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Priming and incubation effects on anagram solving

Katharine K. Lee
San Jose State University

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Lee, Katharine Kai, M.A.

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300 N. Zeeb Rd.
Ann Arbor, MI 48106

PRIMING AND INCUBATION EFFECTS ON ANAGRAM SOLVING

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by

Katharine K. Lee

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APPROVED FOR THE DEPARTMENT OF PSYCHOLOGY

Kevin Jordan, Professor of Psychology, Thesis Chairperson

Robert Cooper, Professor of Psychology

Laree A. Huntsman, Assistant Professor of Psychology

APPROVED FOR THE UNIVERSITY

Serena K. Stanford

ABSTRACT

PRIMING AND INCUBATION EFFECTS ON ANAGRAM SOLVING

By Katharine K. Lee

Numerous mechanisms have been attributed to incubation, which describes the phenomenon of successful problem-solving following a break in problem-solving effort. This study attempted to elicit incubation effects in anagram-solving and contrast two hypotheses of incubation mechanisms. The Memory-Sensitization Hypothesis attributes incubation to spreading activation; during the incubation break, encounters with incidental stimuli trigger the correct solution. The Forgetting-Fixation Hypothesis attributes solution failure to fixation upon inappropriate solutions; forgetting of such solutions during the incubation break reveals the correct solution. The results of this study did not provide evidence for the existence of incubation. There was no improvement in performance with increased incubation time. The results do provide some support for the action of spreading activation over that of forgetting mechanisms in problem-solving. Important methodological issues remain to be addressed before incubation can be ruled out as a problem-solving device.

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Priming and Incubation Effects on Anagram Solving

Katharine K. Lee

San Jose State University

Running Head: INCUBATION EFFECTS AND ANAGRAMS

Footnote

Request for reprints should be sent to Katharine K. Lee, Department of Psychology, San Jose State University, San Jose, CA 95192

Abstract

Numerous mechanisms have been attributed to incubation, which describes the phenomenon of successful problem-solving following a break in problem-solving effort. This study attempted to elicit incubation effects in anagram-solving and contrast two hypotheses of incubation mechanisms. The Memory-Sensitization Hypothesis attributes incubation to spreading activation; during the incubation break, encounters with incidental stimuli trigger the correct solution. The Forgetting-Fixation Hypothesis attributes solution failure to fixation upon inappropriate solutions; forgetting of such solutions during the incubation break reveals the correct solution. The results of this study did not provide evidence for the existence of incubation. There was no improvement in performance with increased incubation time. The results do provide some support for the action of spreading activation over that of forgetting mechanisms in problem-solving. Important methodological issues remain to be addressed before incubation can be ruled out as a problem-solving device.

Priming and Incubation Effects on Anagram Solving

The incubation process describes an initial unsuccessful attempt at problem-solving which later becomes successful following a break in problem-solving effort. The experience of Poincaré, the French mathematician, is often cited in the psychology literature as an example of incubation's successful effects (Anderson, 1990; Dreistadt, 1969; Olton, 1979; Yaniv & Meyer, 1987). Poincaré reportedly was able to derive the solution to a complex mathematical problem by dissociating himself from active work on the problem (Anderson, 1990; Dreistadt, 1969).

Unfortunately, incubation is a phenomenon that is not easily produced or reproduced in the laboratory setting, despite its common-sense application in everyday life. The experimental literature provides inconsistent support for the phenomenon and the existence and prevalence of incubation continues to be contested. Guilford (1979) stated that there is "no doubt that mental incubation is a genuine phenomenon and that it plays an important role in creative problem-solving" (p. 1). Olton (1979), however, has reported difficulty in reproducing the incubation effects observed by previous researchers; in fact, failure to find incubation effects are more common than the experimental evidence in favor of incubation. When incubation is observed, Olton has suggested that the experimental evidence is unreliable. Browne and Cruse (1988) asserted that the inability to replicate incubation results is consistent with the elusive nature of the phenomenon.

Most studies of incubation focus on the incubation period and what mechanisms may operate during that period to produce later problem-solving success. Incubation is depicted as undirected behavior which does not require direct attention. Olton and D. M. Johnson (1976) and Guilford (1979) have suggested that incubation involves processing that is outside conscious control. This description seems to view the processing in a

different light than that of the prevailing cognitive view of problem-solving, which portrays problem-solvers as more deliberate, constructive, and planful in information processing (Howard, 1983). To understand how such a model of undirected problem-solving could be reconciled with a more active view of information processing provides the impetus for examining the mechanisms which may drive incubation.

Olton and D. M. Johnson (1976) described four mechanisms that reflect the non-intentional nature of processing believed to be associated with incubation: set-breaking, selective forgetting, unconscious mental work, and facilitating effects of incidental stimuli encountered during the incubation break. Recently, two theories of incubation effects have been derived using these four mechanisms. The first theory, proposed by Yaniv and Meyer (1987), is called the Memory-Sensitization Hypothesis and has combined the components of unconscious mental work and facilitation by incidental stimuli. The second hypothesis, proposed by Smith and Blankenship (1989), is called the Forgetting-Fixation Hypothesis and combines the components of set-breaking and selective forgetting. By utilizing anagrams, the problem-solving experiment described in this paper attempts to examine the mechanisms associated with incubation effects and attempts to contrast the Memory-Sensitization and Forgetting-Fixation Hypotheses.

The Memory-Sensitization Hypothesis

The Memory-Sensitization Hypothesis suggests that incubation arises from the effects of unconscious mental work and facilitation by incidental stimuli. Yaniv and Meyer (1987) have proposed that when a solution is not successfully accessed from memory, it is insufficiently activated. Unconscious mental work maintains the solution's retrievability. During the incubation break, the solution is triggered by contact with serendipitous information.

Unconscious mental work can be depicted as the "oldest" theory of incubation

(Guilford, 1979; Helmholtz, cited in Dreistadt, 1969; Olton & D. M. Johnson, 1976). This form of unconscious mental work describes the conscious mind setting aside the problem and the unconscious mind taking over to reach the solution. Such unconscious effort implies the concept of spreading activation.

Spreading activation describes a theory of memory organization. In this memory structure, concepts are represented by nodes, and related concepts (or concepts sharing the same properties) are connected to one another via links (Anderson, 1990; Collins & Loftus, 1975; Masson, 1991). During a memory search, activation is initiated from concept nodes and spreads until an intersection is reached (Collins & Loftus). The presentation of the word-concept dog could be expected to lead to the activation of related concept nodes such as bone, cat, and pet. Collins and Loftus stated that the magnitude of the spreading activation is directly related to the strength of links between concept nodes and inversely related to the number of links.

According to Yaniv and Meyer (1987), the incubation interval is advantageous for it provides the opportunity to encounter the problem's solution in another setting. This is the effect of facilitating incidental stimuli, which is consistent with Collins and Loftus' (1975) depiction of memory search. The longer the incubation interval, the more likely a solution could be encountered in another form (Browne & Cruse, 1988). Kubose and Umemoto (1980) proposed that problem-solving efforts prior to incubation lead to more selective perception. Therefore, after having worked on a problem for some time with no success, the problem-solver may be more sensitive to analogies to the problem and its solution in otherwise irrelevant stimuli.

Yaniv and Meyer's experiment (1987) combined a difficult-word retrieval task with a lexical decision task. Subjects were presented with the definitions of difficult words. A sample definition used was "large, bright, colored handkerchief...usually worn round the

neck" (Yaniv & Meyer, p. 192). Subjects were asked to provide the word which fit this definition. For this example, the correct target word was "bandanna."

Following the definition task, subjects were presented with a series of letter strings and asked to judge whether these strings were words or non-words. One of the strings presented was the intended target word of the definitions task. The reaction time to decide whether a letter string was a word or non-word was the dependent variable. A second experiment was conducted which repeated the basic methods of the first experiment, but in addition, required subjects to judge whether or not a series of words had been presented in the first part of the experiment.

Yaniv and Meyer (1987) determined that lexical decisions were significantly faster for target words than for control words when the target word was recalled in the definitions task. They also determined that words were responded to more quickly when their definitions had been previously presented. Yaniv and Meyer suggested that there is some internal monitor involved in overseeing the status of "temporarily suspended endeavors and maintains...extra activation in their memory traces until they have been completed" (p. 200). They suggested that the solution is therefore maintained at a sub-threshold level, and is more readily activated upon contact with the appropriate incidental stimuli.

In summary, the Memory-Sensitization Hypothesis proposes that unsolved problems remain active in memory and that during incubation, problem-solvers are sensitized to detect the proper solution (Yaniv & Meyer, 1987). Stimuli related to the problem's solution thus have a better chance of activating the solution to the threshold level.

The Forgetting-Fixation Hypothesis

Smith and Blankenship (1989) have proposed that incubation allows subjects to simply forget their unproductive search attempts from the initial problem-solving phase.

The initial problem-solving failure is attributed to fixation upon inappropriate solutions. Over time, as the memory trace from the unproductive searches fades, the remaining solution attempts are more apparent and the problem-solver can sort through them to uncover the initially obscured solution. Set-breaking, or release from the initial fixation, could thus be responsible for incubation effects. This proposed model is consistent with a Gestalt model of problem-solving, in which the incubation period allows problem solvers to free themselves from "mental impediments" to correct solutions (Browne & Cruse, 1988, p. 179) and perceive the solution to a problem in a flash of insight, rather than in generating a solution from problem-solving components (Browne & Cruse, 1988; Dreistadt, 1969; Gardner, 1985; Weisberg & Alba, 1981).

Smith and Blankenship's (1989) experiment induced fixation in their subjects with misleading cues accompanying a rebus problem. Rebuses are word forms which represent other words or phrases. For example, the rebus "tim ing" represents the phrase "split second timing" as the word "timing" is split into two parts. In Smith and Blankenship's experiment, a rebus used was "you just me." A misleading cue presented with this rebus was the word "beside." The correct solution to this rebus is "just between you and me."

Following an initial presentation of rebuses, a retest of unsolved rebuses showed that subjects who experienced periods of incubation prior to retest were able to achieve more correct solutions relative to subjects who did not undergo a period of incubation (and were immediately retested). Following the rebus task, subjects were asked to recall the previously presented cues. The results indicated that with incubation, the improvement in performance was correlated with the forgetting of the initially-presented, misleading cues. Thus Smith and Blankenship concluded that incubation enables the problem-solver to forget the incorrect solution attempts, and uncover the correct solutions as predicted by

the Forgetting-Fixation Hypothesis.

Comparison of the Memory-Sensitization and Forgetting-Fixation Hypotheses

Both hypotheses are based on studies investigating word-identification problems and both hypotheses portray the incubation process as a passive contributor to problem-solving. The hypotheses differ, however, on the nature of this effect. The Memory-Sensitization Hypothesis suggests that a proper solution is not fully activated (i.e., it is at a sub-threshold level) when subjects are initially unable to solve a problem. The incubation interval presumably contains some chance information needed to activate the solution. Unsuccessful solution attempts are not addressed by the Memory-Sensitization Hypothesis. Possibly, if subjects generated many (incorrect) solutions, spreading activation from the definitions presented would act to reject the incorrect solutions and lead to the correct one.

The Forgetting-Fixation Hypothesis suggests that initial problem-solving failure may be due to fixation effects. The correct solution may be available, and even activated, but it is obscured by fixation upon incorrect targets. To reveal the proper solution, forgetting of inappropriate solution attempts must occur.

Solving Anagrams

To contrast the mechanisms proposed by the two hypotheses, an experiment was conducted using anagrams as the problem-solving task. Anagrams are words with their letters scrambled; for example, the anagram BPOLMER represents the word "problem." Like the difficult-word retrieval problems presented by Yaniv and Meyer (1987) and the rebus problems presented by Smith and Blankenship (1989), anagram-solving is also a word-related activity. However, anagram-solving has advantages as a problem-solving task over the tasks used by Yaniv and Meyer and by Smith and Blankenship. Solving anagrams involves the unscrambling of letters to make a word. If anagram-solving is

unfamiliar to some subjects, it may not be a difficult task to learn. In addition, assuming that the word frequencies of the anagrams are sufficiently high, most subjects should be able to solve the anagrams. The anagrams used in this experiment were derived from high frequency words (100-250 instances per million words) to reasonably ensure subject familiarity with the solution words. Frequency of anagram words have been found to influence anagram solution time; higher word frequency anagrams are solved more quickly than lower word frequency anagrams (D. M. Johnson, 1966; Ronning, 1965).

In contrast, Yaniv and Meyer's (1987) task of difficult word retrieval depends greatly on subjects' lexicons; the task is not one in which subjects can develop a problem-solving strategy. If a subject did not previously know the difficult word (or its definition) that was presented, s/he would not be able to figure it out later. The range of target word frequencies used by Yaniv and Meyer was 0.22-22 instances per million words.

Smith and Blankenship's (1989) rebuses pose a similar difficulty as a problem-solving activity. Solving rebuses relies upon prior knowledge of idiomatic expressions, and involves a problem-solving behavior that is not common to many tasks subjects may have experienced.

Furthermore, problems that rely on incidental knowledge of difficult words or idiomatic expressions are dissimilar to the types of problems in which we expect incubation to assist. Specifically, if we lack the resources to solve a problem, it would seem unreasonable that we could solve the problem given a mere break from the attempt. Incubation may be most beneficial to those problems in which we are somehow able to generate a solution. In comparison, anagrams are not an unusual challenge in terms of the skill level and prior knowledge needed to solve the problem and they can, in theory, be solved by all subjects, given adequate time and word frequencies.

Anagrams have been used as stimuli in previous studies to examine properties of

problem-solving and lexical organization (D. M. Johnson, 1966; Richardson & P. B. Johnson, 1980; White, 1988). Anagrams have features that are fairly easy to manipulate (such as word length, or the way the anagram is scrambled) thus making them a flexible problem for study. Additionally, anagrams are well-defined problems; they have a definite starting and ending point, and they can generate a basic problem-solving behavior (unscrambling letters).

One variable that has been found to affect anagram solution time is the use of a cue or prime, which may hint at the category to which a solution belongs. Research with anagram-solving and other lexical decision tasks (Becker, 1980, 1985; Ekstrand & Dominowski, 1965; Safren, 1962; Seidenstadt, 1982) has shown that a related prime induces a search into the surrounding concept area, reducing solution time relative to the presentation of an unrelated prime. In the first part of this experiment, anagrams were paired with either related or unrelated primes.

Experiment Overview and Predictions

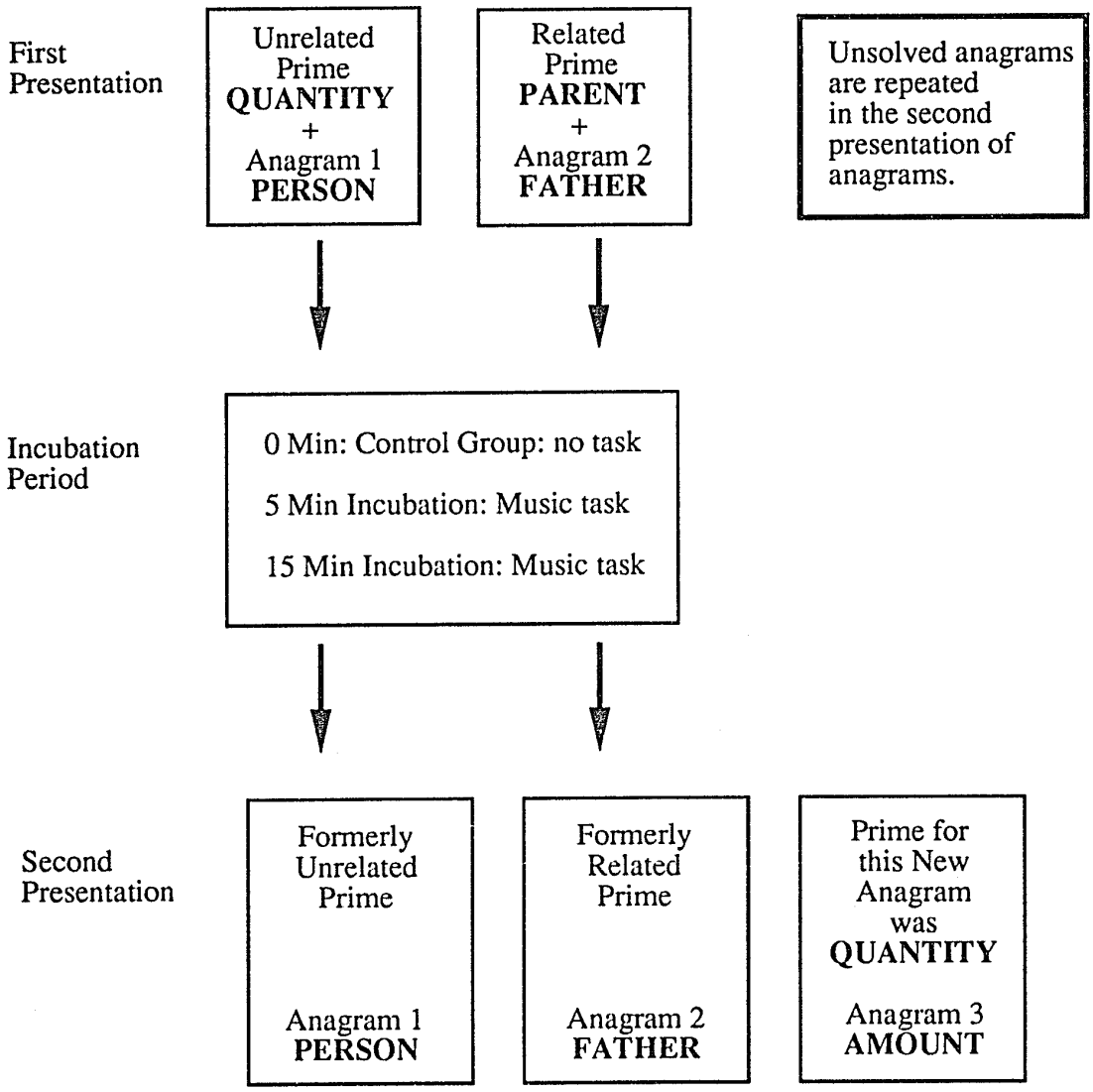
The experiment contrasted the Memory-Sensitization and Forgetting-Fixation Hypotheses of incubation effects using anagrams and manipulating the relatedness of the primes. Subjects were randomly assigned to three incubation conditions: 0 min incubation (control), 5 min incubation, and 15 min incubation. These times were the same as those employed by Smith and Blankenship (1989).

The anagrams appeared twice in this experiment. In the first presentation, the anagrams were paired with related or unrelated primes. Following the incubation periods, anagrams were presented a second time, but without primes. These anagrams were unsolved anagrams from the first presentation, as well as new anagrams (which had not appeared in the first presentation). The primes for the new anagrams had been formerly paired with unrelated anagrams in the first presentation. Following the second

presentation of anagrams, subjects were asked to recall as many primes from the first presentation as they were able.

The Memory-Sensitization Hypothesis predicts that spreading activation is responsible for solution success and that insufficient activation is responsible for solution failure. According to this hypothesis, spreading activation should occur in response to all primes presented, regardless of the prime's relatedness to the anagram. Thus, during the second presentation, the new anagrams (which had never been seen before) would be expected to have solution times comparable to those anagrams that had been previously presented with related primes. The reasoning is that both the related- and new-anagrams had their primes presented prior to incubation. Those anagrams first paired with unrelated primes, however, never had appropriate, related cues provided, and thus they should be comparatively more difficult to solve. Figure 1 provides a schematic illustration of the experimental overview and the predictions under this hypothesis.

The Forgetting-Fixation Hypothesis predicts that subjects become fixated upon unsuccessful solution attempts while they are trying to solve a problem and that the unsuccessful attempts are forgotten during incubation. Under this hypothesis, all primes associated with the unsuccessful attempts should be forgotten, regardless of prime type. There would be no reason for the subjects to remember the related versus the unrelated primes, since they would not know the underlying relationship of the primes and anagrams. Since all primes are presumed forgotten, the new anagrams (whose primes were previously paired with unrelated anagrams) should not be solved any faster than anagrams initially presented with related primes. Over time, however, an interaction between incubation condition and anagram condition should be observed. There should be increased forgetting with increased incubation time. Thus, with increasing incubation time, the three anagram conditions should become more similar in solution time. Again,



Predictions

Memory-Sensitization Hypothesis: Anagram 2 and Anagram 3 should be solved more quickly than Anagram 1, since Anagram 1 was never primed. Anagram 2 should be solved either more rapidly than, or equally rapidly as Anagram 3.

Forgetting-Fixation Hypothesis: As all primes are presumed forgotten, there should be an interaction between anagram condition and incubation condition. In the control condition, Anagram 1 will be solved faster than Anagram 2 and Anagram 3. This difference should dissipate with increased incubation time.

Figure 1. Experimental procedure and predictions.

see Figure 1 for an illustration of the predictions under this hypothesis.

A music perception task was used during the incubation period to control for the facilitation effects of incidental stimuli. Smith and Blankenship (1989) utilized such a task in the incubation period of their study, and found that the task was engrossing and demanding to their subjects, yet did not significantly affect problem-solving performance. Smith and Blankenship told their subjects to listen to instrumental music selections and asked the subjects questions about the music. There were two main reasons for providing this intervening task during incubation. First, it was intended to be distracting, preventing the subjects from actively recalling or rehearsing the primes or the anagrams during the incubation period. Second, the music task was intended to prevent subjects from encountering widely varying stimuli that could trigger correct solutions.

To measure forgetting, following the second anagram presentation, subjects were asked to recall the primes from the first presentation. Both Yaniv and Meyer (1987) and Smith and Blankenship (1989) had some form of recall task at the end of their experiments. Yaniv and Meyer asked subjects to judge whether words presented at the end of the experiment had been seen before. Smith and Blankenship asked subjects to recall the clues presented with the rebus task. Greater forgetting is expected to be associated with greater problem-solving success under the Forgetting-Fixation Hypothesis. The Memory-Sensitization Hypothesis does not specifically suggest that primes would be forgotten, but based on spreading activation, it would stand to reason that less forgetting would be associated with greater problem-solving success.

This experiment employs anagrams with a priming condition, like previous anagram studies (Ekstrand & Dominowski, 1965; Safren, 1962; Seidenstadt, 1982; White, 1988). This experiment differs from the earlier studies by presenting misleading primes which are cues to anagrams presented in a subsequent presentation. Misleading cues have been

used before in anagram experiments (White, 1988), but such experiments did not examine the effects of the misleading cues on later problem-solving. The use of anagrams also distinguishes this study from other incubation studies, which have employed a variety of problem-solving tasks, such as word-association problems (Patrick, 1986) and the Farm Problem, in which an L-shaped figure is to be divided into 4 equal sections (Browne & Cruse, 1988; Dreistadt, 1969).

Method

Subjects

Subjects were 42 undergraduate students (22 females and 20 males) from the subject pool of the San Jose State University Psychology department. Subjects participated in the experiment in partial fulfillment of course requirements. All subjects were native speakers of English.

Stimuli

The anagrams used were 6 letters in length. The anagrams were selected from a word frequency range of 100-250 instances per million words (Kucera & Francis, 1967). The words were scrambled with the aid of a random number table and according to the following two provisions: 1) that no letter of the anagram appear in its correct place in the target word and 2) that no letter of the anagram be immediately preceded or followed by a letter that immediately preceded or followed it in the actual target word. Words that had too many letters repeated (e.g., INDEED, STRESS) were not selected as they were virtually impossible to scramble under the above criteria. Words that were proper nouns, plural forms, and verb forms also were not selected.

A total of 40 anagrams were randomly assigned to one of three groups: related, unrelated, or new. Fifteen anagrams each were assigned to the related and unrelated groups and ten anagrams were assigned to the new group. They were then paired with

related or unrelated primes, accordingly. The primes for the anagrams were chosen with the use of a thesaurus and/or a dictionary. The first ten anagrams of the unrelated group were paired with primes related to the new anagrams. The remaining five anagrams of the unrelated group received primes not related to any other stimuli in this experiment.

Manipulation Check

To check the relatedness of the anagram-prime pairs, each word pair was rated on a 5-point Likert-type scale where 1 signified not at all related and 5 signified very highly related. Raters were four graduate-level students in psychology who had an interrater reliability of $\alpha = .86$. Word pairs that were classified as related had an average rating of 4.18 (SD = 0.40); in only 2 cases did a word pair fall below a "3" rating. Word pairs that were classified as unrelated had an average rating of 1.14 (SD = 0.10); in only one case did a word pair exceed the "3" rating.

Apparatus and Procedures

All stimuli were presented via VGA computer monitor and all data were collected on an IBM-PC compatible computer. A computer program (Tu, 1993) presented the primes and anagrams and collected the subject response times and the recalled primes at the end of the experiment. Subject responses were input via keyboard entries.

Subjects were randomly assigned to one of three incubation conditions: 0 min incubation (control group), 5 min incubation, or 15 min incubation. The three conditions were counterbalanced. For all conditions, subjects were read instructions for the first anagram presentation. Subjects were first presented with 30 anagram and prime pairs (15 related primes, 15 unrelated primes) in random order. They were given 30 s to solve each anagram and if the anagram was not solved, the solution was not provided. At the end of the first trial of 30 anagrams, the control subjects were provided with about a one min break while instructions to continue were read to them. Then the second group of

anagrams were presented, this time without primes. Again, up to 30 s was allotted to solve each anagram. The second group of anagrams consisted of 10 of the unsolved, related-group anagrams, 10 of the unsolved, unrelated-group anagrams, and 10 new anagrams. After solving each anagram, or once time expired, the subjects were asked if they thought they had seen these anagrams before and to indicate their response with a Y or an N keypress.

In the 5-min and 15-min conditions, subjects participated in a music perception task for 5 or 15 min before the second anagram presentation. The music perception task consisted of listening to taped instrumental piano music. The subjects were instructed to think about the following questions: 1) how the music made them feel, 2) what they could guess about the identity of the music, and 3) what the music brought to mind. These were the same questions used in Smith and Blankenship's (1989) experiment.

Following the music task, the incubation-condition subjects were read the retest instructions (the same as those read to the control group) for the second anagram presentation. The remainder of the experimental procedure was the same as for the control group (described above).

At the end of the second anagram presentation, all subjects were instructed to type on the computer screen as many of the primes as they could recall from the first anagram presentation. They were given up to 5 min to do this task.

Following the recall task, subjects were debriefed, shown the solutions to the anagrams if they wished to view them, and excused.

Results

Data Removed from Analysis

After collecting data from the first six subjects, it was discovered that one of the stimuli had multiple solutions. This word (RESULT, which could be rearranged to spell

"LUSTER" or "ULSTER") was removed from the stimulus pool and replaced by another word. The cases which included this word were removed from the data of the first six subjects. A second stimulus word, RETURN, was also removed from the analyses as it appeared in the instructions on the computer ("Press RETURN to continue"). All subjects were exposed to this word, so it was removed from all subjects' data.

First Anagram Presentation

Table 1 presents the mean solution times across the three incubation conditions (0 min, 5 min, and 15 min) and by prime type (related or unrelated) for the first anagram presentation. To assess whether there were any differences among groups prior to incubation, a 3 (incubation condition) x 2 (prime type) mixed ANOVA was conducted on the solution times for the first presentation data. Incubation condition was the between-subjects factor. There was no significant effect found for the interaction [$F(2,33) < 1$]. There was also no significant main effect of incubation condition [$F(2,33) < 1$], which demonstrated that there were no significant differences between the incubation groups prior to the incubation period. There was a significant within-subjects effect of prime type [$F(1,33) = 38.8, p < .001$]. As expected, related primes produced significantly shorter solution times than unrelated primes.

Table 2 lists the percent-solved anagrams by incubation condition in the first presentation. A one-factor ANOVA, with percentage of solved anagrams as the dependent variable and incubation condition as the independent variable revealed no significant differences between incubation conditions [$F(2,39) = 1.69, p > .05$].

Table 3 lists the percent-solved anagrams by prime type. A one-factor ANOVA, with percentage of solved anagrams as the dependent variable and relatedness as the independent variable, further confirmed the advantage of related-prime anagrams solved over that of unrelated-prime anagrams [$F(1,82) = 107.2, p < .001$]. Subjects solved

Table 1

Presentation 1 (Before Incubation) Mean Solution Times (in seconds) by Incubation Condition and Prime Type

	Incubation Condition[a]		
	0 Minutes	5 Minutes	15 Minutes
Prime Type[b]	M (SD)	M (SD)	M (SD)
Related	12.49 (2.56)	12.07 (4.23)	12.83 (3.25)
Unrelated	19.73 (5.12)	17.85 (3.82)	17.45 (4.92)

Note. [a]There was no significant interaction between incubation condition and prime types, nor was there a significant main effect of incubation condition. [b]There was a significant within-subjects effect of prime type [$F(1,33) = 38.8$, $p < .001$].

Table 2

Presentation 1 (Before Incubation) Mean Percentage of Solved Anagrams by Incubation Condition

Incubation Condition	Mean Percent-Solved	Standard Deviation
0 Min. (Control)	26.69	14.19
5 Min.	30.22	12.90
15 Min.	36.34	14.95

Note. No significant effect of incubation condition upon percentage of solved anagrams.

Table 3

Presentation 1 (Before Incubation) Mean Percentage of Solved Anagrams by Prime Type

Prime Type	Mean Percent-Solved (N)	Standard Deviation
Related	48.49 (42)	17.30
Unrelated	12.57 (42)	14.35

Note. Significant effect of prime type upon percentage of solved anagrams [$F(1,33) = 38.8$, $p < .001$].

significantly more related-prime anagrams than unrelated-prime anagrams.

Second Anagram Presentation

For the second presentation of anagrams, it was anticipated that 10 anagrams in each of the related, unrelated, and new groups would be presented, resulting in a total of 30 anagrams presented after the incubation period. This would have required subjects to solve five or fewer of the anagrams in each of the related and unrelated groups. However, the actual number of anagrams presented across all the subjects was unequal because there were subjects who solved more than five anagrams from either or both of the related and unrelated groups in the first presentation. The range of anagrams presented following the incubation period was 18 to 30, with a mean of 27.

Table 4 presents the means and standard deviations of solution times in the second presentation, across incubation conditions and prime types (related, unrelated, and new). A 3 (incubation condition) x 3 (prime type) mixed ANOVA was conducted on the solution times for the second presentation. Incubation condition was the between-subjects factor. There was no significant effect found for the interaction [$F(4,32) < 1$]. There were also no significant main effects of incubation condition [$F(2,16) < 1$] or of prime type [$F(2,32) < 1$], demonstrating that incubation did not benefit anagram solving.

Table 5 presents the mean percent-solved anagrams in the second presentation, across incubation conditions and prime types. A 3 (incubation condition) x 3 (prime type) mixed ANOVA was conducted on the percent-solved anagrams for the second presentation. Incubation condition was the between-subjects factor. There was no significant interaction [$F(4,78) < 1$] or main effect of incubation condition [$F(2,39) = 2.44$, $p > .05$], again indicating no benefit to incubation upon problem-solving success. There was a significant effect of prime type [$F(2,78) = 14.07$, $p < .05$]. There were no further analyses conducted to examine this main effect, as these results do not present any

Table 4

Presentation 2 (After Incubation) Means and Standard Deviations of Solution Times Across Incubation Condition and Prime Type

	Incubation Condition		
	0 Minutes	5 Minutes	15 Minutes
Prime Type	M (SD)	M (SD)	M (SD)
Related	19.64 (3.44)	15.78 (8.38)	16.57 (5.61)
Unrelated	16.21 (6.69)	15.97 (7.91)	14.59 (6.73)
New	16.92 (7.43)	15.38 (3.98)	14.11 (3.06)

Note. No significant differences in solution time across incubation conditions and prime types.

Table 5

Presentation 2 (After Incubation) Means and Standard Deviations of Percent Solved Anagrams Across Incubation Condition and Prime Type

	Incubation Condition[a]		
	0 Minutes	5 Minutes	15 Minutes
Prime Type[b]	M (SD)	M (SD)	M (SD)
Related	10.16 (10.41)	14.64 (10.98)	9.91 (13.80)
Unrelated	12.21 (11.69)	20.71 (17.62)	18.06 (21.51)
New	19.29 (19.79)	32.86 (15.90)	31.43 (17.48)

[a]There was no significant interaction between mean percent-solved anagrams across incubation conditions and prime types. There was also no significant main effect of incubation condition. [b]There was a significant within-subjects main effect of prime type [$F(2,78) = 14.07$, $p < .05$].

information about incubation mechanisms. The results do, however, suggest that the new anagrams appear to be solved with greater success than the related and unrelated anagram types; this finding implies the action of spreading activation, thus supporting the mechanisms proposed by the Memory Sensitization Hypothesis over those of the Forgetting Fixation Hypothesis. This will be further explored in the Discussion.

Recall of Primes

Table 6 shows the percentage of recalled primes whose corresponding anagrams were solved, broken down by related or unrelated prime type. A 2 (prime type) x 3 (incubation condition) mixed ANOVA was conducted on the percentage of recalled primes whose anagrams were solved. Incubation condition was the between-subjects factor. There was no significant interaction [$F(2,26) < 1$], nor was there a significant effect of incubation condition [$F(2,26) = 1.24$, $p > .05$]. These results do not support the existence of incubation effects. However, there was a significant effect of prime type. The percentage of recalled, related primes whose anagrams were solved was greater than the percentage of recalled, unrelated primes whose anagrams were solved [$F(1,26) = 52.55$, $p < .001$]. This again provides some support for spreading activation mechanisms proposed by the Memory-Sensitization Hypothesis.

Recognition of Anagrams

Table 7 describes the distribution of anagrams in the second presentation that were recognized as having been previously presented and whether or not the anagrams were solved. No significant χ^2 relationship was noted [χ^2 (1, $N = 1119$) < 1, $p > .05$], demonstrating a lack of association between solution success and forgetting.

Table 8 describes the frequencies of anagrams correctly identified as previously presented, across incubation conditions. There was no significant χ^2 relationship between correctly identified anagrams and increasing incubation time [χ^2 (1, $N = 1145$)

Table 6

Percentage of Recalled Primes Whose Corresponding Anagrams Were Solved, by Prime Type

	Prime Type[b]	
	Related	Unrelated
Incubation Condition[a]	Mean (SD)	Mean (SD)
0 Minutes	65.00 (35.54)	10.00 (21.08)
5 Minutes	70.46 (30.13)	9.64 (20.63)
15 Minutes	79.16 (39.60)	31.25 (45.81)

[a]There was no significant interaction in mean percentage of recalled primes across incubation conditions and across prime types. There was also no significant main effect of incubation condition. [b]There was a significant within-subjects main effect of prime type [$F(1,26) = 52.55$, $p < .05$].

Table 7

Frequencies of Anagrams Correctly Solved and Recognized as Previously Presented

	Anagram Solved	
Anagram Recognized	Solved	Not Solved
Yes	105	456
No	113	445

Note. Chi-Square statistic not significant [χ^2 (1, N = 1119) < 1, p > .05].

Table 8

Frequencies of Anagrams Correctly Recognized as Previously Presented Across Incubation Condition

Anagram Identification	Incubation Condition		
	0 Minutes (Control)	5 Minutes	15 Minutes
Correct	247	274	249
Incorrect	137	113	125

Note. Chi-Square statistic not significant [$\chi^2(1, N = 1145) = 3.79, p > .05$].

= 3.79, $p > .05$]. This result does not support a relationship between forgetting previously presented information and incubation time.

Discussion

First Presentation Results

The three incubation groups did not differ significantly in anagram-solving performance prior to the incubation periods, as indicated by the first presentation analyses. The significant difference in the percentage of related-prime anagrams solved over that of the unrelated-prime anagrams is evidence that subjects were attending to the primes. As in previous anagram studies, solution times to solve related-prime anagrams were significantly shorter than solution times to solve the unrelated-prime anagrams (Becker, 1980, 1985; Ekstrand & Dominowski, 1965; Safren, 1962; Seidenstadt, 1982).

No Support for Incubation Effects

Based on the analyses conducted in this study, there is no support for problem-solving benefits with incubation. Overall, incubation did not appear to improve problem-solving efficiency. There was no improvement in performance with increased incubation time, as measured by solution time or percentage of solved anagrams. The overall effect of prime type upon solution success was carried throughout the second presentation results. There was a significant within-subjects effect of prime type in percentage of solved anagrams; this suggests that the new anagrams were solved at a greater percentage than the previously unsolved, related and unrelated anagram types. This result is useful for contrasting the mechanisms proposed by the Memory-Sensitization and Forgetting-Fixation Hypotheses, but does not provide evidence for incubation.

There were no significant differences in the recall of primes corresponding to solved anagrams. The recall of primes results did reveal a significant within-subjects effect of prime type; the related primes recalled were associated with more solved anagrams than

were the unrelated primes recalled. This also has some implications for contrasting the Memory-Sensitization and Forgetting-Fixation Hypotheses, but again provides little insight into the incubation question. The other forgetting measures of anagram recognition were not significant and therefore do not provide support for the existence of incubation.

Because incubation effects were not observed, the discussion of the two hypotheses is limited. The discussion will focus on how the mechanisms proposed could affect problem solving in general, and in the context of conditions where incubation could be produced.

Support for the Memory-Sensitization Hypothesis

The results lend partial support for the Memory-Sensitization Hypothesis. The Memory-Sensitization Hypothesis suggested that spreading activation would maintain the memory trace of the primes and improve problem-solving performance. The Memory-Sensitization Hypothesis also proposed that if the appropriate stimuli were encountered during the incubation break, the solution would be activated to higher activation levels and thus would be solved more easily. Because no incidental stimuli were provided during the incubation break, the discussion of the Memory-Sensitization Hypothesis is somewhat incomplete.

Spreading Activation. The recalled, related primes had more corresponding solved anagrams than the recalled, unrelated primes, demonstrating the effects of spreading activation. Also, following the incubation break, there was a greater percentage of new anagrams solved over that of previously presented related- and unrelated-prime anagrams. Two interpretations can be made to the superior performance of the new anagrams. The first suggests that the primes that were related to the new anagrams continued to be activated following their initial presentation and provided a problem-

solving benefit to the new anagrams presented after incubation. This also provides support for the spreading activation position.

The second interpretation attributes the increased solution success with the new anagrams to the innate differences between the stimuli presented after incubation. The anagrams presented following incubation consisted of unsolved anagrams from the first presentation and new anagrams. The previously unsolved anagrams could be considered more difficult by nature of their not having been solved the first time they were presented. The new anagrams, however, which had never before been presented, would likely be mixed in anagram difficulty. Consequently, the new anagrams, composed of a more heterogeneous sample of relatively difficult and relatively easy-to-solve anagrams would be solved with greater success than the previously unsolved anagrams. This second interpretation does not provide any support for the effects of spreading activation.

Measures of Forgetting. The forgetting measure of correctly recalled primes associated with solved anagrams was not significant. This lack of association between forgetting and solution success does not support the Memory-Sensitization Hypothesis, which suggested an association of less forgetting with greater solution success.

Lack of Incidental Stimuli. Further support of the Memory-Sensitization Hypothesis could be provided by the addition of stimuli during the incubation break. For purposes of experimental control, problem-solving stimuli that might have triggered the solution during the incubation break were not provided. The lack of incidental stimuli could have contributed to the lack of observed incubation effects.

Support for the Forgetting-Fixation Hypothesis

The Forgetting-Fixation Hypothesis proposed that forgetting was the key component in producing incubation effects. Based on this hypothesis, the more that incorrect solution attempts were forgotten, the more likely the correct solution would surface. The

recall of primes, the correct identification of anagrams as previously presented, and the solution success of the anagram types were the variables used to assess forgetting.

Recall of Primes. Forgetting was measured by the percentage of recalled primes associated with correctly solved anagrams. More related primes with corresponding solved anagrams were recalled than unrelated primes with corresponding solved anagrams. This suggests that solution success is associated with the recall of primes rather than forgetting of primes.

Correct Identification of Previously Presented Anagrams. The correct identification of anagrams results also fail to support the Forgetting-Fixation Hypothesis; there was no significant relationship between anagrams recognized as previously presented and whether or not the anagram was solved. There was also no significant effect of incubation upon anagrams recognized as previously presented; there was no increased level of forgetting with increased incubation time.

Solution Success of Different Anagram Types. The Forgetting-Fixation Hypothesis predicted that all three types of anagrams (related, unrelated, and new) would have achieved the same solution success with increased incubation time. In fact, the lack of incubation effects would seem to provide support for the Forgetting-Fixation Hypothesis. But the significant main effect of prime type, with new anagrams apparently solved at a greater percentage than the (formerly presented) related and unrelated anagrams, suggests otherwise. Further comparisons of this significant main effect of prime type were not conducted; these results would not have provided any insight into the effects of incubation. As a result, the significant difference in the means can only hint at the mechanisms that could be involved.

The apparently superior performance of the new anagrams over that of the unrelated anagrams suggests that forgetting of the initially misleading primes did not occur. This is

attributable to the fact that the unrelated anagrams never had their appropriate primes presented and thus fared worse than the new anagrams whose primes were presented.

However, the new anagrams also appear to have been solved at a greater percentage than the related anagrams; this finding, in contrast to the above result, does not rule out forgetting of misleading primes. To be consistent with the suggestion that forgetting had not taken place, both related and new anagrams should have been solved at a greater percentage than the unrelated anagrams. To be consistent with the suggestion that forgetting had taken place, all three groups should have performed equally.

It is possible that the superior solution success of the new anagrams is due to the heterogeneous nature of the new anagrams (a mixture of easy and difficult anagrams) over the previously presented anagrams. It is unclear how strong this effect of more difficult, previously unsolved anagrams versus the more mixed-difficulty group of new anagrams may have been. Again, had incubation been observed, support either in favor of, or against, the Forgetting-Fixation Hypothesis might have been more clear.

In summary, the overall, non-significant difference in mean solution times across all prime types and incubation conditions does lend some support for the Forgetting-Fixation Hypothesis. Based on the Forgetting-Fixation Hypothesis, increased incubation time should result in increased similarity of performance (as defined by solution time and percent-solved anagrams). But the associated increase in forgetting with incubation time that is essential to the Forgetting-Fixation Hypothesis is not supported. The results fail to show that forgetting is strongly associated with anagram-solving success.

The comparison of the Memory-Sensitization and the Forgetting-Fixation Hypotheses in this study is problematic because of the lack of observed incubation effects. As previous researchers have noted, incubation has proven difficult to reliably produce in the laboratory setting (Browne & Cruse, 1988; Olton, 1979). Had incubation

effects been produced, the present study's results would have favored the Memory-Sensitization Hypothesis, since spreading activation was clearly observed. The Forgetting-Fixation Hypothesis, however, is not supported by the results of this study.

Methodological Concerns

Because the evidence for incubation is uncertain in the experimental literature, its effects could be considered fragile and easily obscured by the methods used to examine it. Thus it would be useful to explore a number of methodological concerns raised by this study. Addressing these concerns could help in a future examination of incubation using anagrams as the problem stimuli. In particular, I will discuss five areas of concern that arose in this study.

Type of Experimental Stimuli. The type of experimental stimuli presented must certainly have an impact on problem-solving performance. The use of anagrams as a problem-solving task has clear advantages over the use of a difficult word retrieval or rebus task. However, despite the selection of only native-English speaking subjects, there were great individual differences in subjects' interests and abilities to solve anagrams. Very few of the subjects were so acquainted with anagram-solving that they chose to engage in such puzzles on their own.

Patrick (1986) has suggested that incubation may only occur "for high-ability subjects under the right conditions" (p. 173). Thus, the overall subjects' lack of expertise in solving anagrams could have contributed to the failure to observe incubation effects. It would probably have been beneficial to use subjects who were either familiar with, or proficient at, solving anagrams. In future studies using anagrams, some effort should be directed toward contrasting incubation effects between subjects who are proficient at solving anagrams and subjects who are not as familiar with anagrams.

Effects of Frustration and Fatigue. A second consideration (which could also arise

from subject unfamiliarity with the type of problem being presented) is the effect of frustration and fatigue on the problem-solving atmosphere. Many of the subjects reported frustration with the task, and indicated that they felt as though they were failing if they did not solve most (or all) of the anagrams. To alleviate some frustration, subjects may need reassurance that their performance need not be perfect to be useful. Practice sessions could be introduced to better acquaint subjects with the types of anagrams they would be attempting. In addition, deliberately simple anagrams could be interspersed into the stimuli to heighten subjects' sense of accomplishment.

Olton and D. M. Johnson (1976) have suggested that fatigue relief is a contributor to incubation effects. The lack of incubation effects observed in this study may be attributed to fatigue. Future attempts to address the effects of fatigue might incorporate breaks of perhaps 1 to 5 min, after a certain number of anagrams have been attempted, into the experimental procedure.

Selection of Incubation Period. It is unclear whether the selection of 5 min and 15 min incubation intervals were appropriate to produce incubation effects. There does not seem to be an agreed-upon time interval that is generally used in incubation experiments because the tasks presented in such experiments have been so different. It is possible that while 5-min and 15-min incubation intervals were entirely appropriate for demonstrating problem-solving behavior with rebuses (Smith & Blankenship, 1989), these intervals may not have been long enough to detect incubation effects in anagram-solving. Longer time intervals might have improved the sensitivity of the experiment to produce and detect incubation effects.

Problem-solving Time Allotted. A fourth question is whether 30 s was sufficient for subjects to attempt anagram solution. Smith and Blankenship (1989) had given their subjects 30 s to solve their rebus task; this time interval was chosen to facilitate

comparisons with the Smith and Blankenship experiment, as well as make the anagram task fairly fast-paced and challenging. But subjects may not have had enough time to concentrate on the prime-anagram pairs and invest enough effort to attempt solutions. A 30-s interval may have been too brief to allow detection of any strong problem-solving benefit to incubation. Future experiments might consider using longer solution intervals.

In addition, it is unclear whether the time spent on a problem prior to the incubation period should be the same as the time allotted to solve the problem following the incubation period. Perhaps increasing the solution time allotted in the first presentation (relative to that allotted in the second presentation) would have helped improve concentration on the problem.

Attention versus Intention. The final methodological concern involves the way in which incubation has been depicted in the experimental literature. We expect to encounter incubation in an experiment in much the same way as it is reported anecdotally: the success of solving a problem following a break is linked to the problem-solver's lack of effort towards the solution during the break. Based on the problem-solver's point of view, the lack of effort is assumed to mean both non-attentional and non-intentional.

Unlike the problem-solver in the laboratory setting, the incubation literature has portrayed the real-world problem-solver as having devoted much effort towards the problem solution. The problem-solver may have a vested interest in whether or not the problem is solved. Therefore, during the incubation break, the problem-solver may report that s/he was not actively working on the problem, but we can assume that there is some element of intention to continue working on the problem at a later time. In contrast, in this experiment, the subjects were not aware that they would be presented with unsolved anagrams from the first presentation after the incubation period. None of the subjects

would have developed any intention to solve the anagrams formerly left unsolved.

It is unclear how the effects of attention and intention may affect processing. The lack of attention does not automatically imply a lack of intention, and neither concepts should automatically imply non-processing. Processing towards the problem's solution may occur in the incubation interval, and it may be driven by intention to solve the problem. Without any intent to solve the problem, the cognitive system may choose to disregard the problem as a nuisance, extraneous to efficient processing.

Attention and intention may also interact to produce incubation effects. This possible interaction, as well as a clear distinction between attention and intention should be addressed in future studies of incubation. The effects of attention and intention can be examined through manipulation of the experimental procedure. Possibly the use of subjects who find a particular experimental problem interesting or relevant could provide a good measure of intention. Alternatively, subjects could be rewarded for performance that demonstrates either greater attention or intention in problem solving.

In summary, the results of this experiment do not lend support to the notion that incubation is a process beneficial to problem-solving. Like the literature reviewed previously, this experiment found incubation effects to be elusive. Consequently, incubation cannot be said to fit with the current models of cognitive processing.

The results do support the component of the Memory-Sensitization Hypothesis suggesting that spreading activation plays a critical role in incubation effects. Priming was found to improve the solution success of new anagrams over that of the previously unsolved, related and unrelated anagrams. Further study is needed to examine the effects of incidental stimuli during the incubation period in order to strengthen the position of the Memory-Sensitization Hypothesis. The results do not strongly support the basic assumptions of the Forgetting-Fixation Hypothesis, which proposed that forgetting of

incorrect information was associated with solution success. Had incubation effects been observed, the Memory-Sensitization and Forgetting-Fixation Hypotheses might have been more clearly defined.

A number of methodological questions, if addressed, should help produce incubation effects in the laboratory setting, if incubation does indeed exist. Most importantly, a clear distinction between the type of problem-solving effort being examined (non-attentional or non-intentional) should be made. Careful consideration must be used in choosing an appropriate problem-solving task and finding subjects for whom the task is most relevant. Once subjects have a vested interest in the outcome of the problem they are trying to solve, the experimental design may be better able to detect incubation in the laboratory as it seems to exist in the real world of problem-solving.

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Appendix

Experimental Stimuli

Related Anagrams:	Prime	
SPIRIT	vitality	
POLICE	patrol	
NATION	state	
CORNER	angle	
ACTUAL	existing	
MOMENT	instant	Replaced "RESULT."
STRONG	powerful	
EFFORT	struggle	
FATHER	parent	
MIDDLE	central	
HEALTH	fitness	
MODERN	current	
GROWTH	development	
VOLUME	book	
SERIES	chain	
Unrelated Anagrams	Prime	
PERSON	quantity	
ENTIRE	note	
FORMER	opening	
CHOICE	spice	
SUPPLY	beautiful	
MANNER	treasury	

Unrelated Anagrams (continued)	Prime	
RETURN	pattern	(Stimulus removed from analysis)
UNLESS	treat	
NORMAL	emerge	
LONGER	core	
FIGURE	universe	
SINGLE	base	
MARKET	distance	
COUPLE	conventional	
THEORY	response	
New Anagrams	Associated Primes (not presented)	
AMOUNT	quantity	
LETTER	note	
WINDOW	opening	
SEASON	spice	
PRETTY	beautiful	
FISCAL	treasury	
METHOD	pattern	
DOCTOR	treat	
APPEAR	emerge	
INSIDE	core	