were 120 students
troductory psychology course req
to treatment groups.

Design, procedure, and mater

The design, procedure, and mat
to those used in Experiment 1, w
than two levels of fixation, as in
related (related associates printed
related paired distractors), and no
tractors were drawn from the rel
were not used in this experiment
Thus, the experiment manipulate

RESULTS

A one-way ANOVA was comp
(related vs. unrelated vs. none)
analysis found a significant effe
= 6.40. Subjects with no distra
those with related distractors s
related distractors scored mid

n Experiment 2 as a function of hints

o incubation	Incubation effect
.27	.30
.08	.13
.38	−.02
.20	−.04

ed at retest)/(10 − no. solved on RAT-
provement − no incubation improve-

t, or above the median on RAT-1.
he hints + fixation; hints + nonfix-
o hints + nonfixation conditions.
ation effects were found for the low
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lition in which 2-letter hints were
n additional 6 s of solution time was
mpared with the nonfixation group,
vided on RAT-1.
the group that was initially fixated
cubation effect following fixation is
Experiment 1, which was also found

be somewhat greater for low ability
n was not significant. As in Experi-
high ability subjects did not show
contrast to Patrick's (1986) study.

EXPERIMENT 3

Misleading associates were presented simultaneously with RAT problems in Experiments 1 and 2. A potential limitation of this procedure is that it cannot be known how much of the observed fixation effects were caused by the presence of the distractors and how much was caused by the relatedness of the distractors to the target solutions. In Experiment 3, the fixation effect was examined as a function of the relatedness of the distractors to the RAT problems. Distractors were either related or unrelated to the RAT problems (see Appendix). In Experiment 3, as in Experiments 1 and 2, the distractors were presented simultaneously with RAT problems. If the physical presence of the distractors was a source of the observed fixation effects in Experiments 1 and 2, then problem solving with any distractors, related or unrelated, should be worse than with no distractors. If the relatedness of the distractors is a factor, then related distractors should cause worse performance on RAT problems than unrelated distractors. It is also possible that both factors may have an effect.

METHOD

Subjects

Participants were 120 students who volunteered to fulfill part of an introductory psychology course requirement. They were randomly assigned to treatment groups.

Design, procedure, and materials

The design, procedure, and materials used in Experiment 3 were identical to those used in Experiment 1, with the following exceptions: (a) Rather than two levels of fixation, as in Experiment 1, there were three levels—related (related associates printed next to RAT problems), unrelated (unrelated paired distractors), and none (no distractors); (b) the unrelated distractors were drawn from the related distractors of RAT problems which were not used in this experiment; and (c) participants were not retested. Thus, the experiment manipulated one between-subjects variable, fixation.

RESULTS

A one-way ANOVA was computed examining the effect of fixation (related vs. unrelated vs. none) on number of problems solved. The analysis found a significant effect of fixation, $F(2, 117) = 31.41$, $MS_e = 6.40$. Subjects with no distractors solved the most RAT problems, those with related distractors solved the fewest, and those with unrelated distractors scored midway between the other two groups

(Table 5). Newman-Keuls pairwise comparisons (α = .05) indicated that related distractors caused significantly worse performance than did unrelated distractors or no distractors, and that unrelated distractors caused worse performance than did no distractors (critical difference for r = 2 was .11; for r = 3, critical difference was .13).

DISCUSSION

The results of Experiment 3 support both the hypothesis that the words presented alongside the RAT problems deterred problem-solving performance and the hypothesis that the relatedness of the distractors to the correct target solution caused fixation. That unrelated distractors caused worse performance than the condition with no distractors suggests that distraction from attention may have blocked performance. The finding that related distractors caused significantly worse performance than unrelated distractors, however, suggests a different cause of fixation, such as a memory retrieval block. These conclusions hold not only for Experiment 3, but for Experiments 1 and 2 as well.

This description of fixation in problem solving is analogous to output interference, that is, a retrieval block which accrues during free recall, or which is induced by part-list cuing (e.g., Rundus, 1973). According to this model, memory is searched using sampling-with-replacement (e.g., Shiffrin, 1970). During the recall process, each retrieved item, whether retrieved by the subject or provided by the experimenter, is incremented in strength and replaced within the current search set. Thus, after a number of retrievals from a search set have occurred, the set of already-retrieved items is more accessible than the not-yet-retrieved items, thus causing a temporary retrieval block. The part-list cues provided by the experimenter in these memory studies are analogous to the fixating distractors employed in the present experiments to block retrieval of the correct target information.

The accessibility hypothesis suggested somewhat different tech-

Table 5. Mean proportion correct in Experiment 3 for related vs. unrelated vs. no-distractor conditions

Type of distractor		
Related	Unrelated	None
.13	.24	.35

Note. There were 20 problems on the test.

niques for inducing initial fixat
than inducing fixation with sim
primed misleading information
niques were examined in Expe

EXPERIMENT 4

To avoid the interpretive pr
tors, as in Experiments 1, 2, ar
was accomplished before the R
ation condition in Experiment
associates learning (PAL) task w
ulus members of each pair and tl
members. This manipulation wa
the associations of RAT-words
retrieval of the solution would b
Associates Test. It was hypothes
the RAT would be worse followi
with no fixation task.

METHOD

Subjects

Participants were 38 students wh
ductory psychology course require
to three treatment groups: two of
had 10 subjects each, and the fixa

Materials

The same RAT problems used i
periment 4, except that the 20 pr
The PAL task consisted of the 60
associate printed in italics next to e
misleading associates used in Exper
a single page.

Design and procedure

For subjects given PAL (fixation
task. Subjects were given the PAL
pairs in anticipation of a subseque
stimulus member (i.e., a RAT word)
(italicized) member of the pair. St
subjects were given the 60 words an
next to each word, with 5 min allow

ise comparisons (α = .05) indicated ignificantly worse performance than distractors, and that unrelated dis- nce than did no distractors (critical r r = 3, critical difference was .13).

support both the hypothesis that the RAT problems deterred problem- pothesis that the relatedness of the t solution caused fixation. That un- performance than the condition with ction from attention may have blocked elated distractors caused significantly ted distractors, however, suggests a as a memory retrieval block. These xperiment 3, but for Experiments 1

problem solving is analogous to out- eval block which accrues during free part-list cuing (e.g., Rundus, 1973). ory is searched using sampling-with- 0). During the recall process, each d by the subject or provided by the n strength and replaced within the a number of retrieval from a search ady-retrieved items is more accessible , thus causing a temporary retrieval d by the experimenter in these mem- fixating distractors employed in the etrieval of the correct target infor-

suggested somewhat different tech-

n Experiment 3 for related vs. unrelated

f distractor	
nrelated	None
.24	.35

he test.

niques for inducing initial fixation in solving RAT problems. Rather than inducing fixation with simultaneously presented distractors, we primed misleading information prior to the initial RAT. These techniques were examined in Experiments 4 and 5.

EXPERIMENT 4

To avoid the interpretive problems of using simultaneous distractors, as in Experiments 1, 2, and 3, fixation in Experiments 4 and 5 was accomplished before the RAT items were presented. In the fixation condition in Experiment 4, subjects were first given a paired associates learning (PAL) task which used the 60 RAT-words as stimulus members of each pair and the 60 misleading associates as response members. This manipulation was expected to temporarily strengthen the associations of RAT-words to inappropriate responses, so that retrieval of the solution would be blocked on the subsequent Remote Associates Test. It was hypothesized, therefore, that solution rates on the RAT would be worse following PAL (fixation) than in the condition with no fixation task.

METHOD

Subjects

Participants were 38 students who volunteered to fulfill part of an introductory psychology course requirement. Subjects were randomly assigned to three treatment groups: two of the experimental treatment conditions had 10 subjects each, and the fixation/no-incubation group had 8.

Materials

The same RAT problems used in Experiment 1 were again used in Experiment 4, except that the 20 problems were arranged on a single page. The PAL task consisted of the 60 RAT words (3 words/problem), with an associate printed in italics next to each word. The associates were the same misleading associates used in Experiment 1. The PAL list was presented on a single page.

Design and procedure

For subjects given PAL (fixation), the experiment began with the PAL task. Subjects were given the PAL page, and they were told to study the pairs in anticipation of a subsequent test in which they would be given a stimulus member (i.e., a RAT word) and would be asked to recall the response (italicized) member of the pair. Study time was 5 min. For the PAL test, subjects were given the 60 words and were asked to write the correct associate next to each word, with 5 min allowed for this memory task. After the PAL

test, subjects were given the original study list and were asked to write in any associates on their test that they had missed. This procedure was intended to strengthen all associations between the RAT words and the misleading associates.

The RAT problems followed the PAL task for fixation groups, or comprised the only task for nonfixation groups. The 20 RAT items were presented on a single page with instructions printed at the top. Subjects were given 5 min to complete as many of the RAT problems as they could.

RESULTS

The fixation group scored 37% less than the nonfixation group on RAT-1 (Table 6). A t test comparing fixation and nonfixation conditions was computed using scores on RAT-1 as the dependent measure. Fixation significantly decreased performance on RAT-1, $t(36) = 3.12$.

DISCUSSION

A robust effect of fixation was found, even though the fixating distractors were not presented at the same time as the initial RAT problems. Fixation was induced in the paired associates task, and the detrimental interfering effect apparently persisted into the problem-solving phase of the experiment. Thus, this fixation effect was not caused by distracted attention, as could have occurred in the previous experiments, but rather by temporary activation or priming of the incorrect solutions.

EXPERIMENT 5

Although the block of paired associates learned before the RAT problems caused fixation in Experiment 4, the fixating events and the initial attempts to solve the problems were somewhat remote, poten-

Table 6. Mean proportion correct in Experiment 4 for fixation vs. nonfixation groups

Group		
Fixation	Nonfixation	Fixation effect
.24	.39	.15

Note. There were 20 problems on the test. Fixation effect = (nonfixation proportion correct) − (fixation proportion correct).

tially allowing unknown process
thermore, Smith and Blanken
effects in problem solving, demo
retesting of problems. To bette
fixating event, an initial probl
problem, we used a procedure

In Experiment 5, fixation w
RAT problem via a paired as
associates was presented and tes
lem. The paired associates we
words, each paired with its relat
unrelated to the subsequent R
Experiment 5 included an initi
lem. The retest of a problem
initial test of a RAT problem, or
task. Thus, each trial consisted
unrelated to the subsequent RA
then tested, then a RAT proble
or 2 min), and finally a retest

It was predicted that impro
greater for more delayed rete
that improvement following no
of the delay of retest. That is, ir
items, but not for the nonfixat

METHOD

Subjects

Participants were 69 students w
ductory psychology course requir

Design and materials

A subset of 12 of the RAT pro
Experiment 5. Half of the proble
were in the nonfixation condition.
third of the nonfixation items we
retested after 0.5 min of free asso
2 min of free associations. Thus,
Incubation) within-subjects design

The paired associates consisted
next to each word. The associates
in Experiment 1, and were presen
of the paired associates were relate

al study list and were asked to write in
nad missed. This procedure was intended
en the RAT words and the misleading

PAL task for fixation groups, or com-
n groups. The 20 RAT items were pre-
ctions printed at the top. Subjects were
f the RAT problems as they could.

% less than the nonfixation group on
aring fixation and nonfixation con-
es on RAT-1 as the dependent mea-
eased performance on RAT-1, $t(36)$

as found, even though the fixating
at the same time as the initial RAT
in the paired associates task, and the
parently persisted into the problem-
. Thus, this fixation effect was not
could have occurred in the previous
porary activation or priming of the

associates learned before the RAT
riment 4, the fixating events and the
lems were somewhat remote, poten-

in Experiment 4 for fixation vs. nonfix-

	Fixation effect
	.15

the test. Fixation effect = (nonfixation
portion correct).

tially allowing unknown processing to influence problem solving. Furthermore, Smith and Blankenship (1989), in observing incubation effects in problem solving, demonstrated the importance of immediate retesting of problems. To better observe the relationship between the fixating event, an initial problem-solving attempt, and a retest of a problem, we used a procedure that would allow item-by-item tests.

In Experiment 5, fixation was induced immediately before each RAT problem via a paired associates trial. A set of three paired associates was presented and tested immediately before each RT problem. The paired associates were either the three subsequent RAT words, each paired with its related distractor, or three paired associates unrelated to the subsequent RAT problem. The procedure used in Experiment 5 included an initial test and a retest of each RAT problem. The retest of a problem occurred either immediately after the initial test of a RAT problem, or after 30 s or 2 min of a free association task. Thus, each trial consisted of three paired associates (related or unrelated to the subsequent RAT problem) which were presented and then tested, then a RAT problem, then a free association task (0, 0.5, or 2 min), and finally a retest of the RAT problem.

It was predicted that improvement following fixation would be greater for more delayed retests than for an immediate retest, but that improvement following nonfixation would not vary as a function of the delay of retest. That is, incubation was predicted for the fixated items, but not for the nonfixated problems.

METHOD

Subjects

Participants were 69 students who volunteered to fulfill part of an introductory psychology course requirement.

Design and materials

A subset of 12 of the RAT problems used in Experiment 1 was used in Experiment 5. Half of the problems were in the fixation condition and half were in the nonfixation condition. One-third of the fixation items and one-third of the nonfixation items were retested after no delay, one-third were retested after 0.5 min of free associations, and one-third were retested after 2 min of free associations. Thus, Experiment 5 used a 2 × 3 (Fixation × Incubation) within-subjects design.

The paired associates consisted of RAT words with an associate printed next to each word. The associates were the same misleading associates used in Experiment 1, and were presented in sets of three paired associates. Half of the paired associates were related to the critical RAT test words, and half

were not related. There were 12 sets of paired associates, one set preceding each initial RAT problem.

The free association stimuli were one-syllable common English nouns, none of which appeared as a test word or solution to a RAT problem. They were presented as a single word on each slide.

The two response pages consisted of rows of blanks for the subjects' responses. For each trial there were three spaces for the paired associates, a space for the initial solution to a RAT problem, six spaces for each free associate, and another single space for the retest of the same RAT item.

Procedure

Subjects were told to memorize the paired associates in pairs for the immediate paired associates test. For free association slides, they were asked to use the 15 s to generate six free associates to each free association stimulus word. Subjects were instructed on the RAT as in the previous experiments. After subjects had been told what to do on the paired associates test, the Remote Associates Test, and the free association tests, they were shown the test slides at a rate of 15 s/slide. Subjects wrote their responses in the appropriate spaces on the response page as the slides appeared.

RESULTS

Fixation

Performance for nonfixation items was better than for fixation problems on RAT-1 (Table 7). A t test was computed to compare performance on fixation items versus nonfixation items on the initial test of each RAT problem. The effect of fixation was significant, $t(68) = 2.38$.

Incubation

As in Experiments 1 and 2, incubation effects were computed independently for the fixation and nonfixation conditions. Improvement, again defined as the proportion of initially unsolved items that were solved at the retest, was used as the dependent measure. Cases in which subjects solved

Table 7. Mean proportion correct on RAT-1 in Experiment 5 for fixation vs. nonfixation conditions

Condition		
Fixation	Nonfixation	Fixation effect
.15	.19	.04

Note. There were 6 fixation and 6 nonfixation items on RAT-1. Fixation effect = (nonfixation RAT-1 proportion correct) − (fixation RAT-1 proportion correct).

all the initial problems in a con
from those subjects were deleted

An incubation effect was found
in the immediate retest condition
in the condition in which the ret
of incubation was significant for
.03. There was no effect of incub

A 3 × 3 (Incubation × Ability)
scores as the dependent measure.
scoring below, at, and above the
the RAT problems. The Incubat
$F(2, 66) = 2.81$, $MS_e = .10$; incuba
subjects than for the median or l

DISCUSSION

The item-by-item test proced
effects was successful in revealin
4, the fixation manipulation
than by distracting attention, b
curred prior to the initial test
be concluded that simply prece
test serves to fixate problem s
were preceded by a paired ass
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mance following unrelated pai

Incubation effects appeared
consistent with the findings of
over the presentation orders
Experiment 5 may have been in
between fixation and incubatio

Even though improvement s
incubation effects (i.e., greater i

Table 8. Mean improvement and
0-min, 0.5-min, and 2-min incuba

	Incuba	
Condition	0 min	0.5
Fixation	.02	
Nonfixation	.14	

Note. Improvement = (no. newly s
1). Incubation effect = (2-min imp

s of paired associates, one set preceding

e one-syllable common English nouns, ord or solution to a RAT problem. They each slide.
ed of rows of blanks for the subjects' e three spaces for the paired associates, RAT problem, six spaces for each free for the retest of the same RAT item.

the paired associates in pairs for the r free association slides, they were asked sociates to each free association stimulus he RAT as in the previous experiments. to do on the paired associates test, the e association tests, they were shown the Subjects wrote their responses in the page as the slides appeared.

items was better than for fixation A t test was computed to compare ersus nonfixation items on the initial effect of fixation was significant, $t(68)$

ubation effects were computed indepen- tion conditions. Improvement, again de- unsolved items that were solved at the measure. Cases in which subjects solved

on RAT-1 in Experiment 5 for fixation

n	Fixation effect
	.04

5 nonfixation items on RAT-1. Fixation portion correct) − (fixation RAT-1 pro-

all the initial problems in a condition allowed for no improvement; data from those subjects were deleted from the incubation analyses.

An incubation effect was found for the fixation condition; improvement in the immediate retest condition averaged only 2%, compared with 13% in the condition in which the retest was most delayed (Table 8). The effect of incubation was significant for the fixation items, $F(2, 92) = 6.99$, $MS_e = .03$. There was no effect of incubation for the nonfixation items, $F < 1.0$.

A 3 × 3 (Incubation × Ability) ANOVA was computed using improvement scores as the dependent measure. Ability was low, median, or high for those scoring below, at, and above the median, respectively, on the initial tests of the RAT problems. The Incubation × Ability interaction was significant, $F(2, 66) = 2.81$, $MS_e = .10$; incubation effects were smaller for the low ability subjects than for the median or high ability subjects.

DISCUSSION

The item-by-item test procedure for testing fixation and incubation effects was successful in revealing both phenomena. As in Experiment 4, the fixation manipulation operated by diverting memory rather than by distracting attention, because each fixation manipulation occurred prior to the initial test of a RAT item. Furthermore, it cannot be concluded that simply preceding the RAT problems with a memory test serves to fixate problem solving; in Experiment 5 all problems were preceded by a paired associates task, regardless of the fixation condition. A fixation effect was observed by comparing problem-solving performance following related paired associates with performance following unrelated paired associates.

Incubation effects appeared only for the fixation condition, a result consistent with the findings of Experiments 1 and 2. The fine control over the presentation orders and times for the RAT problems in Experiment 5 may have been important for observing this relationship between fixation and incubation.

Even though improvement scores were worse for the fixated items, incubation effects (i.e., greater improvement at retest following a delay

Table 8. Mean improvement and incubation effects in Experiment 5 for 0-min, 0.5-min, and 2-min incubation conditions

	Incubation time			
Condition	0 min	0.5 min	2 min	Incubation effect
Fixation	.02	.00	.13	.11
Nonfixation	.14	.13	.20	.06

Note. Improvement = (no. newly solved at retest)/(2 − no. solved on RAT-1). Incubation effect = (2-min improvement) − (0-min improvement).

compared with an immediate retest) were greater following fixated trials (Table 8). Thus, it appears that the fixation effect was strong enough to carry over to the retest of the RAT problems, and that relief from this persistent fixation did not occur except perhaps for the longest incubation periods.

Ability was related to incubation effects in Experiment 5, with the greatest effect seen in the high ability subjects. This differs from the effect of ability on incubation in Experiment 1 in which low ability subjects showed the greatest incubation effect, and in Experiment 2 in which ability was not related to incubation effects.

GENERAL DISCUSSION

The five experiments demonstrate very clearly that performance on RAT problems can be made to suffer by introducing misleading information either prior to or during the test of RAT problems. All fixation manipulations were effective at decreasing initial RAT scores.

Incubation effects were found in all three experiments which tested incubation, and occurred only following fixation manipulations. Although the results do not demonstrate that fixation is necessary or sufficient for producing the type of incubation effects observed in common everyday experience, they do show a way that reliable incubation effects can be observed in the laboratory. Furthermore, the pattern of incubation following a problem-solving block is consistent with anecdotal accounts of incubation in which the problem solver first "slides insensibly into a groove and may not be able to escape at the moment [after which] the incubation period simply allows time for an erroneous set to die out and leave the thinker free to take a fresh look at his problem" (Woodworth & Schlosberg, 1954, p. 841).

The present experiments demonstrated a variety of techniques, all of which were effective at inducing fixation (i.e., decreased initial problem-solving performance). The Stroop-like effects of the simultaneous distractors may suggest a methodology for observing interference in problem solving, similar to color-word or picture-word interference effects observed in relatively simple naming tasks. The manipulations that may affect attention (Experiments 1, 2, and 3), however, may not be as methodologically clean for inducing a memory retrieval block as techniques that prime memory but cannot cause perceptual distraction at the time of the problem-solving task (Experiments 4 and 5).

Several hypotheses about the cause(s) of incubation have been advanced in the literature on the subject. The set-breaking hypothesis

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discussed earlier (e.g., Woodworth & Schlosberg, 1954) is a commonly offered explanation, but certainly not the only one. The fatigue hypothesis (e.g., Woodward & Schlosberg, 1954, p. 838) states that mental fatigue thwarts initial problem solving, and that after a rest more energy can be given to an unsolved problem. Another hypothesis has it that intermittent conscious work on the problem continues during the incubation period; thus, incubation results from extra work on problems. Both the fatigue hypothesis and the extra work hypothesis assume that the subject is not busily engaged in work during the incubation period, allowing either a rest or extra work during the unfilled time. Although the present set of experiments did not critically test these hypotheses, it should be noted that the incubation filler tasks used in Experiments 1, 2, and 5 were very difficult and demanding, and they were stressed to the subjects as being no less important than the problem-solving tasks.

Another hypothesis was offered by Yaniv and Meyer (1987), who used a modified tip-of-the-tongue (TOT) paradigm (e.g., Brown & McNeill, 1966) to investigate a type of incubation effect. After reading subjects a definition of a rare word which induced the TOT state (i.e., subjects felt that they knew the word but could not name it), Yaniv and Meyer collected a feeling-of-knowing judgment for the word. The unretrieved word was then inserted among other words and nonwords in a lexical decision task (e.g., Meyer & Schvaneveldt, 1971). Priming of initially unretrieved words was found, as evidenced by performance on the lexical decision task. Yaniv and Meyer interpreted this as evidence in support of the memory sensitization hypothesis, which states that the partial activation resulting from the initial unsuccessful retrieval attempt makes the activated target more accessible to subsequent attempts. Yaniv and Meyer explained incubation by hypothesizing (a) that targets for initially unsolved problems are sensitized via the initial retrieval attempts (as evidenced by their data), and (b) that with increased incubation times there are more opportunities for encounters with the relevant target. Thus, according to this explanation, as time goes by it is more likely that the problem solver will "stumble across" the correct target, and will be exceptionally sensitive to recognizing the target as a solution.

Another explanation of incubation effects is that the relevant target information for a problem increases in accessibility over time such that at one point it emerges into consciousness, thus providing the solution to a problem. This type of explanation is consistent with the idea that retrieval or problem solving continues to occur at some unconscious or tacit level after the initial failed attempts. Perkins (1981) referred to this as the "still-waters theory," which states that

"thinking runs deep even though quiet on the surface, or quiet at least as far as the problem of interest is concerned. Active thinking, much as a person might do consciously, proceeds unconsciously for a considerable period while the person rests or attends to other matters" (p. 50). Perkins also listed a number of alternative explanations of incubation experiences, including "physical refreshment, forgetting details, finding new approaches, or noticing clues in unexpected circumstances" (p. 52). After reviewing a number of anecdotal cases of incubation effects ranging from personal experiences to the insights of Charles Darwin, Perkins concluded that "deferring a troublesome problem and returning to it later occasionally helps for reasons that have nothing to do with extended unconscious thinking" (p. 57).

We offer an alternative mechanism by which the accessibility of a target might increase over time after the initial failed attempts at a problem. This mechanism does not depend upon the occurrence of unconscious problem solving. Our hypothesis is based upon the possibility that initial unsuccessful attempts at solving a problem result in a memory retrieval block, similar to output interference (e.g., Rundus, 1973). Given a problem or a memory probe for which a possible (but incorrect) response is a blocking piece of information (i.e., one whose accessibility has been temporarily increased), it should be the case that other possible responses, including the correct target, are at least temporarily decreased in accessibility.[2] This situation operationally defines a retrieval block (e.g., Roediger & Neely, 1982), in which retrieval of the desired target is prevented. As more time elapses after the initial failed attempts, the retrieval block may "wear off"; that is, the blocking material may decrease in accessibility, making the correct target relatively more accessible. Thus, this explanation provides a mechanism for the hypothesized progressive increase in accessibility of an initially unretrieved target.

Evidence in support of an accessibility approach to incubation effects was reported in four experiments by Smith and Blankenship (1989). They used a test-retest procedure similar to that used in the present experiments, with misleading information presented at the initial test. In those studies, although the fixating effects of the misleading information were not examined, it was found that memory of the misleading information was inversely related to incubation effects. That is, with longer incubation intervals, there was greater problem-solving improvement, and poorer recall of the misleading distractors.

That the momentary accessibility of the target solution was decreased by retrieval blocks was indicated in at least two of the present experiments (4 & 5). Factors other than retrieval blocks, however, are also likely to affect target accessibility and, therefore, fixation and

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Because incubation effects ha
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Table 9. Incubation effects as a f

Experiment	High
1	.02 (15)
2	.00 (23)
5	.70 (5)

Note. Ability was determined by s
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ility of the target solution was de- dicated in at least two of the present r than retrieval blocks, however, are sibility and, therefore, fixation and

incubation. For example, increased sensitivity to a solution may also affect target accessibility, as suggested by Yaniv and Meyer (1987). Encountering the target solution or associates of the target during the incubation period will probably increase the accessibility of the solution. Variations in the way that memory is probed may affect target accessibility. Temporary mental fatigue might also result in a momentary block to problem solving. A retrieval block is, however, a reasonable hypothetical cause of failures in initial problem solving, especially because early incorrect retrievals can induce such a block.

Ability, as measured by performance on the initial problem-solving tasks, was not obviously or reliably related to incubation effects in the present experiments (Table 9). Numerically, the largest incubation effects occurred for the group scoring high on the initial RAT in one experiment (5), for the median group in one experiment (2), and for the low scoring group in one experiment (1). Thus, the present results dispute both the conclusion of Murray and Denny (1969) that incubation is restricted to low ability subjects, and of Patrick (1986) that incubation occurs only in high scoring subjects. Instead, we propose that incubation may be most likely to occur when easy-to-solve problems are initially thwarted by fixation. What makes a problem easy in a control (nonfixated) condition may relate, for example, to the subject's problem-solving ability, practice, the presence of useful hints, or the normative difficulty of the problem. In terms of accessibility, this means that when problems with highly accessible solutions (under control conditions) are fixated during or prior to initial problem-solving attempts, the increase over time in accessibility of the temporarily blocked solutions will be great, thus causing incubation.

Because incubation effects have not enjoyed much support in past laboratory studies, finding incubation effects in three of the present

Table 9. Incubation effects as a function of ability

	Ability		
Experiment	High	Median	Low
1	.02 (15)	.13 (3)	.29 (18)
2	.00 (23)	.19 (29)	.02 (27)
5	.70 (5)	.18 (14)	.06 (17)

Note. Ability was determined by scores on RAT-1, above, at, or below the median for the high, median, and low ability groups. Numbers in parentheses indicate the number of subjects in each group. For Experiments 1 and 2, incubation = (incubated improvement) − (nonincubated improvement). For Experiment 5, incubation effect = (2-min improvement) − (0-min improvement).

experiments adds considerably to the empirical foundation of incubation effects in the laboratory. In all three of those findings, incubation was detected only following the fixation manipulation. In no comparison was a reliable incubation effect found without a prior fixation manipulation. These results support the contention that incubation in problem solving can be observed as fixation loses its potency.

Appendix: RAT test items shown in uppercase, distractors in lowercase (related associate/unrelated associate), and solutions in boldface

	Problems			Solutions
1.	LICK	SPRINKLE	MINES	**salt**
	tongue/pupil	rain/square	gold/plaza	
2.	WIDOW	BITE	MONKEY	**spider**
	woman/pail	chew/page	wrench/church	
3.	TYPE	GHOST	STORY	**writer**
	style/world	goblin/school	tale/ankle	
4.	SURPRISE	LINE	BIRTHDAY	**party**
	trick/town	angle/pond	cake/top	
5.	WHEEL	ELECTRIC	HIGH	**chair**
	tire/child	cord/coat	low/letter	
6.	CAT	SLEEP	BOARD	**walk**
	nap/mind	might/vegetable	wood/pump	
7.	SHIP	OUTER	CRAWL	**space**
	ocean/police	inner/soap	floor/money	
8.	BALL	STORM	MAN	**snow**
	soccer/tea	tornado/file	boy/carrot	
9.	FAMILY	APPLE	HOUSE	**tree**
	mother/step	pie/worship	home/errand	
10.	ATTORNEY	SELF	SPENDING	**defense**
	lawyer/nail	me/herd	shopping/scar	
11.	WORM	SCOTCH	RED	**tape**
	bug/diaper	whiskey/farm	green/empty	
12.	WATER	PICK	SKATE	**ice**
	bath/win	choose/milk	board/calf	
13.	RIVER	NOTE	BLOOD	**bank**
	lake/omen	music/April	wound/grouch	
14.	ROUGH	RESISTOR	BEER	**draft**
	smooth/holster	circuit/nude	bottle/sole	
15.	FOOD	CATCHER	HOT	**dog**
	eat/in-law	pitcher/pail	cold/harbor	
16.	HEARTED	FEET	BITTER	**cold**
	broken/bottle	inches/hem	sweet/rifle	

17.	DARK	SHOT
	light/seam	gun/desk
18.	SANDWICH	GOLF
	jelly/sentence	course/r
19.	GRAVY	SHOW
	potato/baseball	movie/st
20.	ARM	COAL
	leg/election	furnace/

Notes

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n uppercase, distractors in lowercase
), and solutions in boldface

		Solutions
	MINES	**salt**
	gold/plaza	
	MONKEY	**spider**
	wrench/church	
	STORY	**writer**
l	tale/ankle	
	BIRTHDAY	**party**
	cake/top	
	HIGH	**chair**
	low/letter	
	BOARD	**walk**
able	wood/pump	
	CRAWL	**space**
	floor/money	
	MAN	**snow**
	boy/carrot	
	HOUSE	**tree**
	home/errand	
	SPENDING	**defense**
	shopping/scar	
	RED	**tape**
n	green/empty	
	SKATE	**ice**
	board/calf	
	BLOOD	**bank**
	wound/grouch	
	BEER	**draft**
	bottle/sole	
	HOT	**dog**
	cold/harbor	
	BITTER	**cold**
	sweet/rifle	

17.	DARK	SHOT	SUN	**glasses**
	light/seam	gun/desk	moon/crank	
18.	SANDWICH	GOLF	CANADIAN	**club**
	jelly/sentence	course/robin	Montreal/neon	
19.	GRAVY	SHOW	TUG	**boat**
	potato/baseball	movie/stitches	pull/profit	
20.	ARM	COAL	PEACH	**pit**
	leg/election	furnace/belly	pear/football	

Notes

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1. Significance levels were fixed at $p < .05$ for all statistical tests reported. Two-tailed tests were used for all t tests reported.

2. Theoretically, this decrease in target accessibility could be accomplished in a number of ways, including lateral inhibition (i.e., activation of the incorrect target inhibits other related targets), or a probabilistic retrieval model (e.g., Rundus, 1973; Shiffrin, 1970). In the probabilistic model, the overall probability of retrieving an item remains at 1.0; therefore, increasing the probability of retrieving an item necessarily decreases the probability of retrieving other responses.

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