

Lilly Both

University of New Brunswick

Douglas Needham

Redeemer University College, Ancaster ON

and

Eileen Wood

Wilfrid Laurier University

Examining Tasks that Facilitate the Experience of Incubation While Problem-Solving

The three studies presented here contrasted the problem-solving outcomes of university students when a break was provided or not provided during a problem-solving session. In addition, two studies explored the effect of providing hints (priming) and the placement of hints during the problem-solving session. First, the ability to solve a previously unsolved problem (incubation) was demonstrated. However, the incubation effect was dependent on the placement of the hint and the kind of hint provided. Incubation occurred with challenging word problems (paired-anagrams). Furthermore, the effect was facilitated when a break from study was provided and where a hint directing the student toward a solution was provided during the break. Verbal ability was not related to performance in problem-solving tasks involving paired-anagrams. In general, there are reliable interventions for promoting incubation in problem-solving situations. These interventions include attention to the task demands and the context of study.

Dans les trois présentes études, on compare les résultats atteints par des étudiants à l'université qui accomplissaient des tâches de résolution de problèmes lors d'une session avec une pause et d'une autre sans pause. De plus, deux études se sont penchées sur l'effet produit par la présentation d'indices pendant les sessions de résolution de problèmes. La capacité de résoudre un problème que l'on n'avait pas réussi à résoudre avant (incubation) a d'abord été démontrée. Dans ce cas, l'effet de l'incubation dépendait de la mise en place de l'indice et du genre d'indice fourni. L'incubation a eu lieu pendant les défis verbaux (anagrammes jumelés). La présence d'une pause pendant la session et le fait de fournir un indice à l'étudiant pendant celle-ci ont favorisé cet effet. L'aptitude verbale n'était pas liée à la performance lors de la résolution de problèmes impliquant les anagrammes jumelés. De façon générale, des interventions fiables existent pour promouvoir l'incubation lors de tâches de résolution de problèmes. Entre autres, citons l'attention portée aux exigences de la tâche et le contexte de l'étude.

Lilly Both is an assistant professor in developmental psychology. Her research interests include social and cognitive problem-solving.

Doug Needham is an associate professor of psychology and the Dean of Sciences and Social Sciences. His research interests include incubation effects, analogical transfer, and values and religiosity during adolescence.

Eileen Wood is a professor in developmental psychology. Her primary interests include cognitive development and computer literacy.

Every educator is familiar with at least one anecdotal report of a learner who strives unsuccessfully to solve a problem and after taking a break is suddenly able to generate the solution to the problem. This phenomenon is known as incubation or the incubation effect. More formally, incubation refers to the facilitation of problem-solving following a break from the problem-solving task (Olton, 1979; Wallas, 1926). Patrick (1986) states that although there is a well-developed anecdotal history for the incubation effect (Ghiselin, 1952; Sapp, 1992), incubation has proven difficult to produce experimentally (Olton & Johnson, 1976), and the mechanisms involved in achieving the incubation effect are not fully understood (Goldman, Wolters, & Winograd, 1992). As a result of the difficulty of establishing incubation in experimental contexts, there are no reliable interventions prepared for educators to promote incubation in the classroom. Such adaptations would be an asset for promoting problem-solving in an educational context. The concern of this article, therefore, is to examine one feature, the materials that facilitate the reliable generation of incubation effects.

Existing research suggests that it may be possible to facilitate incubation by considering the learning context that the problem-solver faces. Features of the learning environment such as the type of problem (Dreistadt, 1969; Penney, Godsell, Scott, & Balsom, in press), the timing of a break (Patrick, 1986), and the length of the break can affect solution outcomes (Goldman et al., 1992). For example, an appropriate problem for producing incubation requires that the problem-solving task have enough variability to allow learners to make measurable progress in a second attempt after reaching a block in the first attempt. In a recent study, Penney et al. obtained incubation when using a multiple-solution anagram task. In this task, problem-solvers derived as many five-letter words as they could from a 10-letter starter word. The perceived advantage of this task was the large number of possible solutions that would not be identified in the first problem-solving attempt and hence could be "discovered" during a second study session. Other researchers (Goldman et al., 1992) have reported incubation when using single-solution anagram tasks (i.e., jumbled letters that can be unscrambled to produce one correct word, e.g., PLACHE = CHAPEL). In the light of these discrepancies, we thought that it would be important to take a closer look at the anagram task as a means for demonstrating the incubation effect. Specifically, we examined a paired-anagram task (i.e., where the letters of one word can be reorganized to produce another word, e.g., IGNORE = REGION).

The paired-anagram is of particular interest because the initial starter word has the potential of producing a *mental set* for the problem-solver. Smith and Blankenship (1989; 1991) argue that irrelevant information is activated during the first problem-solving situation to the extent that the learner becomes fixated on this information. When the learner is given a break, and has an opportunity to work on something else, the fixation or mental set is broken. The problem-solver can then return to the task anew and have the opportunity of activating problem-relevant information. Because paired-anagrams are intact words, they may increase and maintain the activation of inappropriate information, that is, they may create a mental set for the problem-solver. The

incubation interval, then, may be critical for allowing the problem-solver to break the mental set.

Other researchers have argued that incubation effects are observed after the break because participants continue to work consciously on the problem. That is, the break is not truly a break. For example, Browne and Cruse (1988) found that participants who were asked to relax and listen to music during a break from problem-solving outperformed individuals who were given a demanding task during the break (memorizing text) as well as individuals who worked continuously on the problem-solving task. The participants in this relaxation group were also more likely to report working covertly on the problem during the break, which probably resulted in their better performance scores. Thus there is a need to control for conscious problem-solving by providing demanding tasks during the break (Fulgosi & Guilford, 1968).

An additional concern addresses interventions that can be provided for learners to help them in the problem-solving task. In particular, the literature suggests that providing a hint during the break can prime the learner toward the correct solution (Browne & Cruse, 1988). Simply priming students may not be enough to achieve successful problem-solving. Some research indicates that the combination of hints and a break from problem-solving together may be more effective than either breaks or hints on their own (Dreistadt, 1969). In the present study, the use of hints and breaks is examined more closely with a focus on the placement of hints and an examination of the relation of the content of the hints to the solution.

Fatigue is another mechanism that can affect problem-solving performance (Browne & Cruse, 1988; Goldman et al., 1992). The tasks that the learner faces need to be challenging enough to allow an incubation effect to occur, yet not exhaust the learner in the process. Although researchers have offered several explanations to account for incubation effects (Ghiselin, 1952; Goldman et al., 1992), the four most commonly cited are mental set, conscious work, priming, and fatigue. Each of these alternative explanations was considered in the design of the present studies.

In summary, the following studies explore two issues: whether incubation effects can be produced reliably for the paired-anagram problem-solving task; and whether the type and placement of hints affect problem-solving outcomes.

Study 1

The first study examines learners' problem-solving performance when presented with paired-anagrams. In particular, some learners were given a break from problem-solving whereas others were required to work continuously. Although past research is inconsistent in producing an incubation effect, typically the break from study yields higher performance outcomes than continuous study (Peterson, 1974). Differences in achieving incubation may be a product of the abilities of the learner as well as variations in the tasks (e.g., insight problems vs. anagrams). For example, when Murray and Denny (1969) compared high-ability students with students lower in problem-solving ability while solving Saugstad and Raaheim's (1957) ball task, the low-ability students benefited from the break whereas the high-ability students performed best when working continuously. With respect to tasks, incubation is sometimes achieved with some anagram tasks (Peterson, 1974) and not with others

(Goldman et al., 1992, found incubation effects for anagrams after a 24-hour break, but not after a 20-minute break); and sometimes with insight problems (Fulgosi & Guilford, 1968); or other problems (Smith & Blankenship, 1989); and sometimes not (Olton & Johnson, 1976). However, despite variations in methodology and problems, there is sufficient evidence that incubation does occur to warrant further investigation.

The abilities and knowledge that a learner brings to any learning context is an important contributor to his or her successful performance (Murray & Denny, 1969; Wood et al., 1999). Based on earlier incubation studies, we expected that individual differences in ability might affect performance in this incubation task (Smith & Blankenship, 1991; Patrick, 1986). In this study it was expected that verbal skills might be an important contributor to the learner's ability to solve verbal word problems such as paired-anagrams. As such we assessed the effect of verbal ability on performance.

Method

Participants

The 98 participants were undergraduate students attending university in a mid-sized Canadian city (M age = 23.8, $SD=5.9$). Approximately equal proportions of men and women were randomly assigned to one of two conditions: continuous study ($n=49$) or provision of an incubation interval ($n=49$). All students were volunteers who received course credit for their participation.

Materials and Procedure

One set of five paired-anagrams was prepared. Each of the five paired-anagrams (Rawlinson, 1976) had one solution: IGNORE = REGION, FIDGET = GIFTED, ANOINT = NATION, DIRECT = CREDIT, RECIPE = PIERCE. The paired-anagrams used in the present study followed from a pilot study conducted to norm solution times. Each of the paired-anagrams selected for the present study shared equivalent solution rates.

The paired-anagram sets were presented via overhead projection. The order of the paired-anagrams was randomly determined. Participants attended one session. Although all participants were tested in groups, they worked independently. The paired-anagram problem-solving task was presented first. After the paired-anagram task, participants completed the Peabody Picture Vocabulary Test-Revised (PPVT-R) to assess verbal ability (Dunn, Dunn, Robertson, & Eisenberg, 1979). The PPVT-R is a well-established measure with internal consistencies scores ranging from .61 to .88 and alternate form reliability values ranging from .71 to .91 (Dunn, Dunn, Robertson, & Eisenberg, 1979; Center for Psychological Studies, 2003).

In the continuous study condition, participants were presented with each paired-anagram one at a time. Participants were given 40 seconds to solve each paired-anagram. Timing for the solution of the paired-anagrams was required in the continuous study condition to determine whether the participants were able to solve the problems quickly (within the first 20 seconds) or after a longer study period (i.e., up to 40 seconds). A colored sheet of paper was presented at the front of the room throughout the study session. One color denoted the first 20 seconds of the interval, and a second color denoted the last 20 seconds of the solution period. Participants recorded solutions in a booklet and indicated in a

space beside each solution the color that was present when they produced a solution.

In the incubation interval condition, the solution time was divided in order to provide participants with an opportunity for incubation to occur. Participants were given the paired-anagrams for 20 seconds, followed by a break (i.e., distracter tasks), and then another 20-second solution opportunity. In the first solution time interval, participants were presented with each paired-anagram for 20 seconds. After all the paired-anagrams had been presented, participants were given the two three-minute distracter tasks as the break.

The distracter tasks were not related to solving paired-anagrams in any way. Participants were presented with two sheets of paper. On one sheet was a list with 200 numbers followed by one letter from A to E. Students were required to transfer the appropriate letter to a corresponding number on a computer scan sheet. They were instructed to work as quickly and accurately as possible for the entire three-minute interval. For an additional three minutes participants were required to answer a series of short-answer questions, for example, "List three songs that have a person's name in the title (e.g., Billie Jean). For each song, think back to the last time you heard it and describe the circumstances." These activities inhibited participants from continuing to work on the paired-anagrams during the incubation interval. At the end of the distracter tasks, participants were again given the paired-anagrams to solve, each for 20 seconds. At no time were participants in this condition told that they would be given a second opportunity to solve the paired-anagrams.

Results

To determine if incubation occurred for the paired-anagram task, difference scores were calculated by subtracting the total number of solutions generated at the end of 20 seconds from the number of solutions generated at the end of 40 seconds. An analysis of covariance (ANCOVA) was conducted for the paired-anagrams. The two conditions (continuous study or incubation interval condition) served as the between-subjects factor. The PPVT-R served as the covariate. The results indicated that the PPVT-R was not a significant covariate ($F(1,94)=.27, p>.60$). However, there was a significant main effect for condition ($F(1,94)= 5.63, p<.02$) such that more solutions were generated in the incubation interval condition ($M=.74, SD=.71$) than in the continuous study condition ($M=.42, SD=.61$).

Discussion

The first and most important conclusion was that an incubation effect was demonstrated. Of interest, the incubation effect was found when the students had a break from studying. That is, the break facilitated solving paired-anagrams. In the continuous study condition, students may experience a mental set as they fixate on the initial word and hence are unable to solve the problem (e.g., seeing IGNORE makes it difficult to find the word REGION). The break from problem-solving may allow for an opportunity to see the problem anew.

Interestingly, verbal ability did not differentially affect participants' ability to solve paired-anagrams in this study. In fact incubation effects were independent of verbal skill in this study.

Overall, this study indicates that incubation clearly can be encouraged, and providing learners with a break appears to facilitate their ability to solve problems.

Study 2

Study 1 demonstrated an incubation effect when learners were given a break from solving challenging problems (paired-anagrams). Although providing a break is one strategy that an educator may find useful for facilitating problem-solving, it is also possible that preparing students by providing hints might also facilitate problem-solving. In fact studies where hints are provided during breaks typically result in greater learning for students (Dreistadt, 1969). In this study the placement of the hint was of primary importance. In particular we wished to determine whether providing a hint prior to problem-solving would yield an incubation effect and produce differential outcomes for students who worked continuously on the problem versus others who had a break from study.

Method

Participants

The 82 participants (22 men and 60 women) were recruited from an introductory psychology subject pool (M age = 22.0 years, $SD=5.8$) in a small Canadian university. All participants spoke English as their first language. Participants received bonus marks for their participation.

Materials and Procedure

The participants were randomly assigned to one of two conditions: an incubation interval group where participants were given a break from problem-solving or a continuous study group, with equal proportions of males and females in each condition. Participants were tested individually, and the entire session lasted approximately 40-50 minutes. Each testing session began with an experimenter requesting demographic information (sex, age, and first language). All participants were asked to solve five paired-anagrams. Participants in the continuous study condition were presented with hints (imbedded in vignettes) followed by the 40-second solution opportunity for each paired-anagram. Participants in the incubation interval condition were exposed to the hints, a 20-second solution opportunity, a break (i.e., distracter tasks), and finally a second 20-second solution opportunity for each paired-anagram. The hints were presented through five short vignettes printed on 8.5" x 11" paper. Each vignette averaged 141 words in length (range = 135-148 words) and contained on average 11 synonyms (range 8-13) for one paired-anagram. Each synonym primed the solution to the paired-anagram. The paired-anagrams were the same as those used in Study 1. For example, for the paired-anagram PIERCE (solution RECIPE), participants read and heard a paragraph about a cook preparing a meal. In that vignette appeared eight synonyms for the solution word RECIPE (two of which appeared twice) that would prime the solution RECIPE (e.g., ingredients, instructions). However, the word RECIPE did not appear in the vignette. After each vignette was read and heard, the participants were given the related paired-anagram to solve.

In the incubation interval group, participants heard the first vignette and then were given 20 seconds to solve the related paired-anagram. This solution

opportunity was followed by a six-minute distracter task (i.e., the break) where they completed the same speed and accuracy measure as in Study 1, followed by a backward digit task. In the backward digit task they were read a series of three numbers one at a time and had to repeat the numbers in reverse order. These two distracter tasks served as a break from solving the paired-anagrams, yet kept the participant occupied so he or she would not work on the solution. Following the distracter tasks, the participants again were given the paired-anagram on a sheet of paper, and they had an additional 20 seconds to solve the paired-anagram. The participants were not told they would have a second opportunity to solve the paired-anagram. The four other vignette-paired-anagram sequences were presented to the participants in a similar manner.

The continuous study group participants were presented with each vignette individually followed by a 40-second solution opportunity for the related paired-anagram. The solution opportunity was followed by the distracter tasks. Overall, the participants in the continuous study group received the same amount of time to solve the paired-anagram, but were not given a break from problem-solving. The distracter task was administered to keep the timing and fatigue factors similar in both the continuous study group and the incubation interval group.

Results

Mean scores were calculated for the number of words solved at the end of the first 20-second interval and the end of the second 20-second interval for the incubation interval condition, and after 20 seconds and the full 40 seconds in the continuous study condition. The maximum score was 5 for each time period. The mean number of solutions in the incubation interval condition was $M=1.44$ ($SD=1.25$) and $M=1.88$ ($SD=1.36$) words for the first and second intervals respectively. In the continuous study condition the means were 1.29 ($SD=1.08$) and 1.81 ($SD=1.19$) for the 20- and 40-second intervals respectively.

To assess mean differences for the number of words solved as a function of condition and time interval, a 2 (condition) \times 2 (time interval) repeated-measures ANOVA was conducted. Time interval served as the within-subjects factor. There was a significant main effect for interval $F(1,80)=36.78$, $p<.001$ with more words being solved by the end of the second interval. There was no main effect for condition, nor was there a significant interaction, largest $F(1,80)=.18$, $p>.7$. Overall, participants were able to solve more words when they had more time. However, there was no observed incubation effect.

Discussion

In this study the incubation effect found with paired-anagrams in Study 1 was eliminated. There are two means by which the incubation effect could be diminished. First, the break may have hindered problem-solving performance because it may have destroyed the benefits of the prime. If this were the case, then there would have been a difference between conditions, where those receiving a break would have performed less well than the continuous study group. This was not the case. Alternatively, the presentation of a prime at the beginning of study for both conditions may have facilitated problem-solving behavior to such an extent that optimal performance occurred during the first 20 seconds. To examine this we compared the mean performance in the first

20-second interval in Study 2 with the mean performance in the first 20-second interval in Study 1. In Study 2 performance at 20 seconds was two to three times higher than the 20-second interval performance in Study 1 and was similar to the final 40-second performance in Study 1. Priming participants with the story, therefore, facilitated performance early in the study session.

In summary, the current design demonstrated that hints provided prior to study facilitated problem-solving, but did not facilitate the experience of incubation. If the goal of the educator is to provide students with an opportunity to become engrossed with challenging problems and to see that they can solve problems even after reaching a block, then priming students at the onset of the task may not be the best practice. The question then becomes, should students only be given a break, or should we still consider hints as a facilitator to problem-solving performance? Although we demonstrated an incubation effect for a break on its own (Study 1), it is also possible that incubation can occur if hints are provided at some time other than prior to study. In Study 3 we explored this question.

Study 3

In Study 3 we investigated whether placing hints during the break would facilitate incubation effects. Three study conditions were compared. All students received a break and information during the break, but the content of the information varied. Some students received hints that were related to solution outcomes, some received hints that were likely to reinforce the mental set (i.e., mental block), and some received information that was unrelated to the solution outcomes. In all three conditions students were provided with a break from study. If a break alone is the only factor that yields incubation, then all groups will demonstrate incubation, and all groups will perform equally well. If providing hints is a factor, then we should expect differential solution performance among the groups. Based on the results of Studies 1 and 2 and earlier research where hints plus a break yielded optimal outcomes (Dreistadt, 1969), we expected that the break coupled with the hint that primes the solution would lead to incubation and optimal performance. If incubation occurs when students have an opportunity to break a mental set or block, then reinforcing the mental set during the break should inhibit performance relative to either exposure to unrelated hints or hints that prime the solution. Determining how best to manipulate breaks and hints would have important implications for educators in terms of identifying strategies that would facilitate problem-solving performance.

Method

Participants

A total of 105 participants (78 women and 27 men) were recruited from an introductory psychology subject pool at the same Canadian university as in Study 2. Their average age was 21.4 years ($SD=5.9$), and all participants spoke English as their first language. Participants received bonus marks for their participation.

Materials and Procedure

The participants were tested individually. All testing was conducted at a computer terminal. The participants were seated comfortably at the computer and

began the task by completing a brief demographic measure about age, sex, and first language. After completing demographic information, they were told that a paired-anagram would appear on the computer screen and that they had 20 seconds to try to come up with the solution.

Following the presentation of the first paired-anagram, a vignette would appear on the computer screen. The vignette was read aloud by the researcher and the participants were instructed to follow along. After the vignette was read, the paired-anagram was presented for another 20 seconds. The participants were not told that they would have a second opportunity to solve the paired-anagram. The remaining four paired-anagrams-vignette sequences were presented in the same manner. All paired-anagrams were the same as those used in Study 1 and Study 2.

There were three conditions. In condition 1, the vignette reinforced the mental set. For example, following the presentation of the paired-anagram PIERCE, the participants read a vignette about medieval battles waged with swords. Although the word PIERCE did not appear in the vignette, eight synonyms (two of which appeared twice) were used to reinforce the word PIERCE (i.e., stab, puncture, penetrate).

In condition 2, the vignettes primed the solution to the paired-anagram, and these vignettes were the same as those presented in Study 2. For example, following the 20-second presentation of the paired-anagram PIERCE, the participants in condition 2 read the vignette about the cook preparing a meal with synonyms priming the solution RECIPÉ.

In condition 3 the vignettes were unrelated stories (i.e., the solution to the paired-anagram was neither primed nor reinforced).

In all three conditions the length of the stories was consistent between the conditions, with variability in length across the sets. Participants were randomly assigned to one of the three conditions with equal proportions of men and women in each condition. The entire procedure lasted approximately 30 minutes for each participant.

Results

A 2 (time interval) \times 3 (condition) repeated-measures ANOVA was conducted to assess differences in the number of solutions to the paired-anagrams as a function of condition. The time interval served as the repeated measure, and the condition was the between-subjects factor.

There was a significant main effect for the time interval $F(1,102)=59.29$, $p<.001$ and for the condition $F(2,102)=4.27$, $p<.02$. More solutions were generated after 40 seconds than after 20 seconds, and more solutions were generated for the condition where the vignette primed the solution than either of the other two conditions. These main effects, however, were qualified by a significant interaction of time interval by condition $F(2,102)=19.4$, $p<.001$. Tukey B post-hoc tests revealed no differences among the three conditions at the first 20-second interval, but more solutions were generated by the participants in the condition that primed the solution ($M=1.9$ $SD=1.4$) at the second time interval than in any of the other two conditions ($M=.89$ $SD=1.02$; $M=.71$, $SD=.99$) for the mental set and unrelated vignette conditions respectively.

Discussion

Overall, incubation was evident in all three conditions; more problems were solved at the end of 40 seconds than at the end of 20 seconds. As expected from past research (Dreistadt, 1969), providing hints that led to the solution during the break produced the largest performance gains. Interestingly, simply having a break was not sufficient to optimize problem-solving. In fact receiving unrelated hints was no better than having hints that reinforced the mental set. With respect to past literature, these results support the suggestion that providing breaks does promote incubation (Peterson, 1974), but the results also support the literature that finds that the combination of breaks plus helpful hints not only encourages incubation, but does so more effectively than solely providing breaks (Dominowski & Jenrick, 1972). Although it was anticipated that reinforcing the mental set might further detract from performance relative to providing unrelated hints, even when the hint reinforced the mental set there was incubation. It appears that providing a simple break from the individual's own problem-solving behavior or routines was sufficient to provide some level of incubation.

In summary, these findings are especially important given that the optimal hints did not actually feature the solution; instead they primed the learner in the right direction. Clearly, for learning to be maximized the content of hints and the placement of hints must be considered together.

General Discussion

Incubation has been connected to variables such as creativity (Mednick, Mednick, & Mednick, 1964) and general problem-solving (Smith & Blankenship, 1989), suggesting that it may be important to foster opportunities for students to experience incubation. It is possible to achieve incubation, but not on every kind of task and not in every context. These studies demonstrate that incubation can be produced reliably and that interventions (hints) can promote incubation for learners. In an educational context these outcomes can be translated as follows. To promote incubation, students should be provided with challenging problems with an opportunity to work independently on the problems, followed by a break interval, and then followed by an additional study period. To maximize solution success the break should provide students with hints that direct them toward the correct solution. Clearly the present studies provide a foundation for understanding how to facilitate incubation in the classroom setting.

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