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Incubation effects

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After an initial period of unsuccessful work at solving a problem, a subject might either continue to work uninterruptedly or put the problem temporarily aside, returning to it later. The elusive laboratory phenomenon called "incubation" refers to superior performance for those subjects who return to the problem after a delay rather than working continuously on the problem. The *forgetting-fixation* hypothesis states that correct solutions are made inaccessible during initial problem solving when incorrect solutions are mistakenly retrieved. Forgetting (or decreased accessability) of fixated material should make correct solutions relatively more accessible, thus leading to incubation. Four experiments in the present study found incubation effects using a set of picture-word problems called rebuses. Misleading clues were initially presented with some of the problems, to induce fixation artificially. Greater forgetting occurred at retest for groups showing the greatest incubation effects, consistent with the forgetting-fixation hypothesis.

After one has temporarily left an unsolved problem, an unexpected insight into the solution may occur. This phenomenon is known as incubation. The popularity of the concept of incubation suggests that the phenomenon is commonly produced in the laboratory. Olton (1979), however, in a review of the experimental literature on incubation effects, concluded that "experimental evidence in support of incubation is extremely slim" (p. 15). Studies in which incubation effects have not been found include Gall and Mendelsohn (1967), Dominowski and Jenrick (1972), and Olton and Johnson (1976).

In the present study, we hypothesized that retrieval of inappropriate information and strategies from memory during initial problem solving blocks retrieval of the correct information and strategies needed for successful problem solving. The overcoming of fixation, which is essential for incubation, consists of forgetting (i.e., decreasing the accessibility of) inappropriate information so that appropriate information will be relatively more accessible. This general explanation will be referred to as the *forgetting-fixation hypothesis.*

The forgetting-fixation hypothesis provided the idea for an experimental technique for observing incubation in problem solving in the laboratory. The technique involves a test-retest procedure in which problems are given twice: first, with misleading "clues" designed to divert retrieval away from the correct information, and again later, without the misleading information. Improvements from the first to the second period of problem solving were predicted to be greater when the problems were temporarily put aside. This hypothesized outcome operationally defines incubation.

In our studies we used rebus problems, a type of picture-word puzzle. Solutions to the rebuses are common phrases that fit the word-pictures, usually involving idioms. For example, the solution to the rebus "timing tim ing" is "split-second timing," because the second "timing" is split into two parts.

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EXPERIMENT 1

In Experiment 1, the first 15 rebuses were presented with useful clues. The critical rebus, which was given last, was presented with a misleading clue. It was hoped that the usefulness of the clues in early problems would lure the subjects into using the misleading clue to probe memory inappropriately, thus inducing fixation. The subjects were later given the critical item a second time, without a clue present. They were asked to try to solve the problem first, and then to try to recall the previously associated clue. This clue-recall test was used as an index of forgetting of fixated information.

The time and activity inserted between the two presentations of the critical problem were varied. The interval was 0, 5, or 15 min (control, 5-min, and 15-min), and either unfilled or filled with a demanding "music perception task." The forgetting-fixation hypothesis predicted that longer intervals and filled intervals would lead to poorer memory of the critical misleading clue and, concomitantly, to more incubation effects (i.e., higher improvement scores).

Method

The 108 subjects were student volunteers who fulfilled a requirement for their introductory psychology course by participating in the experiment.

The stimuli used were rebuses, which are a type of picture-word puzzle. For the 22 rebuses used, the solutions were all common English phrases. Two rebuses were used as examples, and the other 20 served as experimental stimuli. Each rebus was pictured inside of a rectangular border and was presented on an individual slide. Each clue was printed on the top of the rectangular border. The first 15 experimental rebuses were presented with useful clues intended to facilitate problem solving. The last 5 rebuses had misleading clues. The retest was given with no clues. The last rebus, Item 20, was the critical test item. Item 20 was "you just me" presented with the misleading clue "beside." The correct answer was "just between you and me."

For the music-perception task, instrumental musical selections were played while the subjects answered questions about each piece's identity, how it made the subject feel, and what it made the subject think of. This task was very demanding and engrossing for the subjects.

After the two example problems were explained, the 20 experimental rebuses were presented at a 30-sec rate. The subjects were not informed that there would be a retest. After the 20 clued rebuses, there was an interpolated period that lasted 0, 5, or 15 min. In the 5-min and 15-min conditions, the period was either filled with the music perception task, or unfilled (the subjects were asked to sit quietly). The critical problem was presented again after the interpolated period, this time without clues. One minute was given on the second presentation. The subjects were asked to begin by trying to solve the problem, and they were then asked to try to recall the clue that had previously been presented with that problem.

Results

Improvement. Improvement scores were computed as the score at the retest (0 or 1) minus the score at the initial test (0 or 1). A one-way ANOVA was computed, comparing the control group, the 5-min (filled and unfilled) group, and the 15-min (filled and unfilled) group, using improvement scores as the dependent measure. The groups were significantly different [$F(2,105) = 3.08$, $MS_e = .340$, $p = .05$], with the 15-min group scoring the highest, and the control group the lowest (Figure 1). Two-tailed independent sample t tests indicated that the control group scored significantly worse than the 5-min group [$t(105) = 2.62$, $p = .01$] and the 15-min group [$t(105) = 2.98$, $p < .01$]. The 5- and 15-min groups did not differ [$t(105) = .523$, $p = .60$].

Another one-way ANOVA compared the control group, the unfilled (5- and 15-min) group, and the filled (5- and 15-min) group, again using improvement as the dependent measure. The differences among the groups were marginally significant [$F(2,105) = 2.82$, $MS_e = 3.41$, $p = .06$], with the filled group scoring the highest and the control group the lowest (Table 1). Two-tailed independent sample t tests indicated that the control group scored significantly worse than the filled group [$t(105) = 2.29$, $p < .05$] and the unfilled group [$t(105) = 2.08$, $p < .05$]. The filled and unfilled groups did not differ [$t(105) = .289$, $p = .77$].

Clue memory. The probability with which the misleading clues were recalled at retest was termed clue memory. A one-way ANOVA compared the control group, the 5-min group, and the 15-min group, using memory of the clue from the retested item as the dependent measure. Clue memory was highest in the control condition and lowest in the 5-min and 15-min groups (Figure 1). These differences were significant [$F(2,105) = 4.70$, $MS_e = .238$, $p < .05$]. Two-tailed t tests indicated that the control group recalled significantly more clue words than did the 5-min group [$t(105) = 2.62$, $p = .01$] and the 15-min group [$t(105) = 2.98$, $p < .05$]. The 5- and 15-min groups did not differ [$t(105) = .52$, $p = .60$].

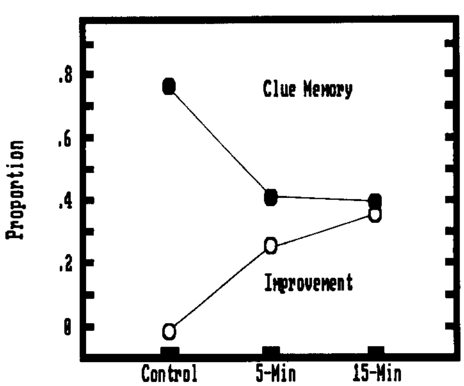

Figure 1. Mean improvement (minimum = −1.0, maximum = 1.0) and clue memory scores (maximum = 1.0) as a function of incubation condition in Experiment 1.

Another ANOVA compared clue memory for the control group, the unfilled group, and the filled group (Table 1). The groups were significantly different [$F(2,105) = 4.75$, $MS_e = .238$, $p < .05$]. The control group recalled a higher proportion of the clues than did the unfilled group [$t(105) = 3.03$, $p < .01$] and the filled group [$t(105) = 2.55$, $p < .05$]. The unfilled and filled incubation groups did not differ from each other [$t(105) = .61$, $p = .54$].

Discussion

Robust incubation effects were found in Experiment 1. Solutions of an unsolved rebus were not observed in a continuous work (control) condition, whereas following incubation, improvements averaged 30%.

It can be seen that the control group not only improved less, but also was more likely to recall the misleading clue than were the 5-min and 15-min groups (Figure 1). This suggests that the forgetting of misleading clues over time may have enhanced problem-solving performance. The results of Experiment 1 supported the hypothesis that the tendency to solve problems increases as fixated information is forgotten.

EXPERIMENT 2

In Experiment 2, the retested rebus was presented with a highly useful clue. This procedure should have made the correct information equally (and highly) accessible to all subjects. As in Experiment 1, the critical rebus was first presented with misleading clues. Following 5 or 15 min of incubation time, filled or unfilled, the subjects were retested on the critical rebus with a useful clue. As in Experiment 1, the subjects were asked to recall the previously presented misleading clue after trying to solve the rebus.

Method

The 102 subjects were student volunteers from introductory psychology classes; they fulfilled part of a course requirement by participating.

The design, procedure, and materials used in Experiment 2 were identical to those in Experiment 1, except that in Experiment 2 the subjects were retested on the critical rebus with a useful clue.

Results

Improvement. A one-way ANOVA compared the control, the 5-min, and the 15-min groups, using improvement scores as the dependent measure. The means differed significantly [$F(2,99) = 4.43$, $MS_e = .128$, $p < .05$]. The 15-min group scored higher than did the control group [$t(99) = 2.06$, $p < .05$] and the 5-min group [$t(99) = 2.85$, $p < .05$]. The control group and the 5-min group did not differ from each other [$t(99) = .27$, $p = .79$].

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Table 1
Mean Improvement Scores and Clue Recall as a Function of Interpolated Activity in Experiment 1 and 2

	Experiment 1		Experiment 2	
	Improvement	Clue Recall	Improvement	Clue Recall
Control	−.06	.78	.05	.86
Unfilled	.28	.37	.20	.75
Filled	.32	.43	.05	.68

Note—Improvement = retest performance minus initial performance; maximum possible improvement = 1.0. Proportion correct is shown for clue recall.

differences were not significant [$F(2,99) = 2.09$, MS_e = .134, $p = .13$].

Clue memory. Clue-memory scores for Experiment 2 are shown in Figure 2. An ANOVA compared the control, the 5-min, and the 15-min groups, using clue memory as the dependent measure. The differences among the means were only marginally significant [$F(2,99) = 2.82$, $MS_e = .185$, $p < .064$]. The control group recalled significantly more than did the 15-min group [$t(99) = 2.08$, $p < .05$], but not more than the 5-min group [$t(99) = .50$]. The difference between the 5- and 15-min groups was marginally significant [$t(99) = 1.96$, $p = .052$].

The ANOVA comparing the control, the unfilled, and the filled groups on clue memory found no significant differences.

Discussion

An incubation effect was again found, as in Experiment 1. The effect was detectable only for the 15-min incubation conditions, and not for the 5-min incubation condition. Clue memory was also affected by the duration of the incubation interval in Experiment 2. The highest mean recall was found in the control group, the next highest in the 5-min group, and the lowest in the 15-min group (Figure 2). That more solutions and more forgetting of misleading clues were found with longer intervals between test and retest supported the forgetting-fixation hypothesis. However, it appears that the filler task did not induce forgetting, nor did it enhance solution rates in this experiment.

EXPERIMENT 3

A somewhat different no incubation/control group was used in Experiment 3. In the control group, the initial 30 sec of work on each rebus was immediately followed

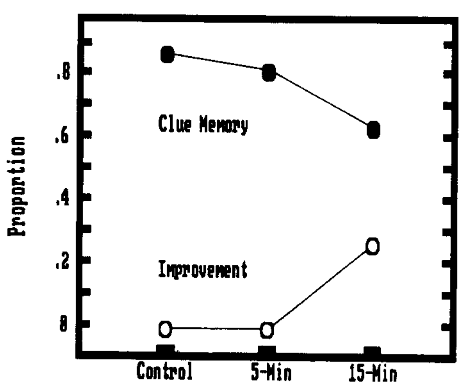

Figure 2. Mean improvement (minimum = −1.0, maximum = 1.0) and clue memory scores (maximum = 1.0) as a function of incubation condition in Experiment 2.

by another 30 sec of work on the same problem. Incubation groups were given intervals between the initial test of the 20-item block and the retest of the block.

In Experiment 3, rebuses with misleading clues were initially embedded within numerous other rebuses, which were presented with useful clues. The subjects were later retested on rebuses without clues. The time between the first test and the retest was varied, and the activity in that interval was also varied.

Method

The 147 subjects were volunteers who fulfilled a requirement for their introductory psychology course by participating in the experiment.

One rebus problem appeared on each page of a 22-page test booklet. The answer sheet consisted of a numbered form that contained clue words, one for each rebus (including the two example problems). For the example problems and for seven of the experimental stimuli, the clues provided extremely useful hints to the correct solutions of the problems. The other 13 clues, however, were intended to be misleading, suggesting phrases other than the correct solutions.

The same music-perception task that was used in Experiment 1 was again used as one of the incubation-interval filler tasks in Experiment 3. Multiplication problems were given in the math problems task. Each problem required the subject to multiply two two-digit numbers.

The subjects were given two 30-sec periods for each rebus. Thus, the subjects were given 1 min of solving time for each item. Their answers were written on the answer sheet next to the appropriate clue words.

Of interest was what occurred between the two 30-sec periods of problem solving on each rebus. In the control group, there was no time between the two periods. For each problem, there was a 30-sec period of work with a clue present, followed immediately by 30 sec on the same problem without a clue present. All other groups worked for 30 sec on each of the other 19 rebuses before returning to the same rebus. For example, for the item in Position 10, there followed 10 problems from the first set and 9 problems from the second set before Problem 10 was reintroduced. Incubation groups had 10 min of other rebuses, 10 min of rebuses plus 5 min of rest, 10 min of rebuses plus 5 min of the music-perception task, 10 min of rebuses plus 5 min of math problems, or 15 min of rebuses. The 15-min rebus group received six extra problems not given to the other subjects. Thus, there were five incubation groups and one control group.

Results

Improvement scores were calculated as the number of problems correctly solved during the second 30-sec period of problem solving that were not solved during the first 30-sec period. The maximum possible improvement score was 20. A one-way ANOVA was computed using interpolated activity (no incubation, 10-min rebus, 10-min rebus + 5-min rest, 10-min rebus + 5-min math, 10-min rebus + 5-min music, 15-min rebus) as the independent variable, and improvement as the dependent measure. Differences among the six groups were significant [$F(5,141) = 4.30$, $p < .01$]. Pairwise comparisons showed that the control group improved significantly less than any of the incubation groups, but that the five incubation groups did not differ among themselves (Table 2).

For the five incubation groups, the number of dropouts was calculated as the number of solutions from the first 30-sec period of work on a rebus that were not remembered on the second work period for that rebus. Whereas the number of dropouts did not significantly differ as a function of incubation group ($F < 1.0$), the ordering of the means indicated that the greater the number of dropouts, the more improvement seen in problem-solving performance from the first to the second test (Table 2).

Discussion

That solution rates improved when time was inserted between the two work periods again supports the idea of incubation in problem solving. The type of activity inserted between the two periods of problem solving did not appear to affect the degree of improvement. This indicates that an opportunity to work surreptitiously on unsolved problems during the inserted time did not affect the subjects' levels of incubation.

EXPERIMENT 4

Experiment 4 replicated the major findings of Experiment 3.

Method

The 101 subjects were volunteers from introductory psychology courses.

The materials for Experiment 4 were identical to those in Experiment 3, except that 10 of the 20 test rebuses had helpful clues and 10 had misleading clues.

There were three conditions in this study. The control group worked through the entire set of 20 rebuses at the rate of 1 min per problem: 30 sec with clues provided, and 30 sec without the clues. The math group worked through the set of 20 rebuses at the rate of 30 sec per problem, then worked on a multiplication filler task for 5 min, then were asked to work on the same set of rebuses previously presented for 30 sec per problem. The story group worked through the set of problems at the rate of 30 sec each, then read a short story. The participants were given 5 min to complete the story. These subjects then worked on each rebus again for an additional 30 sec.

Results and Discussion

The results of Experiment 4 were very similar to the results of Experiment 3 (Table 3). Improvement scores were again calculated as the number of problems correctly solved during the second 30-sec period of problem solving that were not solved during the first 30-sec period. A one-way ANOVA was computed, using interpolated activity (control, math, story) as the independent variable and improvement as the dependent variable.

The effect of interpolated activity was significant [$F(1,45) = 4.56$, $MS_e = 1.03$, $p < .05$]. Newman-Keuls pairwise comparisons ($\alpha = .05$) indicated that the story group performed better than the control group (critical difference = .874), but no better than the math group (critical difference = .726). The math and control groups did not differ.

As in the other experiments, the subjects who were interrupted during problem solving showed significant improvement upon returning to the problem as compared with those who worked continuously.

Table 2
Mean Improvement and Dropout Scores as a Function of Incubation Time in Experiment 3

Condition	Number Improved	Number of Dropouts
Control (no incubation)	.96	—
Incubation		
10 min	2.00	.24
10 min + 5 min rest	2.56	.38
10 min + 5 min music	2.27	.39
10 min + 5 min math	2.22	.41
15 min rebus	2.48	.57

Note—Scores shown are based on a maximum of 20 problems.

Table 3
Mean Improvement and Dropout Scores as a Function of Condition in Experiment 4

Condition	Improvement	Dropouts	Clue Recall
No Incubation			
Control	1.00	.18	18.65
Incubation			
Math	1.40	.20	15.20
Story	2.06	.53	14.75

Note—Improvement = number of initially unsolved problems which were solved at retest. Dropouts = number solved initially but not solved at retest. Maximum cue recall = 20.

GENERAL DISCUSSION

Incubation effects, defined as improvements in problem-solving performance when subjects are retested on problems after an interval, were found in all four experiments. This consistent finding supports the idea of incubation in problem solving, and it suggests that the paradigm used for observing incubation in the present experiments may be very useful.

Measures of forgetting, including clue recall and dropouts, appeared to be related to problem-solving improvements in all four studies, thus supporting the forgetting-fixation hypothesis. Unsuccessful attempts to solve problems in the first test period may have resulted in fixation, especially when misleading clues were presented.

It is possible that the brevity of the initial period of work given to rebuses in the present experiments (30 sec) contributed to our finding incubation effects. The initial period of work given in the studies previously reviewed was 2 to 15 min, durations considerably longer than that used in the present study. Lengthier initial work periods on a problem may induce such a degree of fixation upon initial incorrect solutions that the incorrect ideas are not easily forgotten or put out of mind within the minutes of incubation allowed in most studies.

The filler tasks given in the four experiments did not reliably influence the incubation effects. This suggests that the incubation effects were not due to continued work on rebus problems during the intervals, since the filler tasks should have prevented continued work on the rebuses.

It is hoped that the forgetting-fixation hypothesis and the paradigm used in the present study will provide some of the necessary groundwork for further investigations into the issues of fixation and incubation.

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