

**THE INCUBATION EFFECT:  
IMPLICATIONS FOR UNDERLYING MECHANISMS**

by

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## Abstract

The incubation effect refers to the phenomenon whereby problem solving performance improves when a preliminary period of work on a problem is followed by a break from, rather than continued work on, the problem. To date, the incubation literature has been centered on investigating the most “testable” causal mechanisms of incubation, including the ideas that benefit accrues from incorrect ways of initially thinking about the problem fading over the incubation period before a return to the task, or from a chance encounter with problem-relevant information present in the problem solver’s surrounding environment. Although support for the latter hypothesis was indicated in the present thesis, little support for the former was evidenced here, possibly due to methodological difficulties. Relatively unconsidered in the incubation literature to date has been the popular notion of the role of “unconscious processes.” In the present thesis, the role of such unconscious processes in the incubation effect was conceptualized in the more contemporary terms of spreading activation, involving the idea that a spread of activation related to initial work on a problem may continue for a period of time after directly attending to the problem. In two of the present studies, more sensitive measurement techniques were employed to directly test for the presence of continued problem-related activation after an initial period of work; these studies indicated some support for the spreading activation hypothesis of incubation.

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## The Incubation Effect: Implications for Underlying Mechanisms

Then I turned my attention to the study of some arithmetical questions apparently without much success and without a suspicion of any connection with my preceding researches. Disgusted with my failure, I went to spend a few days at the sea side, and thought of something else. One morning, walking on the bluff, the idea came to me, with just the same characteristics of brevity, suddenness, and immediate certainty, that the arithmetic transformations of indeterminate ternary quadratic forms were identical to those of non-Euclidean geometry (Poincaré, 1929 cf. Ghiselin, 1952, p. 37).

An interesting and rather counterintuitive phenomenon in the area of problem solving is the incubation effect, a condition whereby the probability of successfully solving a difficult problem is increased when a period of intense work is followed by a period in which no active attempts are made to solve the problem. Anecdotal reports of the use of an incubation period have been given by many creative individuals in the sciences and arts, as demonstrated in the introductory quote of how Poincaré discovered the class of Fuchsian functions. Indeed, the beneficial effects of taking one's mind off a problem is a common experience to many of us. Folklore suggests we "sleep on it" when we cannot solve a difficult problem. Many of the students who participated in the following studies reported using strategies such as taking a break when they could not answer a difficult assignment question and leaving the most difficult questions on exams until last, permitting a period of time between their first and final attempts.

Despite the anecdotal evidence for incubation, its existence under more controlled conditions in the laboratory has been less well demonstrated. The findings of early studies (e.g., Dreistadt, 1969; Gall & Mendelsohn, 1967; Murray & Denny, 1969) were complicated by their methodology of providing incubation at the expense of continued work on the problem, rather than the currently more acceptable method of including

incubation in addition to matched working time on the problem. Several studies have empirically demonstrated incubation effects (e.g., Browne & Cruse, 1988; Dreistadt, 1969; Fulgosi & Guilford, 1968; Goldman, Wolters, & Winograd, 1992; Murray & Denny, 1969; Patrick, 1986; Peterson, 1974; Silveira, 1971; Smith & Blankenship, 1989, 1991; Smith & Vela, 1991); however, in most of these studies, the effect is limited to specific conditions, including participants' general ability level, the length of the incubation time and the type of activity filling the incubation period. For example, Murray & Denny (1969) found positive incubation effects for only their low-ability participants whereas Patrick (1986) found only high-ability participants benefited from incubation. Fulgosi & Guilford (1968) found significant incubation effects for a 20-minute, but not a 10-minute incubation period whereas Goldman et al. (1992) obtained positive results in a 24-hour, but not a two-minute incubation condition. Silveira (1971 cf. Posner, 1973) found positive results in both a half-hour and a four-hour condition; however, these results were significant only for participants who had initially worked for a long, as opposed to a brief, time on the problem before incubating.

The demonstration of incubation in the laboratory has also varied depending on the nature of activity in which participants were involved during their break from the problem. Dreistadt (1969) found positive effects of incubation only when it was combined with a pictorial clue to the problem. Browne & Cruse (1988) found that incubation periods filled with either relaxation or a clue to the problem, but not with demanding mental work significantly improved later performance. Patrick (1986), however, obtained positive effects only when the break from the problem was filled with an activity unrelated to the

problem being attempted. Finally, Smith & Blankenship (1989), Smith & Blankenship (1991), and Smith & Vela (1991) demonstrated positive incubation effects when the correct solution to the problem was initially blocked or thwarted through experimental manipulation (see below). There have also been a number of failed demonstrations of incubation (e.g., Dominowski & Jenrick, 1972; Gall & Mendelsohn, 1967; Gick & Holyoak, 1980; Olton & Johnson, 1976; Olton, 1979). Thus, to date, the conclusions of empirical work on incubation have been inconsistent and the results of one study often fail to be replicated in other studies.

Given the state of the previous incubation literature, one might come to one of two conclusions. Considering the inconsistency of the results and the frequent failures of the results of one study to be replicated in other studies, one might conclude that incubation does not exist as an objective phenomenon and that the dramatic accounts of taking one's mind off a problem given by Poincaré and other creative individuals are due to cognitive mechanisms such as selective remembering and selective forgetting. In Olton & Johnson's (1976) words:

incubation may be something of an illusion, perhaps rendered impressive by selective recall of the few but vivid occasions on which great progress was made following separation from a problem and forgetting of the many occasions when it did not (p. 629).

On the other hand, it may also be possible that incubation represents a "true" and objective phenomenon, but one that is very difficult to demonstrate in the confines of an artificial laboratory setting. Olton & Johnson (1976) discussed the failure of the incubation laboratory experiment to sufficiently motivate participants, draw on extensive knowledge and experience in a specific area of expertise, and provide enough time off task, compared

to the anecdotal accounts of its use. Given this difference in context of the laboratory experiment compared to a “real world” problem solving setting, it may be that the measures of incubation employed in such experiments are insensitive to its likely reduced effects in the laboratory context. In this respect, note that the inconsistent results are also the product of a variety of problems that have been used in the incubation literature, which likely vary in terms of their difficulty and complexity, and therefore their appropriateness to the incubation context. Of course, it is difficult to know in advance what might be considered a more sensitive measure of incubation. A key to the answer to this question may relate to the mechanisms through which incubation is thought to operate. Further investigation of the mechanisms by which incubation may occur would benefit from both (1) clarifying whether incubation effects can be demonstrated more reliably through the operation of a given mechanism and (2) providing a greater understanding of how such effects occur. However, the literature investigating the mechanisms through which incubation may occur is much more limited than the research investigating the presence of the effect itself, likely due to the unreliability of the effect in the first place. Several mechanisms have been proposed, however, and I shall turn next to a review of these mechanisms.

### **Proposed Accounts of Incubation**

I begin this discussion with what I consider to be the two least interesting hypotheses for the reported beneficial effects of incubation. One such explanation might be termed the “fatigue hypothesis” (Posner, 1973; Olton & Johnson, 1976). This hypothesis suggests that after working on a problem for a while, mental fatigue builds up

and interferes with the problem solver's ability to continue to actively think about and work on the problem. The function of the incubation period, then, is to give the problem solver a break, reduce fatigue, and re-generate energy to continue work.

A second "uninteresting" hypothesis is that the incubation period simply allows more time for additional work on the problem of the same nature as occurred before the break (Posner, 1973; Browne & Cruse, 1988). Although most introspective reports of incubation deny that any active work on the problem continued during the incubation period, the possibility exists that such work did occur, but was forgotten on the emergence of the solution (Posner, 1973). Thus, according to this account, incubation is due to thinking about the problem, but not remembering that thinking. Of course, if this were the case, any benefit from an incubation period would simply be due to a longer time working on the problem, an uninteresting finding.

Generally, studies of incubation attempt to control for these two accounts. Participants are often required to work on some alternative task unrelated to the problem of interest during the incubation period. In this way, any effect of the break cannot be said to be due to a rest and reduction of fatigue or continued active thinking about the problem. With these rival hypotheses out of the way, we will turn now to a discussion of the three main mechanisms proposed to explain the reported beneficial effects of incubation.

### Unconscious Processes

Probably the most popular assumption regarding the effects of taking a break during problem solving attributes the effects of doing so to unconscious processes, that is, that work on the problem somehow continues implicitly below the threshold of awareness while

conscious attention is directed to other activities or to nothing at all. Although the role of unconscious processes is often stressed in anecdotal reports of incubation (Ghiselin, 1952), it has little or no empirical validation. Distinctions of cognitive processing have been made that include primary versus secondary, rational versus intuitive, serial versus parallel (Neisser, 1967), and automatic versus controlled (Posner & Snyder, 1975; Shiffrin & Schneider, 1977), but such distinctions have not yet been applied to the empirical study of incubation in problem solving.

A large mass of anecdotal evidence, however, has testified to the role of the “unconscious” in creative production in general. Ghiselin (1952) collected and combined into one volume the writings of a number of creative individuals in fields such as arts, literature and science on their creative processes. Ghiselin noted that most of these creative individuals considered a significant part of their work as due to “involuntary” or automatic processes. In fact, Ghiselin concludes in this review that creative production without some role of the unconscious is likely never to occur.

Poincaré was one of the creative individuals included in Ghiselin’s review who stressed the role of unconscious mental work on the problem during the incubation period, as noted in the quotation at the beginning of this thesis. According to Poincaré, during the rest period, many different combinations of ideas are formed in the unconscious. Ideas that are useful or relevant to the problem at hand affect the scientist’s “emotional sensitivity,” which acts as a selection agent, and these ideas break through to consciousness producing the sudden illumination effect. The process underlying this unconscious work is best described using Poincaré’s own analogy:



Perhaps we ought to seek the explanation in that preliminary period of conscious work which always precedes all fruitful unconscious labor. Permit me a rough comparison. Figure the future elements of our combinations as something like the hooked atoms of Epicurus. During the complete repose of the mind, these atoms are motionless, they are, so to speak, hooked to the wall; so this complete rest may be indefinitely prolonged without the atoms meeting, and consequently without any combinations between them. On the other hand, during a period of apparent rest and unconscious work, certain of them are detached from the wall and put in motion. They flash in every direction through the space . . . where they are enclosed, as would, for example, a swarm of gnats or, if you prefer a more learned comparison, like the molecules of gas in the kinematic theory of gases. Then their mutual impacts may produce new combinations (p. 41).

Campbell (1960) presented a theoretical analysis which outlined the role of unconscious processes in creative thought as largely due to chance. Campbell conceives creative thought to be the result of a “blind variation and selective retention” process, in which random fusions of memory representations from different memory cells continuously and unconsciously make contact; when such contact fits some selection criteria, it is selected. In Campbell’s view, this process underlying creative thought is similar to any trial-and-error learning, including the variation process of mutation in organic evolution, with the most adaptable variations being selected.

In contrast to Campbell, but perhaps not so different from Poincaré, more recently developed spreading activation theories provide a more ordered description of the role of unconscious processes. Spreading activation theories (Collins & Loftus, 1975) were developed to explain semantic priming effects and a variety of memory phenomena. Such theories take as their first assumption the proposition that memory is associative and that associations are accumulated in memory through experience. Concepts of anything, whether a noun, action, or whatever, are represented in cognitive space as nodes in a

network. There are relational links between nodes and these links vary in strength depending on factors such as previous experience and frequency and recency of activation of the particular link. Whenever a concept is processed, activation is released from its node and spreads to all nodes linked to that node and then to all nodes linked to each of the secondary nodes activated, and so on. This activation decreases gradually over time.

There are two important characteristics of this spreading of activation. First, it is automatic; activation spreads to concepts linked to the activated concept without voluntary control. Thus, this spreading of activation is thought to occur very rapidly and below the threshold of awareness. All of the associations activated by one node do not enter working memory. In fact, a node requires a sufficient amount of activation to cross the threshold of awareness. Second, although only one concept can be actively, or consciously, processed at a time, due to the serial nature of conscious processing, the spreading of activation between nodes occurs in parallel; that is, when a node becomes activated, it, in turn, activates all nodes linked to it. In the case where more than one concept is actively processed in close proximity, the possibility exists for activation from different sources to summate or intersect.

Recently, ideas of unconscious spreading activation have been applied to the role of insight in problem solving. For example, in Ohlsson's (1992) theory of insight, activation spreads from knowledge structures that encode the problem to other related concepts (cf. Dominowski, 1995). Some empirical support of the role of automatic spreading activation in insight problems has been provided by Bowers, Regehr, Balthazard, & Parker (1990). In Experiment 1, Bowers et al. developed the "Dyads of Triads Task," consisting of two

sets of three words. Within each dyad, one triad was coherent in that all three of the words were associates of a solution word. The second triad in each dyad was incoherent, in that the three words were all associates of different words. Bowers et al. asked participants to generate solutions to the triad they judged to be coherent in each pair. When unable to solve a coherent triad, participants were asked to make a forced-choice decision of which triad was coherent. Results indicated that even when participants could not solve the coherent triad, they still chose the coherent triad at levels significantly greater than chance. Bowers et al. interpreted these findings in terms of spreading activation theory, such that, “clues that reflect coherence automatically activate relevant mnemonic networks in a graded and cumulative fashion” (p. 74). They proposed that each of the stimulus words in a triad automatically activates related associates. When the three words activate an associate common to each of them, this associate has a higher likelihood of crossing the awareness threshold. However, even when sufficient activation is not reached, partial activation of this common associate can still bias forced-choice decisions about which triad is coherent.

In Experiment 3, Bowers et al. developed “The Accumulated Clues Task” (ACT), which consists of 15 words, each a low associate of the solution word. The stimulus words were presented to participants one at a time. After the presentation of each word, participants recorded their best guess as to the solution at that point in time. Bowers et al. then had independent judges rate the associative closeness of participants’ guesses throughout their attempt to solve each ACT item. These ratings revealed a gradual increase in associative closeness of participants’ responses to the solution word as they

proceeded from earlier to later stimulus words. Again, Bowers et al. interpreted this finding as indicating that the automatic activation of associative networks, spreading from the stimulus words and converging on the solution word, serves as the bases for people's intuitions in problem solving.

Most recently, the role of such automatic spreading activation has been implicated in the incubation effect in problem solving. Dorfman, Shames, & Kihlstrom (1996) have introduced the concept of "autonomous activation" to explain increased performance on a problem after a rest period. According to Dorfman et al., on presentation of the problem, its components automatically activate related information or nodes in memory. Then, during incubation, the activation spreads to other nodes related to the problem elements. Gradually, there will be a summation of activation on nodes most important to the problem solution. Activation may eventually converge on the problem solution, and, if sufficient intensity is reached, cross the awareness threshold. To my knowledge, however, there has been no direct empirical investigation of autonomous activation in incubation. Although Dorfman et al. propose that previous empirical demonstrations of the beneficial effects of incubation (e.g., Fulgosi & Guilford, 1968; Goldman et al., 1992; Murray & Denny, 1969; Peterson, 1974; Silveira, 1971; Smith & Blankenship, 1989) provide evidence for the role of autonomous activation in the incubation effect, without any direct investigation of autonomous activation per se, it is difficult to know whether such effects are due to other factors, such as forgetting fixation (to be reviewed shortly).

Nevertheless, given the role proposed by many investigators of unconscious spreading activation in problem solving, an interesting question concerns why unconscious

or “below-awareness” processing should be any more beneficial than alert and active conscious processing. The answer to this question seems to involve a view of consciousness as a limited capacity system, capable of only serial processing, in contrast to the more unlimited parallel processing of unconscious activation (cf. Mandler, 1995). Several empirical investigations bear on this proposition. For example, Spence & Holland (1962) presented the word “cheese” to participants either subliminally or supraliminally. Participants were then presented with a word list containing ten associates of cheese and ten control words not relevant to cheese. Spence and Holland found the recall of cheese associates to be significantly greater in the subliminal than supraliminal group. They interpreted these findings as indicating that when a stimulus (e.g., “cheese”) is presented below awareness, it fans out to a wider range of associates. In contrast, awareness of a stimulus restricts its effects, as one’s response to it becomes organized within only one particular meaning.

In a similar vein, Spence (1964) presented participants with a word list containing the word “cheese” and the ten associates and ten control words as just described and investigated recall before and after the stimulus word “cheese” was recalled. Spence found significantly more associations of cheese recalled before the word “cheese” itself was recalled than after “cheese” was retrieved. Again, he concluded that a stimulus not in awareness activates a greater range of associates than the same stimulus in conscious awareness.

More recently, Marcel (1980) also investigated how the processing of word meaning varies with awareness. Marcel presented participants with three successive letter

strings and measured reaction time to respond to the third letter string. On control trials, the first letter string was associatively related to the third whereas the second was unrelated to either the first or third string (e.g., “hand . . . race . . . wrist”). On critical trials, the second letter string was a homograph, a word with several meanings but identical spellings, for example, “palm.” On these trials, the homograph was associatively related to the third word, for example, “palm . . . wrist.” In addition, the homograph itself was also primed by the first letter string. This first word was related either to the same meaning of the homograph as the third word, for example, “hand . . . palm . . . wrist” (congruent trials), or to a different meaning of the homograph than the third word, for example, “tree . . . palm . . . wrist” (incongruent trials). In addition, the middle homograph word was either masked to prevent participants from fully consciously processing the word, or unmasked to allow full attention to the word.

Unsurprisingly, Marcel found that participants responded significantly faster on congruent trials than on control trials, both when the homograph was masked and when it was unmasked. Incongruence seemed to produce an interference effect, at least when the homograph was not masked; in this case, participants responded significantly slower on incongruent trials than on control trials. Surprisingly, however, Marcel found a facilitation effect for incongruent trials when the homograph was masked, relative to control trials. Thus, it would appear that when the homograph was unmasked and therefore fully consciously processed, prior context biased the meaning of the homograph taken, as indicated by the slower response times on unmasked incongruent trials. However, when masked to prevent full attention to it, prior context did not appear to bias the homograph's

interpretation to the same degree, as indicated by faster response times on the masked incongruent trials. Marcel hypothesized that when processed without awareness, all or many meanings of a word are accessed regardless of context, as capacity in this situation is relatively unlimited. However, in a conscious stage of processing, capacity is more limited and therefore only one interpretation of a word can be processed at a time; the meaning of the word that is accessed will be dictated by prior context.

As already noted, there has been little, if any, direct investigation of the role of unconscious processes or spreading activation in the incubation effect. Indeed, previous authors have cautioned investigators about direct empirical investigation of this explanation of incubation:

The obvious theory – unconscious work, whether conceived as mental or as cerebral – should be left as a residual hypothesis for adoption only if other, more testable hypotheses break down (Woodworth & Schlosberg, 1954, p. 840).

I will consider next one such “testable hypothesis”, namely the role of fixation or “set” in problem solving.

#### Forgetting Fixation Hypothesis

Posner (1973) saw the most crucial time in the entire problem solving process as the first few moments, during which the initial problem representation takes place. Before any problem can be solved, it must be cognitively represented in the problem solver’s mind, so that information relating to the problem can be organized and integrated. For less difficult and more familiar problems, such problem representation proceeds easily; it will reflect aspects of other representations already encountered. Such a problem representation contributes to the development of a rapid solution, as it inhibits the problem solver from

making observations unrelated to the current representation or from developing other representations not useful to the current problem of interest. However, such a problem representation can be quite limiting in the case of difficult or novel problems where retrieving and applying older, often-used problem strategies will be less successful. Indeed, what is often needed for difficult problems is to make new observations or to develop different problem representations. Unfortunately, as Posner notes, once a particular representation of a problem is adopted, people often continue trying to solve the problem within that representation, in a rather rigid manner, without trying out different ways of looking at the problem.

Duncker's (1945) concept of "functional fixity" provides a good example of the possible harmful effects of initial problem representations. Duncker coined this term to explain the phenomenon whereby people have trouble conceptualizing different functions for objects first observed fulfilling a particular function. Duncker presented to his participants a problem that required a cork to be used as a wedge. To some participants, the cork lay free in the centre of the table. Others saw the cork as the stopper to a bottle. Duncker found that almost half of the participants solved the problem when the cork lay free, but only 14 percent of those who saw the cork as a stopper were successful in their problem solving. Thus, participants in the "stopper" condition became fixated on this function of the cork.

Woodworth & Schlosberg (1954) discussed the concept of initial problem representations in terms of what they called "set" and proposed a relation between set and the beneficial effects of an incubation period. Woodworth and Schlosberg defined set as a



readiness to respond, which “facilitates responses for which [the person] is prepared and tends to inhibit any competing responses” (p. 830). They proposed that a set functions by reducing the person’s range of available alternatives. Instead of having to select a response from an unlimited number of responses triggered by a stimulus, a set limits the field of responses in advance, thereby increasing the speed and accuracy with which the person can produce a response that conforms to the demands of the situation. They noted, as well, however, the detrimental effects on problem solving that a set can have in that the problem solver will adhere to only one line of thought despite continued failure. Woodworth and Schlosberg proposed that laying the problem aside during the incubation period allows time for an erroneous set to die out and therefore leaves the problem solver more able to make a fresh start at the problem.

More recently, Smith and colleagues (Smith & Blankenship, 1989, 1991; Smith & Vela, 1991) have empirically demonstrated the effects of what they term “fixation” and the related advantages of incubation. They conceptualize fixation as the retrieval of inappropriate information or problem solving strategies from memory. The recall of this information blocks the emergence of more appropriate strategies. The incubation period, then, allows the problem solver to forget the initially recalled inappropriate information and strategies, allowing more helpful information to become more accessible. In their investigations, Smith and Blankenship have initially thwarted participants’ attempts to solve a problem and then examined the role of an incubation period in undoing this original fixation. Using this method, Smith and Blankenship have demonstrated reliable, consistent incubation effects in the laboratory, a task of some difficulty as already seen.

Smith & Blankenship (1989) demonstrated the role of fixation and “forgetting fixation” in the incubation effect in a set of four studies. Participants were presented with rebuses, a type of picture-word puzzle, the solutions to which are common phrases that fit the word pictures. For example, the solution to the rebus “you just me” is “just between you and me.” After working on rebuses to which helpful clues had been given, fixation was induced on later rebuses by priming the rebuses with misleading clues. For example, the misleading clue given to the rebus “you just me” was “beside.” Participants either received no incubation period or a five- or ten-minute incubation period, that was either filled or unfilled, before being presented with the rebuses again. During this second presentation, the misleading clue was removed and rebuses were presented with no clue, or in some experiments, with helpful clues. On this second presentation, participants were asked both (1) to attempt to solve the problem again, and (2) to recall the clue given with the rebus in the initial attempt. Smith and Blankenship found that participants who had an interval between the first and second presentation of an unsolved rebus with a misleading clue were significantly more likely to solve the rebus on the second presentation. They were also more likely to have forgotten the misleading clue originally presented with the rebus than were participants who did not have an incubation period, supporting their hypothesis that problem solving improves after incubation as a function of fixated information (i.e., the misleading clue) being forgotten.

Smith & Blankenship (1991) used the Remote Associates Test (RAT) as their problem solving measure. The object of the RAT is to find one word that is an associate of three words on a given item. For example, given the words, “Family”, “Apple” and

"House," participants are expected to generate the solution "Tree." In a series of five studies, fixation on RAT items was induced in some participants by priming each of the three stimulus words with a word that, while related to the stimulus word, was inappropriate to the correct solution. For example, the inappropriate primes for the stimulus words, "Family", "Apple" and "House" were "Mother", "Pie" and "Home," respectively. Incubation effects were tested by retesting participants on unsolved RAT items either immediately or after a delay filled with cognitively demanding tasks. Smith and Blankenship found that participants presented with a misleading clue did become fixated on the problem, as evidenced by poorer performance on the task. They also found that performance increased significantly after the incubation period for fixated participants, but not for nonfixated participants.

Smith & Vela (1991) studied the phenomenon of reminiscence in the memory literature, which occurs when material not recalled on one memory test is later recalled on a subsequent test. One explanation of reminiscence suggests that output interference occurs at the time of initial recall, blocking the item to be recalled, and this output interference then reduces over time. Smith and Vela proposed that reminiscence was conceptually related to the concept of fixation in problem solving, and they investigated an "incubated reminiscence effect" in three studies. In these studies, participants were shown pictures of common objects which they were asked to memorize. They were then given two free recall tests that either followed immediately after one another or were separated by filled or unfilled five- or ten-minute incubation intervals. Smith and Vela found greater reminiscence effects at longer incubation intervals.

In summary, both early theory and later empirical evidence supports the role of forgetting fixation in the beneficial effects of incubation. In fact, likely due to the consistent demonstrations of the incubation effect in the just described studies, in contrast to earlier unreliable laboratory findings, some investigators consider the role that a period of time off task plays in disrupting fixation on the problem to be the best explanation for incubation (e.g., Anderson, 1990; Smith, 1995). Other factors, however, have also been implicated to play a role in incubation and it is to one such factor that I now turn.

#### Implicit Clue Hypothesis

Perhaps incubation reflects not only the result of breaking up an incorrect set or fixation on the problem, but also the provision of an opportunity for the problem solver to find a more helpful set or direction to the problem (cf. Dreistadt, 1969). Attempts to explain incubation have also suggested that the period of time off task may be beneficial in that it allows the problem solver to be informed by chance encounters with stimuli and events in the external environment that may be related to the problem (Anderson, 1975; Olton, 1979; Posner, 1973). After noting the unreliability of the incubation effect in studies he reviewed, Olton (1979) suggested that the presentation of a clue to the problem during the incubation interval may lead to a more stable effect, and that it may be this type of information, rather than the interval itself, that improves performance on the problem after time off task. Many scientists have reported that an analogy or stimulus event triggered their solution in making their discoveries. A well-known example is the story of Archimedes, who was commissioned by King Hiero to determine whether his crown was made of pure gold, as purported, or whether it also contained some silver. Archimedes

puzzled over the problem for days until one day when he stepped into his bath and noticed the water running over, being displaced. This, of course, triggered the discovery of his technique of measuring the gold content of the crown by displacement of water (Dreistadt, 1968).

Contrary to the clear relation between the external event and the solution that Archimedes recognized in the above example, reports of other scientists and artists do not indicate any role of an external stimulus in their discoveries. Nevertheless, the possibility exists that such a stimulus or event was implicitly noticed and implicitly informed the problem solver. In fact, this state of affairs has been previously identified and labelled by Bowers (1987). Bowers distinguished between “first-order consciousness,” which involves the perception or noticing of events, and “second-order consciousness,” which involves a comprehension of how the events noticed in first-order consciousness affect and influence one’s behaviour. When a person has noticed an event, but remains unaware of it having influenced his/her thought or behaviour, that person is said to be unconsciously influenced with respect to this second-order consciousness. In the context of incubation, the problem solver may notice the external event and have his/her thinking implicitly informed by the event. In the end, however, s/he may be aware of only the solution suggested by the event and not the role of the event in this process.

Maier’s (1931) classic study using the “Two-String” problem is an example of how an external stimulus can suggest the solution to a problem without the problem solver comprehending the connection between the stimulus and subsequent solution. This problem presents participants with the task of tying together two strings hung from the

ceiling. The strings are distant enough from each other that when one is held, the other cannot be reached at the same time. The participant is permitted to use any of a variety of objects in the room, including a table, chair, pole, and pliers. Although there are several possible solutions to the problem, including anchoring one string with the table or chair and extending or lengthening one of the strings, for example, with the pole, one unique solution is of primary interest: attaching a weight, such as the pliers, to one of the strings, thereby making the string a pendulum that can be swung towards the other string allowing the two to be grasped simultaneously. After permitting participants some time to work on the problem, Maier provided a hint to those who had been unsuccessful: he “accidentally” brushed against one of the strings, setting it in motion. Maier found that participants given this hint were then often able to solve the problem. As well, interestingly, when Maier asked his participants retrospectively what led to their solutions, few of them reported the hint. One quite obvious difficulty with Maier’s study, however, is the lack of a control group to which the solution rates of participants given the hint could be compared.

There exists very limited research investigating the role of chance encounters with external events or information in the incubation effect. Any research of this sort must be distinguished by whether the information presented is explicit or implicit, with respect to the problem solver’s knowledge of its “clue” value. When given explicit information, the problem solver is essentially told, “This is a clue to the problem.” In contrast, implicit information requires the problem solver to have no awareness of its clue value. To be ecologically valid, the role of chance encounters with “clues” in the incubation effect can only be informed by research investigating implicitly presented clues. In “real life” there

is no one breaking through the clouds to explicitly inform the scientist, mathematician, or artist that the next stimulus s/he is to encounter will be a “clue” and that s/he should pay special attention to it. There exists, then, even more limited research investigating the role of events or encountered information in the incubation effect; furthermore, like Maier’s study, much of what exists is dated.

Mednick, Mednick, & Mednick (1964) investigated the effects of providing implicit hints during problem solving on a series of RAT items. During the incubation period, a subset of items that the participant had not previously solved were associatively primed by the completion of simple analogy problems for the target items. For example, when unsolved, an item consisting of the words “Family”, “Apple” and “House” would be associatively primed by asking the participant to complete the following analogy: “Limb : Body as Branch : T\_ \_ \_”. Mednick et al. found that unsolved items that were specifically associatively primed during the incubation period were significantly more likely to be solved on a re-test than items not primed during the intervening time.

Dreistadt (1969) investigated the effects of pictorial analogies and an incubation period on the Farm problem, a problem which requires an L-shaped piece of land to be divided into four equal-sized and same-shaped parts, the solution of which is to use L-shapes for the four parts. The pictorial analogies provided clues to the problem by having similar shapes and divisions as the problem solution. When present, the pictorial clues were available throughout the entire problem solving duration. Participants were presented with either pictorial analogies, an incubation period, or both. Dreistadt found significant effects for both the pictorial analogies and the combination of the pictorial analogies and

incubation period. Participants who received both the pictorial analogies and the incubation period were significantly more likely to solve the problem than those who received the pictures alone. Olton & Johnson (1976), however, were unable to replicate Dreistadt's findings, even though they employed the same set of stimuli in nearly identical conditions and included an incubation period in addition to work on the problem, rather than instead of that work, as in Dreistadt's study.

Browne & Cruse (1988) also investigated the role of implicit hints in the incubation effect using the Farm problem and testing a considerable sample size. Participants were assigned to either a continuous work control condition or an incubation condition. During one of the five-minute incubation conditions, participants were asked to draw geometric shapes on graph paper, a task that was meant to unobtrusively suggest to them the "shape" solution. In two separate experiments, Browne and Cruse found problem solving performance significantly higher in the incubation group where the analogical hint was presented than in a continuous work control group that equated work time on the problem. However, in contrast to Maier (1931), Browne and Cruse concluded that knowledge of the shape-drawing task as a clue was an important influence on its likelihood of effecting a solution. Browne and Cruse based this conclusion on the finding that 60 percent of participants solving the problem indicated that the analogical task was helpful, whereas none of the unsuccessful solvers did so. Apart from these few studies, however, there has been little empirical investigation of whether people can make use of implicitly (as opposed to explicitly) presented information that relates to a problem they are working on during an incubation period.



There is, however, a fairly substantial amount of literature investigating the use of analogies and transfer in problem solving independent of the incubation context. Transfer in problem solving occurs when exposure to some information or analogy related to the problem to be solved improves problem solving performance. Two types of transfer are distinguished: spontaneous and informed transfer. Spontaneous, or uninformed, transfer occurs when participants are not informed of any relation between the information or analogy and the problem to be solved; this situation resembles the implicit clue in the incubation literature. In contrast, in informed transfer, participants are explicitly told about the relation of the information or analogy to the problem, as in the explicit clue in the incubation literature. The results of most interest to the present discussion are the spontaneous or uninformed transfer findings. Unfortunately, a rather consistent finding in the transfer literature is that people generally fail to make spontaneous use of helpful information and analogies to solve related problems, or that they do so under fairly limited conditions (Beveridge & Parkins, 1987; Bowden, 1985; Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983; Holyoak & Koh, 1987; Judson, Cofer, & Gelfand, 1956; Lockhart, Lamon, & Gick, 1988; Landrum, 1990; Perfetto, Bransford, & Franks, 1983; Weisberg, DiCamillo, & Phillips, 1978).

A rather striking example of the failure to spontaneously transfer previously encountered relevant information to a current problem solving setting is Perfetto et al.'s (1983) study which employed insight problems adopted from Gardner (1978). The problems were in the form of riddles, for example, "A man who lived in a small town in the U.S. married 20 different women of the same town. All are still living and he has

never divorced one of them. Yet, he has broken no law." Participants were first exposed to clues, in the form of sentences, which they were asked to rate on a scale of truthfulness for the purpose of collecting data for future studies. Apart from two filler sentences, which preceded and followed the clue sentences, the statements were all blatant clues to the riddles presented immediately following. For example, the sentence clue to the above riddle stated, "A minister marries several people each week." Participants who were informed about the potential helpfulness of the earlier sentences solved significantly more problems than did people in a baseline condition, receiving no prior sentences. Participants who were uninformed about the potential helpfulness of these previous sentences, however, did not spontaneously make use of the sentence clues; their performance was statistically no different from that of the baseline group.

Two replications of Perfetto et al., however, have demonstrated significant spontaneous transfer by varying some of the original conditions. Bowden (1985) allowed participants longer amounts of time to work on the problems and found uninformed participants to improve significantly in problem solving performance over the baseline group. Lockhart et al. (1988) also obtained positive results by varying the manipulation of the clue presentation. They presented the sentence clues in either a declarative form, as in Perfetto et al., or in a "puzzle" form, where the information was conveyed as a puzzle followed momentarily by a word that solved the puzzle. For example, the puzzle form of the "clergyman" clue read, "The man married several women each week because it made him happy" followed by "clergyman." Although Lockhart et al. replicated Perfetto et al.'s findings of no significant differences between the groups receiving the declarative

statement clues and the baseline group receiving no clues, their puzzle-form group did solve significantly more of the riddles than were solved by the baseline group. Lockhart et al. suggested that the results could be understood by the fact that when presenting the sentence clues in a puzzle form, the processing required for their comprehension was more akin to the processing required by the subsequent riddles for their successful solution. In other words, when the analogy is more similar in form to the problem, it is more likely to be spontaneously applied.

Weisberg et al. (1978) attempted to demonstrate spontaneous transfer effects using Duncker's (1945) Candle problem. The task here is to affix a candle to a wall so that it will burn properly without dripping wax. Participants are provided with a candle, box of nails and book of matches. The solution to the problem is to dump the nails out of the box and attach the box to the wall as a candle holder; achieving the solution requires participants to realize the box can have multiple roles. Weisberg et al. had uninformed and informed participants learn "candle - box" as one pair in a list of nine verbal paired associates before attempting the Candle problem. Control participants learned "candle - paper" along with the eight filler pairs. Again, although participants who were informed of the potential helpfulness of the previous task to solving the Candle problem performed significantly better on the problem than did controls, there was no significant difference between the control group and participants who had read the clue pair but were uninformed about its potential helpfulness.

Landrum (1990) attempted to replicate Maier's (1931) results using the Two-String problem. Landrum brushed against one of the strings while giving uninformed participants

instructions relating to the problem. Informed participants were told to think of a pendulum before they began working on the problem. Landrum found that informed participants were significantly more likely to solve the problem than were control participants who received no hints, either implicit or explicit. On the other hand, uninformed participants, who simply viewed the string in motion, did not perform significantly better than controls.

An even earlier study employing the Two-String problem to study transfer did indicate spontaneous transfer could be demonstrated, however, but only under fairly specific conditions. Judson et al. (1956) had participants memorize eight five-word lists. In the experimental group, one of these eight lists was a series of words relevant to the Two-String problem: rope, swing, pendulum, clock, and time. In the control groups, some of the lists to be memorized also contained one of these “critical” words, but they were presented with other words in associative contexts irrelevant to the pendulum solution. When the lists of words were learned and practiced over four days and the Two-String problem attempted on a fifth consecutive day after a recall of the lists, Judson et al. found the experimental group to perform significantly better than the control group. However, when such learning was restricted to one day, with recall and the Two-String problem conducted on the following day, Judson et al. found the experimental group did not produce significantly more pendulum solutions than did their controls.

Judson et al. (1956) also investigated transfer on Maier’s Hatrack problem. The Hatrack problem requires participants to construct a stable hatrack using only two boards and a C-clamp and is solved by wedging the two boards between the ceiling and floor and

holding them in place with the C-clamp, with the clamp also serving as a hook. Again, participants learned lists of words before attempting the problem. One of the lists for the experimental group contained the words plank, prop, reach, ceiling, and floor. Again, some of these words occurred in the control groups' lists, but in different associative contexts. The entire experiment, including memorizing and recalling the lists and attempting the Hatrack problem, was completed within one class hour. Here Judson et al. found the experimental group significantly more likely to produce the correct "ceiling to floor" solution than the control groups.

The most often-used problem in the study of analogical reasoning and informed and spontaneous transfer has been Duncker's (1945) Radiation problem. The problem depicts a situation faced by a doctor who must find a way to use rays to destroy an inoperable tumour in his patient's stomach without destroying the healthy tissue surrounding the tumour. The solution of interest is to simultaneously direct multiple low-intensity rays toward the tumour from varying directions. Much of the research on spontaneous transfer using the Radiation problem has investigated whether previous contact with story analogs, that is, stories which depict situations with similar problem settings, goals and constraints but in different domains, benefit performance on the Radiation problem. For example, one such story is "The General" and describes a general who vows to capture a fortress situated in the middle of a country. There are many roads radiating out from the fortress. All of the roads are mined, so that only small groups of men can safely pass over them. The general's solution is to divide his army into small groups and dispatch each group to the

head of a different road. On his signal, the groups proceed toward the fortress, where they meet and overtake it.

The paradigm typically used first requires participants to read and memorize or summarize the story analog in the guise of a story recall experiment and then attempt the Radiation problem. Informed participants are cued about the possible helpfulness of the story analog; uninformed participants are not. While many of the informed participants produce the convergence solution, significantly fewer uninformed people spontaneously transfer the convergence solution to the Radiation problem, either when the story and problem follow one another immediately (Gick & Holyoak, 1980, Experiment IV), or after a time delay (Catrambone & Holyoak, 1989, Experiments II and III). Furthermore, augmenting the story analog with a statement of the abstract principle underlying the similar solution or by a visual diagram demonstrating the convergence solution does little to significantly increase the ability of uninformed participants to spontaneously transfer the convergence solution (Gick & Holyoak, 1983, Experiments II & III). Indeed, to date, demonstrations of spontaneous transfer using the Radiation problem have been evidenced under only constrained conditions, for example, providing two or more story analogs (Gick & Holyoak, 1983, Experiments IV, V, & VI), presenting instructions with the analogs that help focus participants' attention on important features (Catrambone & Holyoak, 1989, Experiments IV & V), providing analogs which share many salient surface similarities with the problem to be solved (Holyoak & Koh, 1987), and providing a visual diagram that maximizes the presentation of the intensity and summation features that are important to solving the problem (Beveridge & Parkins, 1987).

Overall, the results of research investigating spontaneous transfer are quite surprising. In most of the studies reviewed, the delay between the encounter with relevant information or an analogy and the target problem was minimal, and one might expect that even the demand characteristics of the experiment would suggest an association between the first and second parts of the studies. The results also leave the implicit clue hypothesis on more tenuous scientific grounds. It would seem obvious that presenting a rather blatant, although unannounced, clue to a problem would result in improved problem solving performance, but such a tenet cannot be assumed based on the results of the spontaneous transfer research. Thus, if the “implicit clue” explanation of incubation is to be considered further, subsequent investigation of the hypothesis is in order.

### **Overview of Experiments**

Given the “testable” nature of the implicit clue hypothesis and the need for its further investigation, I began the investigation of the mechanisms involved in incubation by attempting to empirically validate the benefit that an encounter with implicit information related to the problem might have in incubation. It is also important to consider whether the various proposed accounts of incubation might interact with one another to produce the incubation phenomenon. Although the three reviewed hypotheses (unconscious processes or autonomous activation, forgetting fixation, and encounters with implicit clues) represent separate accounts of incubation proposed by different investigators, it is conceivable that a combination of some or all of these mechanisms would best account for the beneficial effects of taking a break from a problem. Thus, three of the four following experiments test for interactions of the implicit clue hypothesis

with a second proposed mechanism of incubation. Given the recent empirical demonstrations of the forgetting fixation hypothesis, I began by examining what role the implicit clue and forgetting fixation hypotheses, and any interaction between them, might play in the incubation effect.

Experiment I, then, investigated the role that fixation and "chance" encounters with implicit clues play in incubation using a multi-item problem set, namely, word fragment completion. The results of this experiment indicated that participants spontaneously benefitted from an implicit clue presented during problem solving. However, no support for the role of forgetting fixation was indicated, possibly due to methodological problems manipulating fixation.

Experiment II continued an investigation of the implicit clue hypothesis with a problem solving set that permitted the presentation of implicit clues during an incubation period. As well, any interaction an implicit clue might have with forgetting fixation was tested by employing methods of manipulating fixation that had been previously demonstrated to be reliable. Results indicated that an implicitly presented clue benefitted performance on some version of each problem. In contrast, again there was no support indicated for the role of fixation.

The support found for the implicit clue hypothesis in Experiments I and II contrasted with the results of the spontaneous transfer literature and motivated the investigation of a new combination of mechanisms proposed to underlie incubation, namely, implicit clues and autonomous spreading activation. Experiment III investigated the role of both implicit clues and autonomous activation in incubation and found that an



interaction between an implicit clue and autonomous activation better accounted for the benefit accrued during a period of time off task over that of an implicit clue alone.

With the role of implicit clues in incubation supported in the first three experiments, Experiment IV focused on a further investigation of the autonomous activation hypothesis, the subject of few, if any, empirical tests to date. Evidence of continuing problem-related spreading of activation after conscious work on a problem has ended was examined. Furthermore, the pattern of such activation over time was observed for both solved and unsolved problems. I predicted that if autonomous spreading activation is involved in the incubation effect, one might expect that such activation should persist longer for unsolved than solved problems. The results of Experiment IV were consistent with this prediction, providing further support for the role of autonomous activation.

## **Experiment I**

Heeding Woodworth and Schlosberg's (1954) advice to begin the study of incubation with the most "testable" hypotheses, Experiment I was designed to further investigate the role that fixation and encounters with implicit clues, and any interaction among these factors, might play in the incubation effect. As noted above, there appears to be evidence both supporting (e.g., Browne & Cruse, 1988; Dreistadt, 1969; Maier, 1931; Mednick et al., 1964) and failing to support (e.g., Beveridge & Parkins, 1987; Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983; Landrum, 1990; Olton & Johnson, 1976; Perfetto et al., 1983; Weisberg et al., 1978) the role of chance encounters with helpful environmental input, necessitating further investigation of this hypothesis.

If consistent support were indicated for the implicit clue hypothesis, however, this might raise some additional questions about other mechanisms hypothesized to be involved in incubation. One important question concerns how much any beneficial effect of incubation would be explained by exposure to the clue itself and what, if any, effects are due to time away from the task. In other words, can the incubation effect be explained by simply providing the opportunity for contact with information related to the problem that might be available in the external environment? If so, then a clue should be equally successful in benefiting performance whether presented with or without a break from the task. Alternatively, clues and time away from the task might produce benefits over and above those of simply receiving a clue to the problem alone.

Given the previous reliable demonstrations of the forgetting fixation hypothesis in the laboratory, one might also wonder how this hypothesis might come into play here.

Perhaps the answer to the above question depends on whether the problem solver is incorrectly fixated on the problem. For example, it may be that when the problem solver is not incorrectly fixated, or is on the right track to solving the problem, relevant information is best presented during continuous problem solving with no incubation period. However, when the problem solver is incorrectly fixated on the problem, it might be better to take her/his mind off the task for a period of time, to allow fixation to decrease, before coming in contact with clues from the environment. In this way, there would be more of an opportunity for relevant information in the environment to spark different representations of the problem, rather than this information becoming somehow integrated into the old incorrect problem representation.

Experiment I compared the influence of an incubation period alone and an incubation period followed by incidental exposure to relevant clues under conditions where participants were either correctly or incorrectly fixated on the problem. The problem solving task employed was word fragment completion (e.g., given “\_l\_r\_ \_et”, participants were to respond with “clarinet”). Fixation was manipulated within-subjects by preceding each of the word fragments with either a relevant associate to the fragment solution (correct fixation) or a misleading irrelevant word (incorrect fixation). In both cases, participants were led to believe that the preceding word would be related to the solution to the fragment. Incubation was manipulated between-subjects; half of the participants took a ten-minute rest break after attempting all of the word fragments once, before attempting unsolved fragments a second time. Half of the participants also received implicit clues to the word fragments; the remaining half did not. The participants who were exposed to

implicit clues received them either after the incubation period or during continuous problem solving with no incubation period. The implicit clues were presented by having participants make lexical decisions to words and nonwords while working on each fragment. The words presented were always helpful and related to the particular word fragment; the nonwords, which closely resembled words, were not relevant to the word fragments.

I predicted a main effect of fixation; that is, participants should perform more poorly on trials where they were incorrectly fixated than correctly fixated. I expected the effect of incubation to vary with correct versus incorrect fixation. The incubation period should improve performance in cases where participants were originally incorrectly fixated on the problem, based on the results of Smith and colleagues (Smith & Blankenship, 1989; 1991; Smith & Vela, 1991). In cases where participants had been correctly fixated on the problem, the incubation period should have less of an effect. With respect to the implicit clue, I expected that being exposed, even incidentally, to helpful information during task completion would improve performance on both correctly and incorrectly fixated trials. However, I also expected that whether an implicit clue was more helpful with or without a preceding incubation period would depend on whether the participant was correctly or incorrectly fixated on the word fragment. In cases where incorrect fixation had occurred, I predicted the implicit clue would be most helpful after an incubation period. Here the incubation period should allow old sets to "die out," permitting the participant to return to problem solving with a fresh mind. The implicit clue might then help the person to think about the problem in a new, more correct way. In contrast, in cases where participants

were previously correctly fixated, it would not be as important for the implicit clue to be presented after an incubation period; it may help equally as much without the time off task.

## Method

### Participants

Sixty University of Waterloo undergraduate students, 28 males and 32 females, volunteered to participate to gain partial credit towards their introductory psychology course. Participants ranged in age from 18 to 54 years, with a mean of 20 years. To volunteer, participants were required to have normal or corrected-to-normal vision and good familiarity with the English language. Thirty participants were assigned to an incubation condition and 30 to a no incubation condition. Half of the participants, 15 in each of the incubation and no incubation conditions, were assigned to the implicit clue condition; the remaining 15 in each of the incubation groups were assigned to a condition where no implicit information was received.

### Materials

The problem solving task used was word fragment completion. The task involved filling in the missing letters to 50 graphemic word fragments to create words, for example, “\_l\_r\_ \_ et” for “clarinet.” Many of the fragments were taken from Tulving, Schacter, & Stark (1982) and Gibson & Watkins (1988), both of which are sources of word fragments having unique solution words, that is, allowing only one legitimate completion. Additional word fragments were also developed to have unique solutions using a 180,000 word-processing dictionary.

To manipulate correct and incorrect fixation, an associated word and a misleading word were developed for each of the word fragments. The associates were highly related to the completed word fragments according to norms of word associations (Palermo & Jenkins, 1964; Postman & Keppel, 1970). For example, the associated word for the word fragment “clarinet” was “flute.” Incorrect fixation was manipulated by using misleading words, which were associates of words other than the completed word fragment they were associated with, or any of the word fragments used in the present study. The misleading word for “clarinet” was “stand.”

To manipulate exposure to implicit information related to the word fragments, clues and non-clues were also developed for each word fragment. The clue words were also associates of the completed word fragments, as reported in Palermo and Jenkins and Postman and Keppel. For example, the clue word for “clarinet” was “reed.” The non-clues were nonwords, designed to closely resemble actual words, that were not relevant to any of the word fragments used. The nonwords were developed by reversing two letters of an actual word. The nonword for “clarinet” was “memorzie.” Appendix A presents a list of the 50 word fragments as well as each of their associated words, misleading words, implicit clue words, and non-clue nonwords.

### Procedure

On entering the laboratory, participants were asked to read over the Information Letter and sign the Consent Form (see Appendix B). Participants were initially told that they would be asked to solve 50 difficult word fragments and that they would see an associate of a solution to the word fragment before each fragment was presented. They

were told to complete the fragment with any correctly spelled word. Participants were given five practice trials to familiarize them with the task; the procedure for the practice trials was identical to the main experiment (see below). The practice trials included only associated and not misleading words, and, if present, a non-clue rather than a clue word. The practice trials and 50 word fragments were completed on a 486 IBM compatible computer using a standard VGA monitor. All stimuli were presented in lower case.

In the main experiment, the order of presentation of the word fragments was randomized for each participant. Each trial began with a fixation symbol, placed centrally on the screen for 1500 milliseconds (ms). Following the fixation symbol, the associated or misleading word was displayed for 700 ms. The presentation of either the associated or misleading word was randomized, except that in the first three trials related associations of the word fragments were always presented. Forty of the 50 word fragments were preceded by an associated word; ten were preceded by a misleading word. Because of the high ratio of associated to misleading words, participants were led to believe by experience that the associates preceding the word fragments were accurate and helpful aids to solving the fragments. It was therefore expected that participants would presume the misleading associate as potentially helpful and become "stuck" or incorrectly fixated on it as a way to think about the answer for the word fragment.

After the presentation of either the associated or misleading word, the word fragment was displayed. If completed correctly, the fragment was removed from the screen after the participant pressed [Enter]. If not completed accurately, the fragment remained on the screen until the maximum time limit had been reached, at which time the

fragment was removed and a new trial begun. Both accuracy and reaction time (RT) to complete the fragments were measured.

The maximum working time limits permitted on the word fragments varied with respect to participants' incubation condition. Half of the participants were assigned to an incubation condition and the remaining half to a no incubation condition. In the incubation condition, participants worked on each of the 50 fragments for a maximum of 30 seconds, took a ten-minute rest interval in which they played a simple computer game, and then attempted again any unsolved fragments, each for another 30-second period. The second 30-second problem solving period proceeded exactly as described above except that the word fragments were not preceded by their associate words. No preceding associated or misleading words were displayed in post-incubation trials. Participants in the incubation condition were informed about it only at the point in time when it occurred. At this time, they were told that another factor of problem solving being investigated was the helpfulness of an incubation period, or break in problem solving. They were told they would take a rest break for ten minutes and then return to solving some more word fragments again. Participants were not told, however, that they would attempt again the fragments not initially solved. Participants in the no incubation group simply worked on each word fragment for a continuous 60-second period with no intervening rest interval.

Half of the participants, 15 in each of the incubation and no incubation conditions, were exposed to implicit clues to the word fragments by responding to a lexical decision task mid-way through their attempt to solve each word fragment. This clue was designed to be implicit in the sense of participants coming across information without having any



prior reason to suspect it may be helpful to the particular problem, similar to what might happen in everyday life. Participants assigned to the implicit clue condition were told, in their initial instructions to the task, that one factor of problem solving being investigated was the effect of disruptions on problem solving performance and that they would receive some disruptions while working on some of the word fragments. They were informed that either a word or a nonword would flash on the screen at some point while they were working on the fragment. They were asked to respond as quickly as they could to identify the letter string as a word or nonword and then get back to solving the main problem, the word fragment. Participants were never explicitly informed of the potential helpfulness of the lexical decision tasks.

The letter strings presented for lexical decision were always presented at 32 seconds into the problem solving on a particular word fragment, regardless of whether an incubation period occurred or not. Thus, for the no incubation group, the letter string occurred 32 seconds into their 60-second continuous attempt at solving the word fragment, provided the fragment had not been solved by this time. In the incubation condition, the lexical decision task occurred two seconds into their second attempt at solving originally unsolved fragments. The letter strings were displayed for 700 ms and appeared in various locations on the screen. Participants responded by pressing “Y” for a word and “N” for a nonword. Once the letter string had been displayed on the screen, the “Y” and “N” were the only characters accepted until one or the other had been pressed. At this point, participants could resume working on the word fragment. Half of the letter strings were words and half were nonwords for fragments originally presented with both associated and

**misleading words. Besides this constraint, the assignment of a word or nonword to a particular word fragment was random. The words were implicit clues related to the particular word fragment the participant was working on. The nonwords, which closely resembled words, were not helpful or relevant to the particular word fragment. Both accuracy and RT to the letter strings were measured. The 30 participants not assigned to the implicit clue condition simply attempted the word fragments with no intervening lexical decision tasks.**

**Participants took, on average, about one hour to complete the entire task. On completion, participants were debriefed about the purpose of the study, including the deception that occurred, and received a written description of the study (see Appendix C). During the debriefing, participants were asked for their perceptions about whether they found the associated words helpful and the incubation period helpful (if assigned to the incubation condition). Participants were also asked if they ever noticed that the words in the lexical decision task were sometimes related to the word fragments.**

### **Results**

**Tables 1a and 1b display the mean percentage of correctly and incorrectly fixated fragments solved before and after 30 seconds, the point before which both incubation and the lexical decision "distracter" tasks were introduced. Analyses tested the predicted effects of fixation, incubation, and implicit clues, as well as the interaction between these factors.**

**Table 1a**  
**Mean Percentage of Fragments Solved Before 30 seconds**

	M	SD
Incorrect Fixation	13.3	11.5
Correct Fixation	60.3	14.4

**Table 1b**  
**Mean Percentage of Fragments Solved After 30 seconds**

	No Incubation				Incubation			
	No Lexical Decision Task		Lexical Decision Task		No Lexical Decision Task		Lexical Decision Task	
	M	SD	M	SD	M	SD	M	SD
Incorrect Fixation	6.7	9.0	6.0	6.3	8.0	8.6	7.3	8.8
Correct Fixation	5.8	4.2	7.5	5.3	4.3	3.3	4.3	2.6

### Fixation

To investigate the success of the fixation manipulation before the introduction of either the incubation or implicit clue manipulations, the proportion of incorrectly fixated fragments solved before 30 seconds was compared to the proportion of correctly fixated fragments solved before 30 seconds (see Table 1). Recall that correct and incorrect fixation were manipulated with the associated and misleading words. A MANOVA contrast revealed a significant effect of fixation,  $F(1,59) = 824.4$ ,  $MS_e = 80.4$ ,  $p < .0001$ , with correctly fixated fragments being significantly more likely to be solved in the first 30 seconds of problem solving than incorrectly fixated fragments.

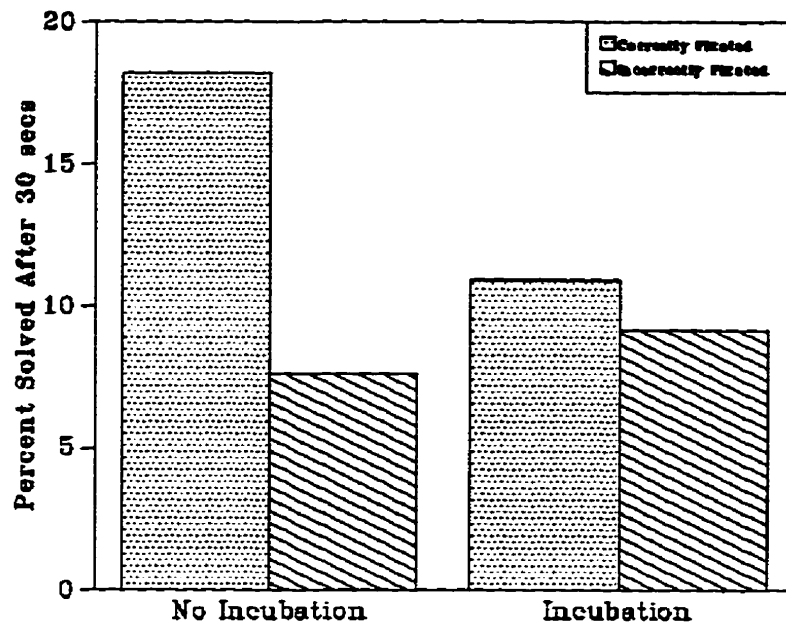
### Incubation

Analyses involving the incubation variable tested improvement scores.

Improvement scores were proportion scores calculated separately for correctly and incorrectly fixated fragments as:

$$\frac{\text{the number of fragments solved only after 30 seconds (i.e., between 30 and 60 seconds)}}{\text{the number of fragments yet unsolved at 30 seconds}}$$

As predicted, a MANOVA with fixation as a within-subjects factor and incubation as a between-subjects factor revealed a significant fixation x incubation interaction [ $F(1,58) = 6.2$ ,  $MS_e = 92.5$ ,  $p < .02$ ]. As shown in Figure 1, however, this interaction was largely due to decreased performance on correctly fixated fragments after an incubation period, rather than to the predicted increased performance on incorrectly fixated fragments after incubation. Separate one-way ANOVAs comparing performance with and without an incubation period were computed for correctly and incorrectly fixated fragments. A significant difference was indicated between the incubation and no incubation conditions for correctly fixated fragments [ $F(1,58) = 7.0$ ,  $MS_e = 111.8$ ,  $p < .01$ ], with significantly more correctly fixated fragments solved in the no incubation than in the incubation condition. Counter to predictions, however, there was no significant difference in the proportion of fragments solved after 30 seconds between the incubation and no incubation conditions for incorrectly fixated fragments [ $F(1,58) < 1$ ,  $MS_e = 93.3$ ,  $p < .54$ ]. Thus, providing a break in problem solving had the most effect on fragments that had been correctly fixated by significantly decreasing performance after incubation; in contrast, interrupting problem solving with an incubation period had little effect on fragments on which participants had been originally incorrectly fixated.



**Figure 1. Mean improvement scores for percent of correctly and incorrectly fixated fragments solved in the no incubation and incubation conditions.**

### Implicit Clue

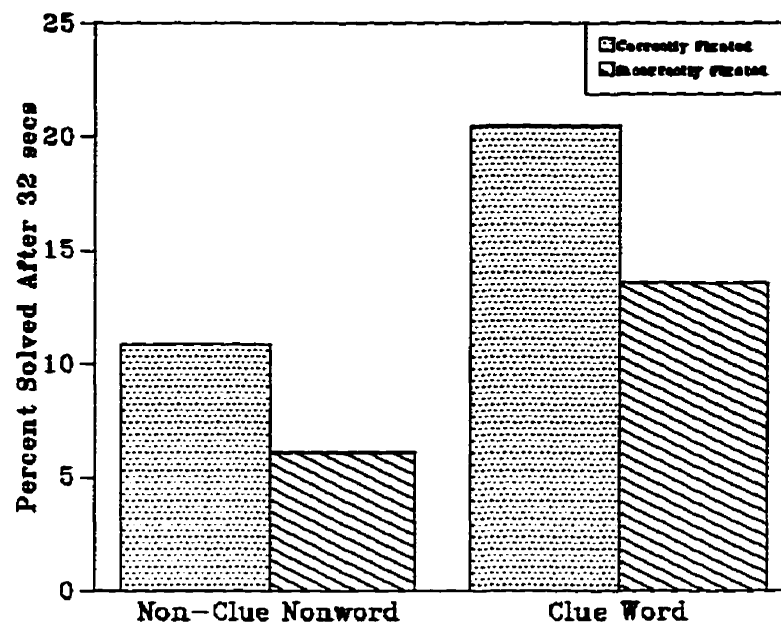
Similar to the incubation factor, analyses involving tests of exposure to implicit clues to the word fragments were tested using improvement scores. Again, improvement scores were proportion scores calculated separately for correctly and incorrectly fixated fragments

as:

$$\frac{\text{the number of fragments solved only after 32 seconds (i.e., between 32 and 60 seconds)}}{\text{the number of fragments yet unsolved at 32 seconds}}$$

The effect of receiving implicit information about currently attempted word fragments was tested in two ways. First, this effect was tested by comparing the lexical decision condition to the no lexical decision condition. Comparisons were made between participants assigned to the lexical decision condition, and thus exposed to both clue words and non-clue nonwords, and participants not assigned to the lexical task condition, and therefore receiving no clue or non-clue words. A MANOVA with fixation as a within-subjects factor and lexical decision task condition (present versus absent) as a between-subjects factor indicated no significant main effects due to participating in the lexical decision task [ $F(1,58) = 1.0$ ,  $MS_e = 104.4$ ,  $p < .31$ ], and no interaction between fixation and lexical decisions [ $F(1,58) < 1$ ,  $MS_e = 100.2$ ,  $p < .61$ ].

Second, predictions about the effects of being exposed to implicit clues were tested using within-subjects comparisons of performance on word fragments where clue words were flashed for lexical decision to performance on fragments where non-clue nonwords were presented for lexical decision. A MANOVA with the two within-subjects factors of fixation and clue type (word versus nonword) revealed a significant main effect of clue type [ $F(1,21) = 6.8$ ,  $MS_e = 233.1$ ,  $p < .02$ ], with fragments having an implicit clue word flashed for lexical decision being more likely to be eventually solved than fragments in which the non-clue nonword had been displayed (see Figure 2). No fixation x implicit clue interaction was found [ $F(1,21) < 1$ ,  $MS_e = 152.2$ ,  $p < .69$ ]. Thus, regardless of whether participants were correctly or incorrectly fixated on a fragment, an implicit encounter with information related to that fragment increased the likelihood of eventually solving it.



**Figure 2. Mean improvement scores for percent of fragments solved when a non-clue nonword versus a clue word were presented as stimulus words in a lexical decision task, presented as a distracter task to participants working on word fragments.**

#### Fixation x Incubation x Implicit Clue Interaction

To test the predicted fixation x incubation x implicit clue interaction that the effect of an implicit clue would vary when presented with versus without a preceding incubation period depending on participants' fixation status, a MANOVA with within-subjects factors of fixation and clue type and a between-subjects factor of incubation was computed. No significant three-way interaction was revealed, however [ $F(1,20) < 1$ ,  $MS_e = 158.7$ ,  $p < .71$ ].

## Discussion

### Forgetting Fixation Hypothesis

#### Incorrect Fixation

Experiment I failed to provide empirical support for the forgetting fixation hypothesis of incubation. This hypothesis explains the problem solver's initial inability to solve the problem as due to incorrect "sets" or fixations in cognitively representing the problem and the beneficial effects of incubation as due to a forgetting of this initial incorrect set. The difference between the percentage of incorrectly fixated fragments solved in the incubation condition (9.2 percent) and no incubation condition (7.7 percent) was minimal and nonsignificant.

This result, of course, stands in contrast with a number of previous studies by Smith and colleagues that have demonstrated improved performance after an incubation period for problems on which participants had been initially incorrectly fixated. The finding is particularly perplexing in light of even more recent work by Smith, Carr, & Tindell (1993 cf. Smith, 1995) that also used word fragments and demonstrated incubation effects. Here Smith et al. manipulated correct and incorrect fixation by exposing participants to a preceding incidental task containing both solutions to some of the subsequent word fragments (correct fixation) and words orthographically similar to fragment solutions that were not the solutions themselves (incorrect fixation). In comparison to the proportion of fragments solved after being exposed to neutral words that were unrelated to the fragment solution, performance on fragments where correct fixation had been induced was elevated and performance where incorrect fixation had been



manipulated was decreased. Smith et al. found an incubation effect for the incorrectly fixated cases; more of the fragments where participants had previously seen the orthographically-similar word were solved on a retest that occurred after a delay than on an immediate retest.

One explanation for the failure to find increased performance after incubation on originally incorrectly fixated fragments in the present study is the possibility that the difficulty level of the word fragments created a type of low ceiling level on the total potential percent of fragments solved that could not be surpassed, regardless of whether incorrect fixation was present or absent. In the case where the participant had been originally incorrectly fixated on the fragment, received an incubation period, and then faced the fragment again, this time with no misleading word, perhaps the participant's failure to solve the fragment had nothing to do with whether they were incorrectly fixated or not, but rather had to do with the high difficulty level of the fragment. Note that losing one's incorrect fixation does not necessarily implicate gaining correct fixation; rather the individual is left without either incorrect or correct fixation, akin to what we might call a baseline level. It is possible that the fragments were very difficult to solve at such a baseline level, with no helpful associated word for guidance. I did, in fact, specifically attempt to select difficult word fragments for the study to ensure that many of the fragments would not be solved during the first 30 seconds of problem solving, so that the manipulations of incubation and implicit clue could be assessed during the later 30 seconds of problem solving. The difficulty level of the word fragments is further supported by the low solution rates of incorrectly fixated fragments. Across all conditions, participants

solved a mean of only 13.3 percent of incorrectly fixated fragments in their initial 30 seconds of problem solving and 20.3 percent over the total 60 seconds. Thus, it is possible that, despite losing the incorrect fixation, participants could not find the correct fixation to solve significantly more of such difficult word fragments.

A second possible explanation for the lack of significant incubation effects for incorrectly fixated fragments is the prospect that the incorrect fixation manipulation was not powerful enough. Although there was a significant difference between the percent of correctly and incorrectly fixated fragments solved in the initial 30 seconds of problem solving (60.3 versus 13.3 percent, respectively), this difference could, conceivably, be due solely to the relevant associate word increasing performance above a hypothetical baseline level, rather than the irrelevant misleading word decreasing performance below baseline. Because there was no condition with no associate word, this baseline level cannot be ascertained and compared to these values in this study.

There were several differences between the way fixation was manipulated in the present study as compared to the Smith et al. study, which did demonstrate positive incubation effects using word fragments. Smith et al. attempted to manipulate “implicit fixation;” participants were not told of any relation between the prior incidental task where they saw the fragment solutions and orthographically-similar “blockers,” yet being exposed to these stimuli affected their later performance. The fixation manipulation here was more explicit: Participants were specifically told that the preceding words should be helpful in solving the fragments. Perhaps it is easier to “do away with” this more explicit type of fixation, after one’s initial attempts at the problem yield no gains. Implicit fixation may

affect participants' representation of the problem more subtly, perhaps without their complete awareness, and may therefore be more difficult to discard.

A second difference between the Smith et al. study and the present experiment in the way fixation was manipulated is the use of orthographic versus semantic fixation. Smith et al. attempted to create incorrect fixation by blocking the correct fragment solution by an orthographically-similar word. In the present study, incorrect fixation was manipulated semantically by preceding fragments with misleading associates to their solutions. It is possible that manipulating fixation on word fragments is more potent orthographically than semantically because of the "data-driven" nature of the problem solving task.

#### Correct Fixation

Although incubation made no significant difference for cases where participants were incorrectly fixated on the word fragments, it did significantly alter performance for correctly fixated cases. When participants had been previously correctly fixated on the fragment, the incubation condition significantly decreased performance compared to cases where no incubation period occurred and participants were permitted to work continuously on the fragment. In the incubation condition, participants would originally be given a relevant and helpful associate to the problem solution and sometime later, after attempting other word fragments and spending ten minutes off task, they attempted the word fragment again. By this time, participants likely had difficulty remembering the associated word and, without it, had more difficulty solving the fragment; in essence, participants here forgot their correct fixation.

This finding may have implications for previous work on incubation. It is possible that when the problem solver is correctly fixated, or is on the “right track” to solving the problem, taking a break from the problem may actually impair performance. Previous literature on incubation, including the literature investigating the influence of fixation on incubation, however, has not discussed any possible detrimental effects of incubation when correctly fixated on a problem. It is possible that some of the previous failures to empirically demonstrate incubation may be partially explained by invoking this explanation: Perhaps the beneficial and detrimental effects of incubation, for problem solvers who are respectively incorrectly and correctly fixated, cancel each other out. The multi-item problem solving task used in the present study, however, would seem to increase the probability of finding impaired performance after incubation when correctly fixated; here it would be very difficult for participants to recall the 50 associate words after working on intervening fragments and taking ten minutes off task. In anecdotal reports of incubation, individuals are most often working on one main larger and more complex problem. It would be interesting to investigate whether similar results of incubation impairing performance on correctly fixated problems occur when using one main problem type, where there is less to “forget” as opposed to a 50 multi-item problem set.

### Implicit Clue Hypothesis

When participants received the clue word during the lexical decision “distracter” task, they solved significantly more word fragments than when they received the non-clue nonword. Thus, participants in this study did spontaneously make use of implicit

information in their environment, a finding which stands in contrast to the bulk of the literature on spontaneous transfer in problem solving. The clue presented was meant to be implicit in the sense of participants not being told of any relation between it and the word fragments; instead they were told it was part of a distracter task. Participants' retrospective subjective reports provide support for this implicit quality; when asked afterwards, many of participants did not recognize any relation between the lexical decision words and the word fragments they were working on and were quite surprised that there was indeed such a relation.

The reports of being unaware of the lexical decision letter strings as clues are consistent with Maier's (1931) finding that few participants reported the "swinging" hint as helpful in leading them to the solution. Such reports support a conclusion that participants have been unconsciously influenced, in the sense of their being unaware of the influence of the lexical clue word on their problem solving behaviour (Bowers, 1987). This finding, however, is inconsistent with Browne & Cruse (1988), who found that knowledge of the clue-value of the implicit hint did affect its likelihood of leading to a solution. Although the implicit clue hypothesis itself does not depend on whether participants are conscious or 'unconscious' of the influence of the clue, the mechanisms through which an implicit clue may affect behaviour pose an interesting question. A post-hoc analysis was computed comparing the percentage of fragments solved with the implicit clue word for participants who later reported noticing a connection between these words and the word fragments and participants reporting being unaware of such a connection. A MANOVA of percentage of fragments solved with a clue word as a within-subjects factor and noticing versus not

noticing as a between-subjects factor indicated no significant main effect of noticing [ $F(1,20) < 1$ ,  $MS_e = 337.1$ ,  $p < .82$ ]. Participants solved relatively equal numbers of fragments with the help of the implicit clue regardless of whether they noticed or did not notice the relation of the clues to the word fragments. Thus, dissimilar to Browne and Cruse, the results of this exploratory analysis seem to indicate that knowledge of this relation is not necessary for its effect.

Although the generalized conclusion from the spontaneous transfer literature suggests that people are unable to spontaneously benefit from an implicit clue or analogy (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983; Landrum, 1990; Perfetto et al., 1983; Weisberg et al., 1978), the present study seems to indicate that participants did just that. Several differences exist between the present study and the research on spontaneous transfer that might help explain these differential findings. One difference concerns the context of presentation of the implicit clue. In the present study, the implicit clue was received in the problem solving context itself, that is, while participants were working on the word fragments. In other studies finding null effects, the clue or analogy is presented in a separate context. The manner of clue presentation in the present study makes it difficult to draw strong conclusions about the implicit clue hypothesis, as it is yet unknown whether a clue presented during a period of time off the problem will also significantly benefit performance. Note, however, that the presence of an implicit clue did not interact with incubation; it was equally beneficial to receive a clue with no incubation as after a period of time off task, suggesting that an implicit clue can be helpful even when not presented during continuous problem solving.

Although this study laid some groundwork by demonstrating that, under some conditions, people can spontaneously make use of implicitly-presented, problem-related information, further research is necessary to investigate whether this process can occur during an incubation period. The problem solving task used in the present study, of course, is less amenable to this design; it would seem a lot to expect that flashing 50 clue words to participants during an incubation period would significantly benefit their performance. Again, it would seem that using larger more complicated problem types would be more useful for this purpose, as implicit clues to the problem could then be presented during the time off task with realistic expectations that memory traces of the clues would be present on returning to the problem.

The context of the presentation of the clue word in the present study may also have implications for the finding, discussed above, that the effect of a clue word on word fragment performance did not depend on a priori knowledge of its clue status. Because of the temporal proximity of the clue word to its associated word fragment, it is very likely that some representation of the clue word, even if faded, persisted after the participant returned to working on the fragment. In Browne and Cruse's study, the implicit clue was presented during the actual incubation period, that is, during a break away from the problem. In this case, it may be more important for the problem solver to be aware of the potential helpfulness of the stimulus on encountering it, so s/he can maintain its representation in active memory, thereby making it available upon return to the problem.

Counter to predictions, the presence of an implicit clue did not interact with fixation or incubation. Thus, both correctly and incorrectly fixated participants benefited

equally from the clue word with no incubation period or immediately after an incubation period. The explanations discussed in the 'Incorrect Fixation' section above, with respect to the difficulty level of the fragments and the possible failure to actually manipulate incorrect fixation, may also be implicated in the failure to find that implicit clues are best presented after an incubation period for incorrectly fixated fragments but with no intervening incubation for correctly- fixated fragments.

In summary, further research is required to clarify several results from the present study. For one, further investigation of the role of forgetting fixation in incubation is necessary to determine if the failure to validate the beneficial role of incubation for incorrectly fixated problems (which stands in contrast to previous work by Smith and colleagues) in Experiment I was due to the difficulty level of the word fragments or difficulties manipulating incorrect fixation with this problem set, or whether such results indicate that forgetting fixation fails to improve performance after incubation in some cases. Secondly, the possible detrimental effects of incubation for problems on which participants are correctly fixated requires further investigation on tasks other than multi-item problem sets which help to guarantee the forgetting of multiple fixations. Finally, to further investigate the implicit clue hypothesis, it would be necessary to determine if people can make use of implicit clues that are presented during an incubation period rather than during problem solving. Experiment II attempted to address these issues.



## **Experiment II**

Experiment II continued an investigation of the role of fixation and implicit clues in the incubation effect. Experiment I's failure to replicate the results of earlier studies demonstrating improved performance after incubation when participants are incorrectly fixated necessitated further investigation of the role of incorrect fixation in incubation. This was attempted in Experiment II by employing, in most cases, previously empirically demonstrated methods of manipulating fixation on frequently used problems. As well, following from the results of Experiment I, the role of incubation in cases where participants are "on the right track," or correctly fixated, in their problem solving was investigated using, in most cases, problems not involving a succession of multiple items. The implicit clue hypothesis was further investigated by determining whether implicit information presented in a separate context during time away from the problem, rather than in the context of the problem solving itself, affected later performance on the problem.

The word fragment completion task of Experiment I was replaced by insight problems. Three well known insight-type problems were used: Duncker's (1945) Candle problem and Radiation problem, and a series of ten Remote Associate Test (RAT) items. The task in the Candle problem is to affix a candle to a wall so that it will burn properly without dripping wax using only a restricted number of objects that includes a box of nails. The solution to the problem is to dump the nails out of the box and attach the box to the wall as a candle holder. The Radiation problem depicts a situation faced by a doctor who must find a way to use rays to destroy an inoperable tumour in a patient's stomach without destroying the healthy tissue surrounding the tumour. The solution of interest is to

simultaneously direct multiple low-intensity rays toward the tumour from varying directions. The RAT items each consist of three words, with the object being to find one word that is related to all three.

Participants were either initially correctly or incorrectly fixated on each problem. As much as possible, this fixation was based on manipulations used in prior research. For example, an early study by Glucksberg & Weisberg (1966) investigated factors affecting functional fixedness on the Candle problem. Using a paper-and-pencil group form of the Candle problem, in their first experiment, Glucksberg and Weisberg had participants attempt the problem in one of three conditions that varied with respect to labels that were provided for the objects in the problem. In one condition, Glucksberg and Weisberg provided labels for all of the objects in the picture, including the candle, tacks, box, and matches. In another condition, only the label "tacks" appeared on the box. Finally, in a third condition, which presented the original form of the problem, no labels were provided. Glucksberg and Weisberg found significant differences between the "all labelled" condition versus the "tacks" only and no labelling groups with a higher number of correct solutions given as the initial solution to the problem in the "all labelled" group. No significant differences were found between groups in the number of total correct solutions given, however, as most people did eventually solve the problem given enough time to do so. Similarly, their second experiment, which used time to solve, rather than percent solved as the dependent variable, and a manipulative, rather than paper-and-pencil problem form, also found the "all labelled" condition solved the Candle problem significantly faster than did the "tacks" only and no labelling groups. Thus, it would appear that labelling all the

objects in this problem helps to direct participants' attention towards the box, the critical object necessary for its solution, thereby inducing correct fixation. In contrast, providing no labelling, or labelling the box only with "tacks," maintains participants' incorrect fixation on the box as only a "holder" of the tacks, rather than as an object to be used independently in the problem.

Each problem in the present study was also presented in a different condition that varied with respect to incubation, and included: (1) a no incubation period, where participants worked continuously on the problem for the full amount of time allotted, (2) an incubation period during which participants worked at an unrelated activity (no clue incubation), and (3) an incubation period in which participants worked at a task containing helpful information relevant to the problem at hand (clue incubation). The related and unrelated activities developed to administer to participants during the incubation period also relied heavily on previous work, in areas such as spontaneous transfer in problem solving. To assess the importance of participants recognizing the clue-value of the incubation activity in benefiting their later performance, participants were interviewed post-experimentally about their awareness of the clues presented during incubation.

Similar to Experiment I, I was interested in the effects of an incubation period, in and of itself, versus an incubation period containing an implicit clue to the problem. I expected the effect of the incubation period alone (i.e., the incubation period that did not include the implicit clue) to vary depending on whether the participant was initially correctly or incorrectly fixated on the problem. Again, according to the forgetting fixation hypothesis, the incubation period, alone, or without a clue, should benefit participants who

were originally incorrectly fixated, because it allows time off task to lose one's fixation. With respect to correctly fixated participants, based on the results of Experiment I, I was interested in whether the incubation period alone would impair performance by interrupting participants when they were on the "right track" to problem solving.

According to the implicit clue hypothesis, however, the results should be different in cases where participants receive a task containing a clue during their incubation period. Here, it might be expected that the incubation period would be helpful regardless of whether the participant was correctly or incorrectly fixated, due to the facilitating effects of coming in contact with the implicit clue. According to Maier (1931) and the results of Experiment I, participants' awareness of the connection between the implicit clue and the problem should be unrelated to the clue's impact on their performance. However, according to Browne & Cruse (1988) whose study more methodologically resembles the present experiment, the clue's ability to benefit performance should depend on an awareness of it.

## Method

### Participants

Eighty-nine University of Waterloo undergraduate students, 56 males and 33 females, volunteered to participate to gain partial credit towards their introductory psychology course. Participants ranged in age from 18 to 44 years, with a mean of 21 years. Participants were randomly assigned to one of nine different "orders," which varied with respect to the presentation order of the problems and the incubation conditions (no incubation, clue incubation, and no clue incubation).

### Materials

The paper-and-pencil version of Duncker's (1945) Candle problem (Glucksberg & Weisberg, 1966), Gick & Holyoak's (1983) version of Duncker's (1945) Radiation problem and a series of ten RAT items, taken from Smith & Blankenship (1991), served as the problem solving tasks.

Correct and incorrect fixation were manipulated separately for each problem. Based on Glucksberg and Weisberg's study, fixation was manipulated for the Candle problem by labelling either all of the objects in the problem, including "candle", "box", "nails", "hammer" and "matches" (correct fixation), or providing only the label "nails" on the box (incorrect fixation). A neutral form of the problem, administered to participants after their incubation period, was also developed and consisted of the exact same problem description and visual picture, but included no labels on any of the objects in the picture (see Appendices D, E, and F for the correct and incorrect fixation and neutral forms of the Candle problem).

The correct and incorrect fixation forms of the RAT items were taken directly from the previous work of Smith & Blankenship (1991) and essentially serve as an attempt to replicate part of this work. Correct fixation was manipulated by providing the first letter of the solution word for each RAT item, which previously has been found to significantly improve performance on these RAT items (Experiment II, Smith & Blankenship, 1991). The written instructions on these problems alerted participants that the initial letter of the solution was provided. Incorrect fixation was induced by placing, in parentheses, next to each of the three RAT stimulus words, a word that was an associate to that stimulus word,

but unrelated and inappropriate to the correct solution word. Here, the written instructions made note that the words in parentheses were examples of the kind of associates that were correct solutions to the problems, as per Smith and Blankenship. The neutral version of the RAT items presented the three stimulus words with no associated words or initial solution letters (see Appendices G, H, and I for the correct and incorrect fixation and neutral versions of the RAT items).

To my knowledge, there has been no previous work manipulating correct versus incorrect fixation on the Radiation problem. In the present study, fixation was manipulated on this problem by directing participants' attention to a single word to "think of" as they worked on the problem. In the correct fixation form, the statement, "Think of: Multiple" followed the problem description; in the incorrect fixation version the word "Intensity" replaced "Multiple." "Multiple" was selected to represent correct fixation because it is a concept critical to the convergence solution, the solution of interest here. "Intensity" was chosen to induce incorrect fixation because it is quite unrelated to the convergence solution and reinforces the incorrect idea that high intensity rays must be used to kill the tumour. In addition, employing high-intensity rays in some way was a solution generated by a number of Duncker's original participants, and therefore may be proficient in "hooking" participants into this line of thinking. In the neutral version, the problem was presented alone with no "Think of" statement (see Appendices J, K, and L for the correct and incorrect fixation and neutral forms of the Radiation problem).

To manipulate exposure to implicit clues during the incubation period, several tasks were developed for participants to work on during their time off the problem. These were

based on tasks used previously in the spontaneous transfer literature. To preserve the implicit quality of clues presented, the tasks were designed to be self-contained and to have as little manifest correspondence with their associated problems as possible.

The incubation task for the Candle problem relied on an earlier study by Weisberg et al. (1978) investigating transfer from learning the paired associate “candle - box” to performance on the Candle problem (see above). In the present study, participants receiving a clue incubation period were asked to commit to memory a list of 20 paired associates, with the last associate being the critical “candle - box” pair, during their break from the Candle problem. In the no clue incubation period, where participants received an incubation period but no implicit clue to the problem, a task identical to the one above was completed, except that the last pair on the list was “candle - paper,” rather than “candle - box.” Twenty paired associates were used, rather than the nine used in the Weisberg et al. study, to ensure a certain level of difficulty and, therefore, a minimum amount of time to complete the task. Because the incubation period was eight minutes long, it was necessary for participants’ time to be filled for the entire eight minutes. All of the pairs were fairly highly associated (for example, “table - chair”), except for the final pair. Both the lower level of association of this last pair and its position in the list were expected to increase its salience to some extent (refer to Appendices M and N for the clue and no clue Paired Associates Tasks for the Candle problem).

“The General” story (Gick & Holyoak, 1980), which depicts how a general dispenses multiple small groups of men down several different roads that intersect at a fortress was used as an implicit hint to the Radiation problem. Participants were first

asked to read the story and then to give a summary of it and make ratings of its plausibility and comprehensibility on a seven-point scale. In the no clue incubation, participants followed an identical procedure, but with a different story unrelated to the Radiation problem. The story used in the no clue condition was “The Identical Twins” and was also taken from Gick & Holyoak (1980) (refer to Appendices O and P for the clue and no clue story incubation tasks for the Radiation problem).

To expose participants to implicit clues to the RAT items, I employed a procedure akin to the early work of Mednick et al. (1964). Simple analogy problems for each of the RAT item solution words were developed. In each case, the solution word was the word to be completed in the analogy. Ten “critical” analogies were developed. An example of a critical analogy is, “Limb : Body as Branch : \_ \_ \_ \_”, as “Tree” is a solution of one of the RAT items. Interspersed with these critical analogies were analogies unrelated to any of the RAT items that served as “buffer” items. Several buffer items were included at the end of the Analogy Task to ensure participants’ incubation time would be filled. Most participants, however, did not solve all of the unrelated buffer items at the end of the task. A similar Analogy Task was developed for the no clue incubation group, consisting of the buffer items included above, as well as additional analogies unrelated to the RAT items (see Appendices Q and R for the clue and no clue Analogy Tasks for the RAT items).

### Design

Each participant received each of the three problems in different conditions that varied with respect to the fixation and incubation factors. In each case, the correct fixation version of the first two problems was presented and the incorrect fixation form was the last



problem attempted. This was done to avoid participants becoming suspicious about misleading information being presented early in the experiment. Each problem was also presented in one of three different incubation conditions: (1) no incubation, which involved only continuous work on the problem, (2) no clue incubation, where performance was interrupted to work at a task unrelated to the problem, and (3) clue incubation, where work on the interpolated activity contained the implicit clue or analogy related to the problem being attempted. The order of these incubation conditions was counterbalanced, so that each condition appeared equally as the first, second, and third problem attempted. As well, the order of the problems themselves was counterbalanced, so that each problem was presented equally as the first, second, and third problem to be solved. This design resulted in nine different orders (see Appendix S) to which participants were randomly assigned.

### Procedure

On entering the laboratory, participants were asked to read over the Information Letter and sign the Consent Form (see Appendix T). Participants were initially told that the study was investigating different factors involved in problem solving and that they would be asked to try to solve a few different problems. As well, participants were told that some of the problems would give them hints about how to think about the problem so as to solve it. Participants were asked to signal the experimenter as soon as they thought they had a possible solution to the problem, before recording it on paper. They worked individually and independently on the problem at a separate table while the experimenter remained in the room. When they indicated having a solution, they were asked to verbally explain their solution to the experimenter. If the solution was incorrect, participants were

informed of this and asked to continue working to find the correct solution. If not solved before the time limit for the problem had been reached, participants were simply told that they would move on to the next problem at this time. If participants' verbal descriptions indicated a correct solution, they were asked to record it on the page and time to solve was recorded by the experimenter. Because participants' verbal explanations of their solution took varying amounts of time to describe, time to solve was recorded at the participants' first mention of a possible solution.

Participants were assigned to one of the above nine "orders" and solved each of the problems in a different condition, with respect to the fixation and incubation factors. Each person attempted the first two problems in a correct fixation form and the final problem in an incorrect fixation version. As well, participants solved one problem in each of the three incubation conditions, namely, no incubation, clue incubation, and no clue incubation. When incubation occurred, participants were informed of it at the point of their break from the problem, if, of course, they had not previously solved the problem. At this point, they were told that one factor of problem solving being investigated was the effect of an incubation period, or taking one's mind off the problem, and that they would be asked to perform another task to take their mind off the current problem. Subsequently, either the problem-related (implicit clue) or unrelated (no clue) activity was administered during an eight-minute incubation period. After either the no clue or clue incubation, participants returned to the neutral version of the problem and continued working for the remaining time. Participants not receiving incubation were involved in continuous work on either the incorrectly or correctly fixated version of the problem for the duration of the allotted time.

The maximum time permitted on the problem and the exact procedure that occurred during each of the incubation periods varied with the problem being attempted, as follows.

In the case of the Candle problem, participants in both of the incubation groups initially worked on the problem for one minute. Because Glucksberg & Weisberg (1966) found that most participants will eventually solve the Candle problem given sufficient time so that the most sensitive measure of performance on this problem is time to solve, I gave participants a relatively short initial working period before incubation was introduced so that factors relating to incubation might be evaluated using measures such as time to solve. During the eight-minute incubation period, participants were involved in either the clue or no clue version of the Paired Associates Task. During the first three minutes, people were asked to read over and memorize the 20 paired associates. After three minutes, the experimenter took the list from the participant and read, as the stimulus words, each of the first words in the pair, in a random fashion, with the critical pair, whether "candle - box" or "candle - paper" always coming last. Participants responded to each stimulus word with the target word, the word they recalled it being associated with. If no response occurred after approximately three seconds, the experimenter went on to the next word.

After this first memory test, participants were handed the list of paired associates again and asked to take one more minute to study the pairs and prepare for a second memory test, "the other way around," that is, with the stimulus word of the previous test now being the target word and vice-versa. In actuality, participants' second study period varied in time, with the end of this period occurring one-and-a-half minutes before the end of the eight-minute incubation period, to ensure that participants were actively involved for

the full eight minutes. At this point, the second and final memory test occurred. Here, the experimenter read as the stimulus words the second words on the list, in a random fashion, again with the exception that the critical pair came last. Participants were then told they would return to the problem they had begun work on previously and were again reminded to signal the experimenter as soon as they had a possible solution. They were then given two more minutes to work on the neutral version of the Candle problem. Participants in the no incubation condition worked on either the correct or incorrect fixation version of the Candle problem for three continuous minutes.

In the case of the Radiation problem, which has been found to be a more difficult problem (Gick & Holyoak, 1980; 1983), participants were given five minutes to work on the problem before being presented with either “The General” (implicit clue) or “The Identical Twins” (no clue) story. In either case, they were asked to read over the story and were told they would be asked to summarize and recall the story after reading it. Each participant signalled the experimenter after reading the story. At this point, a second page, with instructions to give a summary of the story and make ratings of its plausibility and comprehensibility, was administered. The story itself was placed to the side of the participant so that s/he could refer to it if needed. Participants were asked, however, to complete the summary of the story in their own words.

After eight minutes had passed, participants were informed of the end of incubation and their summaries were collected, regardless of their progress. Most participants were able to finish the summaries, but not always the two ratings by this time. If participants did finish their summaries before the end of the eight-minute period, they were asked to

read over their summaries and provide some more details. The justification given to participants for this concerned the need to spend a certain amount of time thinking of something other than the problem, and the requirement that such a time period be consistent for all participants. After incubation, participants were given another five minutes to work on the neutral form of the Radiation problem. Participants in the no incubation condition worked continuously on the correct or incorrect fixation form of the Radiation problem for ten minutes.

The ten RAT items were each initially attempted, consecutively, for one minute. During incubation, participants were asked to complete either the clue or no clue form of the Analogy Task, which they were told involved completing the blanks with the appropriate word and providing a brief explanation underneath for why the word “fit” in the space. Before beginning, participants were also given an example of an analogy. People rarely completed all of the analogies in the space of eight minutes, although most often the “critical” analogies were finished by this time. Again, the task was removed from participants at the end of the eight-minute time limit, regardless of their progress. The Analogy Task was the only task presented during incubation that relied on participants to generate the critical implicit clue word themselves. Thus, it was very important that participants responded with the correct words on critical trials on the clue form of the task. I attempted, on such trials, to make the analogy solutions rather obvious, and, for the most part, participants completed the analogies as expected. However, in some cases, participants chose words other than the critical words to complete the analogies. Thus, after removing the task from participants, the experimenter quickly scanned the critical

items on the task. In cases where critical words were not indicated, short periods of discussion ensued in which the experimenter curiously wondered about the person's reasoning on the particular analogy and then commented that another word for that analogy might be . . . (the critical word). Directly after finishing the Analogy Task, participants were given another minute to re-attempt each RAT item not solved on first attempt. People in the no incubation group simply worked on each RAT item for two continuous minutes in either the correct or incorrect fixation form.

Both accuracy (solved versus unsolved) and solution time were measured for all problems. After attempting all three problems, participants were asked if they had ever heard of or seen any of the problems they had worked on during the experiment. Additionally, they were questioned about their impressions of the incubation period, whether they found it beneficial, and if so, how it may have been helpful. If participants did not spontaneously mention the helpfulness of an implicit clue presented during incubation, they were specifically asked whether they noticed any relation between incubation tasks and the problems they worked on and whether they ever found the incubation task to be helpful in solving a problem. On average, participants took about 50 minutes to complete the experiment. On completion, participants were debriefed about the purpose of the study and the nature of the deception that occurred and were given written feedback about the experiment (see Appendix U).

## Results

Table 2 presents the mean percentage of total problems solved before and after the points at which incubation would occur when presented, collapsed across the fixation and

incubation conditions. Analyses were completed to test the predicted effects of fixation and implicit clues in incubation.

**Table 2**  
**Mean Percentage of Problems Solved Before and After Points of Incubation**

	Candle Problem		Radiation Problem		RAT Items	
	M	SD	M	SD	M	SD
Before	51.1	47.1	42.7	49.7	47.4	29.9
After	36.0	44.6	21.4	41.2	9.7	11.4

### Fixation

To evaluate the success of the fixation manipulation, the percentage of correctly and incorrectly fixated problems solved during initial problem solving (i.e., before the point at which incubation would be introduced) was compared for each of the problems. Table 3 displays the mean percentage of problems solved in the correct and incorrect versions in each of the three problems.

**Table 3**  
**Mean Percentage of Correctly and Incorrectly Fixated Problems Solved Before Points of Incubation**

	Correct Fixation		Incorrect Fixation	
	M	SD	M	SD
Candle Problem	50.0	47.4	52.6	47.2
Radiation Problem	51.9	50.4	28.6	45.8
RAT Items	62.6	23.1	19.0	18.3

Surprisingly, the means for the percentage of incorrectly and correctly fixated Candle problems solved initially did not differ [ $F(1,87) < 1$ ,  $MS_e = 2238.4$ ,  $p < .80$ ]. This result is surprising when contrasted with the results of Glucksberg and Weisberg discussed earlier. One factor possibly influenced this result. As noted in the 'Procedure' section, at the conclusion of the study, participants were asked whether they had seen or heard of any of the problems they had worked on during the study. Participants almost uniformly responded negatively to this question until approximately three-quarters of the way through the experiment. At this point, many of the participants began solving the Candle problem more easily and quickly. Some of these participants also reported reading about it in their introductory psychology text in the course of studying for exams. Thus, it would seem that the problem appeared in students' textbooks, but, for the most part, went unnoticed until the latter part of the term when students began reviewing material for exams. Obviously, when noticed, it significantly increased the participant's likelihood of solving the problem before the point of incubation. A second evaluation of fixation that compared the percentage of correct and incorrect fixation Candle problems solved after eliminating participants who acknowledged seeing the problem in their text ( $N=5$ ) also found a nonsignificant difference between these groups [ $F(1,82) < 1$ ,  $MS_e = 2222.2$ ,  $p < .74$ ]. However, it is possible that other remaining students had read about the problem and had it influence their performance without having an explicit memory for the problem. If this is the case, participants who completed the study earlier in the term and did not initially solve the incorrect fixation version of the problem could be considered "incorrectly fixated." The means of percent of problems solved for the correct and incorrect fixation



forms of the Radiation problem and RAT items did differ significantly,  $F(1,87) = 4.9$ ,  $MS_e = 2370.6$ ,  $p < .03$ , and  $F(1,87) = 82.6$ ,  $MS_e = 464.2$ ,  $p < .0001$ , respectively, with significantly more problems solved initially on the correct fixation than incorrect fixation forms of the problems in both cases.

### Incubation

Differences in percent solved between the incubation conditions (no incubation, clue incubation and no clue incubation) were tested by comparing improvement scores. Similar to Experiment I, improvement scores were calculated as the difference in the solution score before and after the point on the problem where incubation would occur, that is, after one minute for the Candle problem and each of the RAT items and after five minutes for the Radiation problem. More specifically, improvement was calculated as follows:

$$\frac{(\text{Solved after Incubation}) - (\text{Solved before Incubation})}{\text{Not Solved before Incubation}}$$

Differences in time to solve between the incubation groups were also compared in cases where the problem was eventually solved. Time to solve is represented here as the time to solve the problem after the point at which incubation occurred. For each of the three problems, ANOVAs with percent solved or time to solve as the dependent variable and incubation and fixation factors were computed to test the hypothesized effects of incubation alone (incubation with no implicit clue) and incubation involving an implicit clue, and their interaction with fixation.

Candle Problem

Tables 4 and 5 present the mean improvement scores and time to solve correctly and incorrectly fixated Candle problems in each of the incubation conditions.

**Table 4**  
**Mean Percent of Candle Problems Solved After Point of Incubation**

	Correct Fixation		Incorrect Fixation	
	M	SD	M	SD
No Incubation	66.7	45.0	42.9	34.5
No Clue Incubation	30.0	44.7	28.6	39.3
Clue Incubation	75.0	37.8	71.4	48.8

**Table 5**  
**Mean Time to Solve (in seconds) Candle Problem After Point of Incubation**

	Correct Fixation		Incorrect Fixation	
	M	SD	M	SD
No Incubation	30.3	25.0	75.0	36.7
No Clue Incubation	102.3	34.8	91.8	41.5
Clue Incubation	74.5	42.2	21.8	22.5

An ANOVA contrast of percent of Candle problems solved revealed a significant main effect of incubation [ $F(2,43) = 3.5$ ,  $MS_e = 1791.8$ ,  $p < .04$ ], but no incubation x fixation interaction [ $F(2,43) < 1$ ,  $MS_e = 1791.8$ ,  $p < .71$ ]. One-way contrasts of the

incubation factor indicated two significant differences between groups: (1) more Candle problems were solved in the no incubation condition (59 percent) than in the no clue incubation condition (29 percent) [ $t(46) = 2.0, p < .05$ ], and, (2) more problems were solved in the clue incubation (73 percent) than in the no clue incubation condition (29 percent) [ $t(46) = -2.7, p < .009$ ]. No reliable differences, however, were found between the clue and no incubation groups, although the means did differ, especially in the incorrect fixation condition (see Table 4).

An ANOVA contrast of time to solve the Candle problem revealed a significant main effect of incubation [ $F(2,32) = 7.1, MS_e = 1146.3, p < .003$ ], and a fixation  $\times$  incubation interaction [ $F(2,32) = 6.7, MS_e = 1146.3, p < .004$ ]. One-way contrasts clarified the main effect of incubation as paralleling the percent solved results: Participants in the no clue incubation condition took significantly longer to solve the Candle problem than both those in the no incubation group [ $t(35) = -3.2, p < .003$ ] and the clue incubation group [ $t(35) = 2.5, p < .02$ ]. Again, the clue incubation condition did not differ reliably from the no incubation condition.

This main effect of incubation for time to solve the Candle problem was moderated by a fixation  $\times$  incubation interaction, however. The incubation condition yielding the fastest performance on the Candle problem depended on whether the problem had originally been presented in the correct or incorrect fixation form. For incorrectly fixated cases, participants solved the problem significantly faster when given a clue incubation than no incubation [ $t(12) = 2.4, p < .03$ ], or no clue incubation [ $t(12) = 3.2, p < .008$ ]. In contrast, when correctly fixated, participants solved the problem significantly faster when

they received no incubation than when they were given either a clue incubation [ $t(20) = -2.8, p < .01$ ], or a no clue incubation [ $t(20) = -3.7, p < .001$ ] (see Table 5).

### Radiation Problem

Tables 6 and 7 present the mean improvement scores and time to solve correctly and incorrectly fixated Radiation problems in each of the incubation conditions.

**Table 6**  
**Mean Percent of Radiation Problems Solved After Point of Incubation**

	Correct Fixation		Incorrect Fixation	
	M	SD	M	SD
No Incubation	22.2	44.1	25.0	46.3
No Clue Incubation	25.0	46.3	25.0	46.3
Clue Incubation	44.4	52.7	55.6	52.7

**Table 7**  
**Mean Time to Solve (in seconds) Radiation Problem After Point of Incubation**

	Correct Fixation		Incorrect Fixation	
	M	SD	M	SD
No Incubation	261.0	8.5	91.5	92.6
No Clue Incubation	235.5	77.1	33.5	23.3
Clue Incubation	57.7	96.6	80.8	97.7

Although the percentage solved in the clue incubation condition differed in magnitude from the other incubation conditions (see Table 6), an ANOVA contrast of percent solved on the Radiation problem yielded no significant effects for incubation

[ $F(2,45) = 1.6$ ,  $MS_e = 2333.3$ ,  $p < .20$ ] or the incubation  $\times$  fixation interaction [ $F(2,45) < 1$ ,  $MS_e = 2333.3$ ,  $p < .94$ ].

An ANOVA contrast of time to solve the Radiation problem revealed no main effect for incubation [ $F(2,11) = 2.1$ ,  $MS_e = 7393.9$ ,  $p < .17$ ], but a tendency towards significance for the fixation  $\times$  incubation interaction [ $F(2,11) = 3.1$ ,  $MS_e = 7393.9$ ,  $p < .08$ ]. Given this strong tendency towards significance and my a priori predictions regarding the interaction between fixation and incubation, further one-way contrasts of incubation were computed separately for time to solve correctly and incorrectly fixated Radiation problems. Results of these contrasts indicated no significant differences between any of the incubation groups when participants were incorrectly fixated on the problem. When correctly fixated, however, they solved problems in the clue incubation condition significantly faster than in the no incubation [ $t(5) = 2.8$ ,  $p < .04$ ] and no clue incubation [ $t(5) = 2.5$ ,  $p < .05$ ] conditions (see Table 7).

#### RAT Items

Tables 8 and 9 present the mean improvement scores of RAT items and the time to solve correctly and incorrectly fixated RAT items in each of the incubation conditions.

**Table 8**  
**Mean Percent of RAT Items Solved After Point of Incubation**

	Correct Fixation		Incorrect Fixation	
	M	SD	M	SD
No Incubation	29.2	31.3	11.6	17.3
No Clue Incubation	18.8	29.0	17.2	14.8
Clue Incubation	19.5	23.8	25.3	21.7

**Table 9**  
**Mean Time to Solve (in seconds) RAT Items After Point of Incubation**

	Correct Fixation		Incorrect Fixation	
	M	SD	M	SD
No Incubation	21.6	15.8	19.8	17.5
No Clue Incubation	18.9	15.2	24.8	12.2
Clue Incubation	19.1	14.0	22.3	11.5

An ANOVA of percent RAT items solved revealed a nonsignificant main effect of incubation [ $F(2,81) < 1$ ,  $MS_e = 634.9$ ,  $p < .78$ ] and a nonsignificant fixation x incubation interaction [ $F(2,81) = 1.5$ ,  $MS_e = 634.9$ ,  $p < .23$ ]. One-way contrasts of incubation for correctly and incorrectly fixated problems revealed a tendency for participants incorrectly fixated on RAT items receiving the clue incubation condition to solve more items than participants receiving no incubation [ $t(28) = -1.7$ ,  $p < .10$ ]. No significant differences between the incubation conditions were indicated when participants were correctly fixated (see Table 8).

An ANOVA of time to solve RAT items also indicated no significant main effect of incubation [ $F(2,41) < 1$ ,  $MS_e = 206.1$ ,  $p < .97$ ] nor a fixation x incubation interaction [ $F(2,41) < 1$ ,  $MS_e = 206.1$ ,  $p < .78$ ].

#### Noticing the Implicit Clue

Analyses were also completed to examine the effects of recognizing versus not recognizing the clue value of the implicit-clue incubation activity on subsequent performance on each of the three problems. Following their participation, participants

were interviewed about whether they had noticed that the activity presented during incubation was sometimes related to or helpful in solving the problem they had been working on. Answers to this question were scored dichotomously; that is, any report of awareness of the incubation task as a clue was scored positive, whereas reports of no awareness of this relation were scored negative. Tables 10 and 11 display the mean percent solved and time to solve (after the point of incubation) for participants who were both aware and not aware of the incubation activities as a clue to each of the three problems.

**Table 10**  
**Mean Percentage Solved After Points of Incubation for Participants Aware and Not Aware of Incubation Task as a Clue**

	Aware		Not Aware	
	M	SD	M	SD
Candle Problem	78.6	39.3	68.8	45.8
Radiation Problem	80	44.7	38.5	50.6
RAT Items	16.7	0.0	21.6	23.3

**Table 11**  
**Mean Time to Solve (in seconds) After Points of Incubation for Participants Aware and Not Aware of Incubation Task as a Clue**

	Aware		Not Aware	
	M	SD	M	SD
Candle Problem	53.4	49.7	55.2	40.5
Radiation Problem	28.8	51.5	103.8	108.3
RAT Items	22.0	0.0	20.4	13.1

### Candle Problem

ANOVA contrasts for the Candle problem revealed no effects of recognizing the “candle-box” pair as a clue to the problem on the percentage of problems solved [ $F(1,13) < 1$ ,  $MS_e = 1844.1$ ,  $p < .67$ ] or time to solve [ $F(1,11) < 1$ ,  $MS_e = 2096.2$ ,  $p < .95$ ]. Recall, however, the problem of a high level awareness of this problem in general (see above).

### Radiation Problem

Participants who reported finding “The General” story helpful in solving the Radiation problem solved a greater number of problems, but this difference was not significant [ $F(1,16) = 2.6$ ,  $MS_e = 2423.1$ ,  $p < .13$ ]. No significant difference was indicated in the mean time to solve the Radiation problem between participants who recognized the story as a clue and those who did not [ $F(1,7) = 1.6$ ,  $MS_e = 7840.8$ ,  $p < .25$ ].

### RAT Items

Only one participant reported noticing any relation between the Analogy Task and the RAT items. Thus, no significant differences were found in percent solved [ $F(1,25) < 1$ ,  $MS_e = 543.9$ ,  $p < .84$ ] or time to solve [ $F(1,14) < 1$ ,  $MS_e = 171.9$ ,  $p < .91$ ] between the participant who noticed the clue quality of the task and those who did not.

## Discussion

### Forgetting Fixation Hypothesis

#### Incorrect Fixation

Minimal support was indicated for the forgetting fixation hypothesis. This hypothesis predicts that a break from the problem, in and of itself, serves to allow originally incorrect ways of thinking about the problem to be forgotten, thereby resulting in



improved performance on a retest. None of the three problems studied here indicated increased performance, with respect to either percent solved or time to solve, on incorrectly fixated problems after an incubation period filled with activity unrelated to the problem. Of course, interpretations invoking the role of incorrect fixation on the Candle problem are complicated by the failure to demonstrate differential initial performance on the correct versus incorrect versions and therefore questions about whether incorrect fixation was ever manipulated. Note, however, that several other findings were indicated between incubation groups within both the incorrect and correct versions of the Candle problem, suggesting that there is some empirical difference between the two versions. Furthermore, the results in the no clue incubation condition for the Candle problem are consistent with results from the other two problems: In no case did participants' performance benefit from receiving an incubation period alone.

Again, the results of no improved performance after an incubation period alone stand in stark contrast to previous work by Smith and colleagues. Especially surprising is the failure to replicate Smith & Blankenship (1991) using their same materials. One possibility always prevalent in failures to replicate is a difference in the power, which is influenced in part by number of observations. Smith and Blankenship used 20 RAT items, whereas the present study employed only ten. However, I also more than doubled the sample size used in the Smith and Blankenship study (89 versus 39 participants, respectively). Although the method of the present study very closely paralleled that of Smith and Blankenship, some slight differences in methodology were present. One such difference concerned the nature of the task completed during the incubation period.

Participants in Smith and Blankenship's study read a science fiction story during incubation whereas participants in the present study completed the unrelated Analogy Task. The Analogy Task designed for the incubation period in the present study is, in many ways, quite similar to the RAT items, as both are associate word problems. This similarity, in fact, was noted by several participants. It is possible that incubation activities competing for the same types of cognitive processing required by the problem itself actually interfere with the beneficial effects of the break from the problem. This, of course, would especially be the case when the incubation period was not helpful in the sense of containing an implicit clue to the problem.

Consistent with this possibility, Patrick (1986), using the RAT as his problem solving measure, studied the effect of incubation periods filled with either other RAT problems or with unrelated spatial rotation tasks for high- and low-ability participants. Patrick found a significant effect of incubation for high-ability participants when they were given the unrelated spatial tasks during incubation, but not when given the similar RAT problems. Note, however, that an interpretation that similar incubation activities compete with cognitive processes related to the original problem and thereby lessen the incubation's beneficial impact leads to a different way of thinking about the function of the incubation period than does the account given by the forgetting fixation hypothesis. According to this hypothesis, all that occurs over incubation is forgetting; the more one forgets, the better. Therefore, competing incubation activities that "block" one's initial work on the problem should only benefit later performance, according to this explanation. If, however, incubation tasks similar to the problem compete and thereby impair later performance on

the problem, it would appear that it is important for some things not to be forgotten, or to be maintained over incubation. I will return to this idea in Experiment III.

Although performance did not improve on incorrectly fixated problems after an incubation period alone (that is, a break filled with an unrelated activity) in two of the three problems, it did improve after an incubation period containing an implicit hint. The clue incubation period significantly decreased the time taken to solve the incorrectly fixated version of the Candle problem and had a tendency to increase the percent of incorrectly- fixated RAT items solved. It is possible, then, that a hint embedded in time away from the problem is especially helpful when one is incorrectly fixated on the problem. Perhaps the break allows old sets to be forgotten so that the clue might spark new and more correct sets to the problem. Of course, to maintain such a conclusion, it would be necessary to compare an implicit clue condition both with and without an actual break from the problem, a comparison the present study did not make. Inconsistent with this interpretation, however, is the result that clue incubation benefitted problem solving performance the most on the Radiation problem when participants were correctly, rather than incorrectly fixated. Integrating this last finding into an understanding of the benefit of the clue incubation might suggest its impact varies with problem difficulty, rather than with correct or incorrect fixation. It would appear that on easier problems (the Candle and RAT problems) the implicit clue incubation was most helpful on the incorrect fixation form of the problem. The correctly fixated version of these problems made relatively easy problems even easier and they benefitted little or not at all from clues. However, on a more difficult problem, the Radiation problem, the clue incubation significantly benefitted

performance on the correct but not on the incorrect fixation version. Here, correct fixation likely brought down the difficulty level of the problem to an average level, but not to such an easy level that it could not benefit from clue incubation.

### Correct Fixation

Some, albeit inconsistent support was indicated for the proposition that an incubation period may actually impair performance when the problem solver is on the “right track.” Correctly fixated Candle problems were solved significantly faster when participants worked on the problem continuously than when they were interrupted with either a no clue or clue incubation period. Of course, again, the results concerning correct and incorrect fixation on the Candle problem must be interpreted with caution due to the failure to empirically demonstrate initial differences in performance between the two versions. The fact that even an incubation period containing an implicit clue to the problem impaired performance, however, strengthens the idea that, for some problems, the problem solver is really better left working than interrupted for a break. Participants’ performance on correctly fixated problems was not significantly impaired by incubation on either the Radiation or the RAT problems, although the means for both the percent solved and time to solve were in the right direction for the no clue incubation versus no incubation conditions on correctly fixated RAT items.

### Implicit Clue Hypothesis

Some support was also indicated for the implicit clue hypothesis. Incorrectly fixated participants solved the Candle problem significantly faster when given an incubation period containing an implicit clue than when no incubation occurred. The

means for the percent of Candle problems solved were also in the predicted direction, for both correct and incorrect fixation, with more problems solved with clue incubation than no incubation, but the differences here did not reach significance. On the Radiation problem, correctly fixated participants reached a solution significantly faster when given a hint during incubation than when they simply worked continuously. Again, the means for both the percent of correctly and incorrectly fixated Radiation problems solved were in the predicted direction, but were not significantly different. Finally, there was a non-significant tendency for participants incorrectly fixated on the RAT items to solve more problems when given a clue incubation period than when no incubation occurred.

Thus, on some versions of the above problems, participants benefitted from the presence of an implicit clue presented during a break from the problem. Participants were uninformed about the clue; they had no awareness or reason to suspect that the filler activity performed during incubation contained a clue to the problem. Thus, any use of the clue on their part was spontaneous. Furthermore, unlike Experiment I, this spontaneous use occurred in the context of a break from the problem, rather than during problem solving, increasing its generalizability to 'real life' settings. It would seem that a clue presented even during a period of time off the problem can significantly benefit performance.

Similar to Experiment I, noticing and reporting the relevance of the implicit clue did not significantly improve its influence on problem solving performance. ANOVAs of percent solved on all three problems indicated no significant differences between noticing and not noticing the relation of the clue to the problem. Results were similar using time to

solve, even though this is the variable on which significant differences between the implicit clue incubation and no incubation were found. Unfortunately, the results of these analyses for the Candle Problem are thwarted due to the high level of awareness on this problem overall, as knowledge about the solution to the problem itself eliminates the usefulness of any clue. However, the results of the Radiation Problem and RAT items contrast with Browne and Cruse's (1988) findings, and indicate that even when the implicit clue is presented in a context separate from the problem, awareness of the relation between the clue and the problem is not necessary for the clue's later influence on problem solving performance. This, of course, is not to say that being aware of that relation would not improve such performance, but only that benefits to performance can also occur when the problem solver is reportedly unaware of the relevance of the clue event to the problem.

Although all of the problem types indicated a higher percentage of problems solved in the clue incubation than no incubation conditions on either the incorrectly fixated or both the incorrect and correct fixation versions, the differences were never significant. The failure of most of these differences to reach significance is surprising, considering the magnitude of differences between conditions often involved. Likely contributing to this null finding is a small sample size. Although 89 students participated in the study, each participant contributed only one of six possible observations to each problem (incorrect/correct fixation x no incubation/no clue incubation/clue incubation).

Furthermore, many of the problems were solved before incubation, eliminating them from further analysis. The final sample size per cell averaged around eight. It would appear that time to solve, however, is a more sensitive variable, as reliable differences between

groups on this variable were indicated despite such small sample sizes.

The effect of the implicit clue did not reach significance on all three problems; as noted above, there was only a tendency for clue incubation to improve performance on the RAT items. This constitutes a non-replication of Mednick et al. (1964), who found that a subset of unsolved RAT items that was associatively primed, using analogies, during an incubation period, was significantly more likely to be solved on a retest than items not primed. Of course, Mednick et al. did not attempt to originally incorrectly fixate people by presenting misleading words with each stimulus word. However, it is difficult to conceive how this would diminish the effects of a clue incubation, as according to other theorizing (Smith & Blankenship, 1989; 1991; Smith et al., 1993 cf. Smith, 1995; Smith & Vela, 1991), incorrectly fixated participants should benefit most from this. Mednick et al., however, chose only five originally unsolved items to associatively prime, and presented participants with only five analogies to complete, all of which related back to earlier unsolved RAT items. In contrast, in the present study, participants had up to ten items associatively primed by the analogies, depending on the original number left unsolved. Furthermore, these items were embedded in a number of buffer analogies, that is, analogies unrelated to the RAT problems altogether. It seems, then, that receiving implicit hints for multi-item problems is less influential than receiving a hint for one main larger-type problem and that embedding clues for multi-item tasks in non-relevant material weakens their effect on performance.

In addition, the implicit clue did not significantly benefit performance on all versions of all three problems; instead it was specific to either the correct or incorrect

versions, depending on the particular problem. One way of understanding these results, as mentioned above, invokes the concept of problem difficulty. It would seem that an implicit clue embedded in an incubation period is most beneficial to problems of medium-level difficulty, which here represent the incorrect fixation version of the easier problems (the Candle and RAT problems) and the correct fixation form of the more difficult Radiation problem. Providing a clue incubation to very easy problems has the potential of disrupting performance, whereas very difficult problems will rarely be solved, even with the help of clues. Thus, it would seem that in laboratory investigations, people can spontaneously make use of related and helpful information they encounter in their environment on a break from solving larger, more complex-type problems of medium-level difficulty.

It is also interesting to consider whether the results regarding the effect of an implicit clue differ from those of the spontaneous transfer literature. Although the means of percent of problems solved were in the predicted direction, only the results of time to solve were significant in the present experiment. Previous investigations of spontaneous transfer on the Candle problem (Weisberg et al., 1978) and Radiation problem (Gick & Holyoak, 1980; 1983; Catrambone & Holyoak, 1989) have similarly failed to find that clues or analogies significantly improve the percent of problems solved, but these studies did not make such evaluations using time to solve. As noted above, the tests of percent of problems solved between the implicit clue incubation and no incubation groups in the present study may have failed to reach significance because of small sample sizes. Furthermore, a comparison of the means of percent of problems solved reported by these



investigators to the means obtained here suggests some differences. For example, Weisberg et al.'s uninformed implicit-hint group solved 15 percent more Candle problems than their control group; in the present study, a gain of 28 percent was made in the clue incubation versus no incubation conditions for the incorrectly fixated version, the form most similar to the problem presented by Weisberg et al. Similarly, Gick & Holyoak's (1983) uninformed implicit-hint participants improved 20 percent over their baseline control; in the present study, incorrectly fixated participants improved by 31 percent with clue incubation over no incubation.

If the differences between the means reported by Weisberg et al. and Gick and Holyoak and those obtained here do represent true differences between the studies, it is possible that some methodological difference between the studies accounts for these differences. A number of plausible explanations exist, including differences in problem presentation, slight differences in the wording of instructions to participants, small variations in the time allowed to work on the problem, and so on. However, for the most part, the methodology used in the present experiment paralleled quite closely that used in the earlier studies, except for one main difference: the timing of the clue or analogy. The typical paradigm in research on spontaneous transfer -- and the one used in both the Weisberg et al. and Gick and Holyoak studies -- is to present participants with the implicit clue or analogy before they are given the problem. Because my interest was in studying the relevance of contact with helpful information in the incubation effect, this information was presented after some initial work on the problem in the present study. Perhaps the effect of implicitly presented information relevant to a problem is different when the same

information is presented after some initial struggle with the problem than before any contact with it. It is to this question that I turn next.

### **Experiment III**

Experiment II raised the question of whether an implicitly presented clue provided in an incubation-type setting after an initial period of working on the problem would produce greater benefits than the same clue presented before contact with the problem. Also unconsidered to this point has been the 'spreading activation' hypothesis of incubation (Dorfman et al, 1996), the idea that, after an initial working period, problem-related activation may continue to spread during an interval in which the problem solver is no longer actively thinking about the problem.

Yaniv & Meyer (1987) proposed an explanation of incubation that relates to both of the above issues. They based their hypothesis on results from a laboratory study using a rare-word definition task. Participants first attempted to generate a rare word from its definition and made confidence ratings and feeling-of-knowing judgments. Some time later, participants were presented with definition words they had answered correctly, incorrectly, or never-retrieved, as well as other words and nonwords, in a lexical decision task. Expectedly, Yaniv and Meyer found facilitation effects for the correctly-retrieved words on the lexical decision task. Interestingly, however, they also found priming effects for the never-retrieved, but not for the incorrectly-retrieved, words. These priming effects varied with participants' feeling-of-knowing judgments, with greater priming effects for never-retrieved words that had higher rated feelings of knowing. Such results were indicated when the lexical decisions were made both one and four minutes after originally working on the definition. Furthermore, Yaniv and Meyer (Experiment 2) also included an 'Old/New' recognition task, in which the definition words and other words were presented

for recognition discrimination 30 minutes after exposure to the original definitions, and again found priming effects for the unretrieved definition words.

Based on these results, Yaniv and Meyer developed the 'Memory Sensitization' hypothesis of incubation. This hypothesis proposes that initial work on a problem partially activates memory traces appropriate to solving the problem. During an ensuing incubation period, this partial activation then sensitizes the person to encounters with events or inputs in their environment that relate to the problem. Contact with such information can result in the initially activated memory traces being raised above conscious thresholds. Note that this description of events places a good deal of emphasis on the residual partial activation that relates to the problem and implies that environmental inputs will have varying effects depending on the timing of their presentation. This is because the residual, partial problem-related activation plays a role by sensitizing the problem solver to "pick up" on relevant information available in his or her surroundings. Such residual activation, of course, is available only after some initial work on the problem.

To my knowledge, there are very few studies directly investigating the effect of the timing of clue presentation on problem performance. Of the studies that do, most deal with explicitly-presented hints rather than the implicitly-presented clues of interest here. Burke, Maier, & Hoffman (1966) investigated the importance of the timing of explicit hints on Maier's (1945) Hatrack problem. Burke et al.'s hints consisted of informing participants that either the ceiling is part of the construction or that the clamp is used as the hook in the correct solution. These hints were given either at the outset before initial problem presentation, or after 30 minutes of problem solving. Burke et al. found a

nonsignificant trend, for both hints, for better performance in the 'before' than in the 'after' condition.

Maier & Burke (1967) also investigated the effectiveness of the above ceiling and clamp hints on the Hatrack problem when presented at different points during problem solving. Participants were informed about the role played by the ceiling or clamp either at the outset, or 5 or 15 minutes after working on the problem. Participants in the delayed clue conditions who solved the problem before clue presentation were eliminated from the analysis. Each participant was allowed 20 minutes after receiving the hint to work on the problem. The performance in each of the three experimental groups was compared to a control group that equated the time spent on the problem. For the ceiling hint, the five-minute delay clue condition showed the most gain compared to its control, but the differences between this group and the 15-minute delay and outset clue groups were not significant. No differences in performance were evident across the different times of presentation for the clamp hint.

In both of the above studies, the hints given were explicit as opposed to implicit. It is quite possible that the timing of hint presentation interacts with hint explicitness. According to Yaniv & Meyer's (1987) Memory Sensitization hypothesis, residual activation from initial work on the problem serves to sensitize problem solvers to problem-relevant information in their environment. Of course, the role of such 'sensitization' is considerably downplayed when one knows, quite explicitly, that certain information is related to and will be helpful for solving the problem. Instead, such partial sensitizing activation will be most important with implicit hints where the problem solver is not aware of the relevant

information in the environment and must spontaneously make use of it. Explicitly presented hints may be most effective when presented at the outset of the problem where they can guide early thinking about the problem. Gick & Holyoak (1980, Experiment V) directly compared the effect of presenting “The General” story analogy before and after some initial period of work on the Radiation problem when participants were not explicitly informed that the story provided a clue to the problem. They found no significant differences in performance in the before and after conditions. However, participants in the delayed-clue condition who solved the problem before clue presentation were eliminated from the analysis, whereas no similar adjustments were made in the before-clue condition. Such an adjustment results in a biased comparison in favour of the before-clue condition. Here, the before-clue condition includes both participants who would have solved the problem on their own with no clue as well participants who solved the problem with the help of the clue; the delayed-clue condition includes only participants who solved the problem with the help of a clue, and excludes participants who solved the problem on their own before the clue presentation. Furthermore, as discussed above, laboratory investigations of the implicit clue hypothesis seem most amenable to medium-level difficulty problems. In contrast, the original form of the Radiation problem is a very difficult problem, with only ten percent of controls reaching a solution.

Antonietti, Cerana, & Scafidi (1994) investigated the effects of mentally visualizing a problem before and after attempting the problem on the performance of arithmetic, geometric, and practical problems. In an ‘imagery-before’ condition, participants were asked to visually imagine the situation and stimuli that they were then presented with in

the problem they subsequently attempted. In an 'imagery-after' condition, participants were presented with the problem and then asked to visualize the problem before attempting a solution. In general, Antonietti et al. found stronger effects of mental visualization in the imagery-after than in the imagery-before condition; this effect was most pronounced for problems which originally induced functional fixedness, such as the Candle and Two-String problems. Antonietti et al. also found that the effectiveness of the visualization was modulated by the difficulty of the problem; positive effects of mental visualization were greater when the problem was less difficult.

In Experiment III, I attempted to clarify the above mixed results concerning the timing of an implicitly presented clue and its implications for the mechanisms of incubation. Using a within-subjects design, implicit hints presented before and after contact with the problem were compared to a no-hint control condition. Participants attempted three insight problems, one in each of three clue conditions: clue before, clue after, and no clue. Again, the hints to the problems were presented in the guise of separate tasks, and were often referred to as problems themselves.

If sub-awareness activation relating to the problem sensitizes the problem solver to relevant information or clues in the environment, an implicitly-presented clue will benefit performance most when presented after some preliminary work on the problem has initialized such activation than when presented before any work on the problem has occurred.

## Method

### Participants

Sixty-three University of Waterloo undergraduate students, 17 males and 46 females, volunteered to participate to gain partial credit towards their introductory psychology course. Participants ranged in age from 17 to 25 years, with a mean of 19 years. Participants were randomly assigned to one of nine different “orders,” which varied with respect to the presentation order of the problems and of the clue conditions.

### Materials

A paper-and-pencil version of Maier’s (1931) Two-String problem and Maier’s (1945) Hatrack problem (here termed the Coat-Rack problem; see Appendices V and W) and the correct fixation version of the Radiation problem used in Experiment II (see Appendix J) served as the three insight problems in Experiment III. Although I had initially intended to include the Candle problem, the Hatrack problem was substituted after discovering that three of the four introductory psychology classes’ assigned textbooks included a discussion of the Candle problem. Introductory psychology professors were contacted and indicated no plans to discuss the above three problems in class.

Again, exposure to implicit clues was manipulated by developing separate tasks with embedded clues. As in Experiment II, “The General” story (Gick & Holyoak, 1980; see Appendix O) served as the implicit hint to the Radiation problem. Participants were asked first to read the story and then to give a summary of it and make ratings of its plausibility and comprehensibility on a seven-point scale.



Analogies, similar to the analogies presented for the RAT items in Experiment II, were developed to present implicit hints for the Two-String problem. Based on Judson et al. (1956), which measured participants' performance on the Two-String problem after they memorized a critical word list containing the words, "rope", "swing", "pendulum", "clock," and "time", among other word lists (see above), six critical analogies were developed for the present study and had as their solution the words, "two", "strings", "hang", "tie", "swing," and "clock". Additionally, the last analogy contained the word "swing" within the analogy, although its answer was a non-critical word. Also included in the task were three additional "buffer" analogies (see Appendix X).

The hint to the Hatrack problem was similar to the paired associates task used with the Candle problem in Experiment II based on Weisberg et al. (1978). However, in the present study, the paired associates task was structured as a rating task; participants were asked to rate the degree of relatedness of 15 word pairs, the last of which was the pair, "boards - ceiling." All of the pairs were fairly highly associated, except for the final pair (see Appendix Y).

### Design

Each participant received each of the problems in one of three different conditions that varied with respect to clue presentation: (1) clue before, where the task containing the implicit clue was completed before its related problem, (2) clue after, where the task containing the implicit clue was completed after some initial work on the problem in an incubation-type setting, and (3) no clue, where the task containing the implicit clue to the problem was not completed. The order of the clue conditions was counterbalanced, so that

each condition was represented equally as the first, second, and third problem attempted. As well, the order of the problems themselves was counterbalanced, so that each problem was presented equally as the first, second, and third problem to be solved. This design resulted in nine different orders (see Appendix Z) to which participants were randomly assigned.

### Procedure

On entering the laboratory, participants were asked to read over the Information Letter and sign the Consent Form (see Appendix AA). Participants were initially told that the study was investigating different factors involved in problem solving and that they would be asked to try to solve a few different problems and work on some tasks that I was developing for future research. Again, participants were asked to signal the experimenter as soon as they thought they had a possible solution to the problem, before recording it on paper. They worked individually and independently on the problem at a separate table while the experimenter remained in the room. When they indicated having a solution, they were asked to verbally explain their solution to the experimenter. If the solution was incorrect, participants were informed of this and asked to continue working to find the correct solution. Although a number of possible solutions exist to the Two-String problem, including extending or anchoring one of the ropes, the solution of interest here was the less frequent “swinging” solution. Thus, when participants noted other plausible solutions to the problem, they were encouraged to continue to find another way to solve the problem. Participants were given a maximum of ten minutes per problem; if not solved after ten minutes, they were simply told that they would move on to the next problem. If

participants' verbal descriptions indicated a correct solution, they were asked to record it on the page and time to solve was recorded by the experimenter. Again, time to solve was recorded at the first mention of a possible solution.

Participants were assigned to one of the above nine "orders" and solved each of the problems in a different clue condition, namely, clue before, clue after, and no clue. In the clue-after condition, participants were interrupted after three minutes of initial work on the problem if they had not already solved the problem. They were told that one factor of problem solving being investigated was the effect of an incubation period, or taking one's mind off the problem, and that they would be asked to perform another problem or task and then return to the present problem. At this point the clue activity for the problem was administered. In both the case of "The General" story and the analogy task, the activity was referred to as a "problem." The paired word associates were referred to as a task. On returning to the problem after completing the clue activity, participants were given a maximum of seven more minutes to attempt a solution.

The same administration procedure was followed regardless of whether a clue activity preceded or followed initial work on the problem. When administered "The General" story, participants were asked to read over the story and were told they would be asked to summarize and recall the story after reading it. Each participant signalled the experimenter after finishing reading the story. At this point, a second page, with instructions to give a summary of the story and make ratings of its plausibility and comprehensibility, was administered. The story itself was placed to the side of the participant so that s/he could refer to it if needed. Participants were asked, however, to

complete the summary of the story in their own words.

When administered the paired-word associates task, participants were initially asked to rate the degree of relatedness of each pair. After completing the ratings, they were given a surprise recall test of the pairs and told that the experimenter was interested in whether the semantic processing of words results in their being committed to memory. The experimenter read each of the first words in the pair as the stimulus words in a random order, except that the critical "boards - ceiling" pair always came last. Participants responded to each stimulus word with the target word, the word they recalled it being associated with. If the participant had not memorized the critical pair, they were given the list of associates to study again and were retested one minute later.

Similar to Experiment II, participants completing the Analogy Problem were told to complete the blanks with the appropriate word and to provide a brief explanation underneath for why the word "fit" in the space. They were given an example of an analogy before beginning. Again, it was important that participants responded with the correct words on critical analogies. Thus, in cases where critical words were not indicated, short periods of discussion ensued in which the experimenter wondered aloud about the person's reasoning on the particular analogy and then commented that another word for that analogy might be . . . (the critical word).

Participants were given as long as required to complete the clue activities. On their completion, they immediately began or returned to the related problem. In the case of the no clue condition, participants attempted the problem with no presentation of the related activity, before or after.

Both accuracy (solved versus unsolved) and solution time were measured for all problems. After attempting all three problems, participants were asked if they had ever heard of or seen any of the problems they had worked on during the experiment. Second, they were asked about whether they found anything helpful in solving the problems they were able to solve. Finally, participants were explicitly questioned about whether they found any of the tasks or problems they worked on helpful in solving other problems they attempted. On average, participants took about 45 minutes to complete the experiment. On completion, they were debriefed about the purpose of the study and were given written feedback about the experiment (see Appendix AB).

### Results

The percentage of Radiation, Two-String, and Hatrack problems solved were relatively equal, with 35, 33, and 31 percent of problems solved, respectively. For the purposes of data analysis, problems were grouped into the no clue, before clue, and after clue conditions. Table 12 presents the mean percentage of problems solved and time to solve for the three conditions.

**Table 12**  
**Mean Percentage of Problems Solved and Time to Solve (in minutes) for the Before**  
**After and No Clue Conditions**

	No Clue		Before Clue		After Clue	
	M	SD	M	SD	M	SD
Percent Solved	23.8	42.0	36.5	48.5	38.9	48.7
Time to Solve	8.8	2.6	8.4	2.9	7.8	3.1

### Percent Solved

To test the facilitation of a clue presented before versus after contact with the problem, paired-sample t-tests compared the before- and after-clue conditions to the no clue control condition, and subsequently directly to one another. Clues presented before working on the problems had only a tendency to significantly increase the percent of problems solved compared to the baseline no clue condition [ $t(62) = -1.9, p < .07$ ]. Clues presented after some preliminary work, however, did significantly increase the percent of problems solved [ $t(62) = -2.0, p < .05$ ]. There was no difference, however, in a direct comparison of the before- and after-clue conditions in terms of percent of problems solved,  $p < .74$ .

### Time to Solve

Similar to percent solved, there were no significant differences in the time taken to solve problems in the clue-before versus no clue conditions, [ $t(62) = 1.0, p < .33$ ]. Participants who were presented with the clue after initial problem solving, however, did solve the problems significantly faster [ $t(62) = 2.1, p < .04$ ]. Because there was no significant difference between the no clue and before-clue groups, these two conditions were collapsed and compared to the after-clue condition. The results of this analysis indicated that when presented with a clue after initial work on the problem, participants solved the problems significantly faster than when introduced to the same clue before their work began, or when no clue was presented at any point of problem solving [ $t(62) = -2.14, p < .04$ ].

### Time Spent on Clue Activities

Because participants were permitted unlimited amounts of time to complete the clue activities, it is possible that any differences in the effects of the clues are related to differential amounts of time spent on the clue task. Thus, it is important to compare performance on the problems with the time spent on their associated clues. An ANOVA contrast revealed no significant differences in the time spent on “before” clues for solved versus unsolved problems [ $F(1,60) < 1$ ,  $MS_e = 19.7$ ,  $p < .91$ ]. Similarly, there was no significant correlation between the time spent on a clue presented before the problem and the time taken to solve the problem [ $r = -.14$ ]. An ANOVA contrast of the time spent on “after” clues also indicated no significant differences between solved and unsolved problems [ $F(1,58) = 1.6$ ,  $MS_e = 19.8$ ,  $p < .20$ ]. However, there was a significant correlation between the time spent on the “after clue” and the time to solve the problem,  $r = .31$ ,  $p < .05$ . It would seem, however, that the more time spent on the “after” clue, the longer it took to solve the problem. Finally, there were no differences in the amount of time participants spent on a clue when presented before versus after the problem was originally administered [ $t(58) < 1$ ,  $p < .69$ ].

### Noticing the Clue

Again, I was interested in the effects of noticing the clue-value of the implicit clue activity on problem performance. I first tested whether there was any difference in noticing the relation between the clue task and the problem when the clue was given before versus after problem presentation. A paired-samples t-test did reveal a significant difference in recognizing the clue [ $t(61) = -2.3$ ,  $p < .02$ ], with the “after” clue significantly

more likely to be recognized as a clue to the problem than the “before” clue. An ANOVA contrast revealed no significant differences of noticing a clue presented before the problem on the percent of problems solved [ $F(1,60) < 1$ ,  $MS_e = 2405.6$ ,  $p < .71$ ], or the time to solve [ $F(1,60) < 1$ ,  $MS_e = 8.6$ ,  $p < .43$ ]. In contrast, however, when the clue activity was completed after some initial work on the problem, recognizing the relation between it and the problem was significantly related to the percent of problems solved [ $F(1,61) = 5.6$ ,  $MS_e = 2210.2$ ,  $p < .02$ ] and the time to solve the problems [ $F(1,61) = 10.1$ ,  $MS_e = 8.0$ ,  $p < .002$ ] (see Table 13).

**Table 13**  
**Mean Percentage and Time to Solve (in minutes) for Participants Aware and Not Aware of Clues When Presented Before and After Problems**

	Percent Solved				Time to Solve			
	Aware		Not Aware		Aware		Not Aware	
	M	SD	M	SD	M	SD	M	SD
Clue Before	50.0	70.7	36.7	48.6	10.0	0.0	8.3	3.0
Clue After	78.6	39.3	34.0	47.8	4.6	2.4	8.2	3.0

### Discussion

Experiment III represents a test of the Memory Sensitization hypothesis (Yaniv & Meyer, 1987) and indicates some support for this explanation of incubation. The Memory Sensitization hypothesis conceptualizes the incubation effect as due to an interaction between a spread of activation that continues for some time after the problem has been put



aside, and some related information, or clue, in the problem solver's environment. The residual activation sensitizes the person to the clue and, in turn, the clue further enhances the problem-related spread of activation in a way that may eventually converge on the problem solution. The results of the present study indicated that clues presented after some preliminary work on the problem significantly increased the probability that the problem would be solved compared to problems presented with no clues. In contrast, differences in the percent of problems solved between problems for which clues had been previously presented and problems with no clues failed to reach significance. The results of the time-to-solve data revealed a more clear-cut facilitation for the role of the clue presented after initial work compared to both the before-clue and the no clue conditions. Thus, it would appear that an implicit clue is more helpful after work on a problem has begun and problem-related spreading activation has been initialized. Again, however, it appears that the predicted effect is indicated more strongly with the more sensitive time-to-solve measure than with percent of problems solved.

The differences found between administering a clue after versus before problem presentation cannot be said to be due to differential amounts of time in contact with the clues themselves, as there was no significant difference in the amount of time taken to complete the clue activity when presented after than before the problem. There was, however, a significant difference in whether the implicit clue task was noticed as a clue to the problem when presented before versus after work on the problem began. The relation between the implicit clue task and the problem was noticed and reported more often when the clue task followed some initial work. Furthermore, recognizing the clue-value of the

implicit hint activity was significantly related to the percent of problems solved and speed of solving problems when the clue was completed after, but not before, problem presentation. Thus, participants who had invested in some preliminary work on the problem spontaneously noticed and made use of clues, whereas those who were given the same clues before beginning the problem were less likely to notice the clues and, even when they did notice them, the clues did not benefit their problem solving performance.

What implications do the present results have for understanding of the mechanisms underlying incubation? Earlier in the thesis, I asked the question of whether an implicit clue, in and of itself, may be responsible for any beneficial effects seen after an incubation period, or whether any other mechanisms are also involved. If we accept the above results as indicating greater facilitation when a clue is received after, as compared to before, work on a problem has occurred, then any theory of incubation must incorporate into its explanation more than just the beneficial effects received from a clue itself; such a theory will have to account for results varying with the timing of the clue. I would argue that a sub-conscious problem-related spreading of activation that continues after the problem is no longer consciously considered plays a role in incubation. Consistent with the Memory Sensitization hypothesis, the role such continuing activation seems to play is to sensitize the problem solver to notice and “pick up” on information related to the problem that is contained in her or his surroundings. As indicated by the results concerning noticing the implicit clue task as a clue, a clue presented after original problem presentation is more likely to be noticed as a clue than the same clue presented before work on the problem began. Moreover, when noticed, clues after, but not before problem presentation, resulted

in a greater percentage of problems solved and faster solution times. Of course, it is only after problem-related activation has begun that the problem solver can be more responsive to environmental inputs that relate to it. At least one role of such automatic activation, then, is to help the problem solver to spontaneously notice available clues in his or her surroundings.

One might also wonder whether a continuing spread of activation might, in and of itself, result in problem solutions without the help of an implicit clue. Conceptually, the spread of activation to new associations in a network is similar to a clue or other problem-related information found in one's environment, but exists internally, rather than externally. Note, however, that the present results do not indicate this automatic spread of activation to be a very strong effect. Although, in the present study, the effect was revealed using the time-to-solve measure, it was not indicated by the less sensitive percent solved measure. There are likely good reasons for such a weak effect. As noted by Olton (1979), laboratory studies are very poor approximations of the conditions under which incubation appears in the "real world." Anecdotal reports of incubation are usually given by very motivated people with developed knowledge and expertise in the problem area who struggle with a problem of considerable importance to them over very long periods of time. It is quite possible, then, that the strength of problem-related spreading activation would increase with increased motivation, an increased network of associations specific to the area of expertise related to the problem and greater amounts of time. It is also possible, however, that spreading activation, even under more "real world" conditions, is moderate at best. Such automatic activation probably does not converge on the problem

solution with sufficient intensity to cross the awareness threshold in most cases. If it did, reports of incubation effects would be much more prevalent and there would be little difficulty in empirically demonstrating the phenomenon. However, the fact that such residual activation does not always lead to successful problem completion does not, in itself, dispute its presence and the role it may play towards that end.

In summary, the emphasis here has been to suggest the role of a third mechanism in incubation, namely, continued problem-related spreading activation, or what Dorfman et al. (1996) would term “autonomous activation.” A type of automatic activation that continues after conscious work on the problem has terminated appears to be weak, but present. As a result, its investigation necessitates the use of quite sensitive measurement techniques. Although it is possible that such activation does, either alone or with the help of environmental inputs, result in the solution to a problem, its presence does not always guarantee the effect and thus will be difficult to evaluate using blunt measures such as whether the problem is solved or unsolved. Instead, the burden will be on the creative investigator to design tasks capable of sensitively testing autonomous activation. Yaniv and Meyer’s (1987) procedure of measuring reaction time in a lexical decision task containing answer words to previously attempted rare definitions represents one such creative measure.

### **Experiment IV**

As already noted, Yaniv and Meyer (1987) provided evidence that autonomous spreading activation can continue for some time after direct conscious work on a problem has terminated. Yaniv and Meyer found faster reaction times (RTs) in a lexical decision task to words that were answers on a previous definition task, as compared to matched control words, even when participants had previously been unable to generate the answer in the word definition task. These facilitation effects for originally unretrieved words were demonstrated one, four, and 30 minutes after participants first attempted to generate the word in the definition task.

Shames (1994, Experiment I; cf. Dorfman, Shames, & Kihlstrom, 1996) imported Yaniv and Meyer's procedure to a study using RAT items as the problem solving task. Participants first attempted RAT items for a five-second period and then indicated, by using a Yes/No response, whether they knew the answer to the puzzle. Thereafter, participants responded to a lexical decision task that included the answers to the previous RAT items, unrelated control words, and nonwords. Shames found a significant priming effect for originally unsolved RAT items in the lexical decision task, but a smaller and nonsignificant priming effect for solved items. Shames (1994, Experiment V) replicated the priming effects for unsolved items using a larger set of stimuli, but was unable to replicate the differential effects for solved versus unsolved items. Dorfman et al. interpreted Shames' finding in Experiment I in terms of a Zeigarnik-like effect of better memory for uncompleted than completed tasks. They proposed that before a problem is solved there exists a kind of cognitive tension due to continued activation relating to the

problem. Once the problem is solved, however, closure is achieved and the cognitive tension dissipates.

Based on the above reasoning, one might expect a different pattern of continued activation over time for solved versus unsolved problems, such that autonomous activation persists longer when a problem is unsolved than when it has been previously solved. The present study tested this assertion using Yaniv and Meyer's (1987) procedure and materials. Participants were involved in a rare-word definition task where they attempted to generate a rare word, given its definition. After varying amounts of time, participants made lexical decisions to previous answer words and matched controls as well as to other unrelated words and nonwords. After completing all of the definitions and associated lexical decisions, participants were given an 'Old/New' recognition task where they made Yes/No decisions about whether the words had been seen in the previous lexical decision trials. The stimuli for this task included the target definition words as well as the matched control words used in the lexical decision trials.

If an autonomous spreading activation process is involved in the incubation effect, one might expect that such sub-threshold automatic activation will persist longer for unsolved than for solved items. That is, there should be a differential rate of decline of activation for solved versus unsolved definitions, with activation of unsolved definitions persisting longer over time and activation relating to solved definitions dying off more quickly. Thus, whereas I expected large facilitation for solved definitions when the rare words were presented very soon after being solved, I predicted this facilitation should decline when tested after longer delays. In contrast, for unsolved items, the facilitation

effect may not be initially as great as for solved items, but it should be evident over longer delays after initially attempting the definitions.

## Method

### Participants

Ninety-two University of Waterloo undergraduate students, 41 males and 51 females, volunteered to participate to gain partial credit towards their introductory psychology course. Participants ranged in age from 18 to 38 years, with a mean of 20 years. To volunteer, participants were required to have normal or corrected-to-normal vision and good familiarity with the English language. Participants were randomly assigned to one of two lists of word definitions.

### Materials

One hundred and two of Yaniv & Meyer's (1987) definitions of rare words were used in the present study. These definitions were normed to produce a "tip-of-the-tongue" state in a college population. The rare-word definition task requires words to be generated, given their definitions. For example, the corresponding word to the definition, "a small boat used in the river and harbour traffic of China and Japan, propelled with an oar" is "sampan." The 102 definitions were divided into two lists, with 51 of the definitions serving as the target items on List 1 and the other 51 serving as the target items on List 2. Five filler items were added to each list so that, in total, each list contained 56 definitions. Participants were assigned to complete one of the two lists (see Appendix AC for the two lists of words and their definitions).

A set of five lexical decision stimuli were developed to correspond to each

definition. All participants made lexical decisions to all of the items in each set, regardless of which definition list they were assigned to. Within each set, one of the letter strings was the answer to its associated definition. A second letter string was a matched control word and was the answer to a paired definition from the second list, that is, the list not seen by the particular participant. In this way, the same items served as both the target (answer) words and control words across participants. The third, fourth, and fifth letter strings in each set of lexical decisions were an unrelated word and two nonwords; these stimuli were taken from Stolz & Neely (1995). All letter strings within each lexical decision set were matched for length (see Appendix AD for the lexical decision stimuli).

The stimuli for the recognition test consisted of the 51 target words, that is, the answers to the definitions previously seen by the participant, the 51 matched control words, namely, the answers to the definitions not seen by the participant, and 51 unrelated new words. Again, all stimuli within each set of three words (target, control, and new word) were matched for word length (see Appendix AE for the recognition task stimuli).

### Procedure

On entering the laboratory, participants were asked to read over the Information Letter and sign the Consent Form (see Appendix AF). They were told they would be asked to work on two separate types of problems, one being a fairly difficult word definition task and the second a more simple task where speed was important. All stimuli were presented using a 486 IBM compatible computer on a standard VGA monitor.

Participants began by completing 20 practice lexical decisions. Each letter string appeared centrally on the screen for a maximum of 2000 ms. Responses were made by



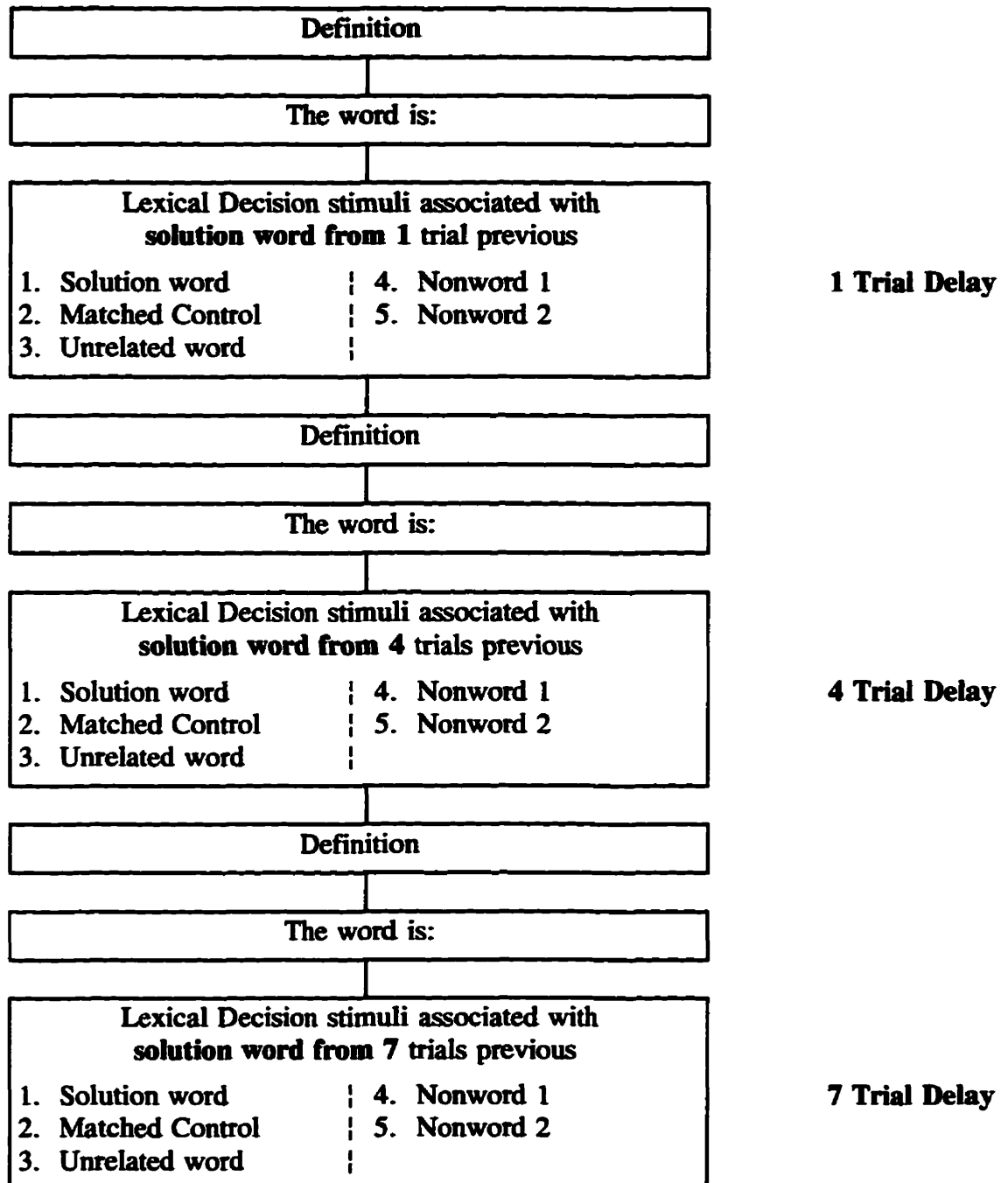
pressing a “1” for a word and “0” for a nonword. If the student responded incorrectly or did not respond within 2000 ms, an “ERROR” message was presented for 250 ms. A one-second delay occurred between the presentation of the lexical decision stimuli. After completing the 20 lexical decision practice trials, participants completed three sets of practice definitions and lexical decision sets, presented in the same manner as in the main experiment (see below).

In the main experiment, each trial began with a fixation symbol, presented centrally for 2000 ms. Following this, the definition was presented, again centrally. Five seconds following the definition presentation, the phrase, “The Word is” was displayed directly below the definition; at this point, participants could enter a response. To respond, participants typed their answer using the keyboard. Asterisks appeared on the screen in place of the letters of the answer they were typing to prevent repetition priming from affecting the lexical decision results of solved definitions. Regardless of whether the response was correct or incorrect, after typing a response and pressing the [Enter] key, the screen cleared. However, to encourage participants to spend some amount of time thinking of definitions they were unsure of, they were prevented from simply hitting the [Enter] key without first attempting an answer. In this case, the definition remained on the screen and the trial continued. Participants were given a maximum of one minute per definition. At this point, the definition cleared automatically from the screen. After a 2000 ms delay elapsed, the warning message, “Prepare for the Word/Nonword Task” was presented for 2000 ms and participants responded to a set of five lexical decisions. The order of presentation of the letter strings within each set was randomized, with the constraint that

either the unrelated word or a nonword was always the first string presented to serve as a “warm-up” stimulus. The lexical decisions proceeded exactly as in the practice trials.

Unlike Yaniv and Meyer’s study, the lexical decision trials immediately following a word definition attempt were not the letter strings that corresponded to the particular word definition. Instead, to investigate problem-related activation levels over time, participants completed the set of lexical decisions corresponding to a particular word definition after varying amounts of time (see Figure 3). One third of the time the lexical decision set for a particular word definition appeared in the trial following that definition, that is, one trial later. One third of the time the lexical decisions were completed four trials after their corresponding definition was attempted. Finally, one third of the time the lexical decisions associated with a word definition were completed seven trials after the definition attempt. In each case, however, the procedure appeared the same to participants: Attempt a word definition and respond to five lexical decisions. Participants were not informed about any relation between the word definitions and the lexical decision trials. After making lexical decisions to all five letter strings, a 2000 ms inter-trial interval occurred before the next trial began with a fixation symbol and definition presentation.

After attempting all the definitions and lexical decisions, participants were asked to complete a ‘surprise’ Old/New recognition task. Here, participants were told that all of the stimuli would be words and were asked to indicate whether the word had been presented before as one of the stimuli in the lexical decision tasks, or whether it was a ‘new’ word, not seen as part of the previous lexical decisions. The order of presentation within each set of three words, consisting of a definition word, matched control and new word, was

**EXPERIMENT IV - PROCEDURE**

**Figure 3. The sequence of events of a trial in the main experiment in Experiment IV.**

randomized. Each word was displayed for 2000 ms and participants responded using "1" for an old word, that is, a word they had seen before in a previous lexical decision task, and "0" for a new word.

On average, participants took about 80 minutes to complete the entire task. On completion, participants were debriefed about the purpose of the study and received a written description (see Appendix AG). During the debriefing, participants were asked about whether they noticed any relation between the lexical decision stimuli and the word definitions.

#### Data Analysis

To investigate the presence of residual problem-related activation, comparisons were made between responses to target (answer) words and the matched control words on the data from the lexical decision and recognition tasks. The presence of persisting activation is indicated by facilitation in responses to target words over controls.

To test predictions about the persistence and delay of activation relating to solved and unsolved problems, planned trend analyses of facilitation were computed separately for each of the three solution states, namely, solved, unsolved, and incorrectly solved. The definitions were solved correctly 19 percent of the time, completed with a word other than the target word 35 percent of the time and left unsolved, or blank, 46 percent of the time. Within each solution state, further analyses compared facilitation, that is, responses to target answer words over control words, across the various trial delays.

One participant had an error-rate on the lexical decision trials in excess of 40 percent and was eliminated from further analysis. RTs were trimmed using a within-

subjects procedure developed by Van Selst & Jolicoeur (1994) which takes into account sample sizes in eliminating out-of-range RTs. This procedure resulted in the elimination of 1.76 percent of the total RT values.

### Results

Table 14 presents the overall mean RTs and error rates from the lexical decision trials for the target and control words. Overall, responses to target words in the lexical decision task were faster than responses to control words [ $F(1,41) = 20.2$ ,  $MS_e = 1174.7$ ,  $p < .0001$ ]. No overall significant differences were found in error rates [ $F(1,90) < 1$ ,  $MS_e = 30.4$ ,  $p < .37$ ], however.

**Table 14**  
**Overall RT and Error Data from Lexical Decision Trials**

	Mean RT (ms)		Percent Errors	
	M	SD	M	SD
Target Word	830.0	166.4	20.6	9.9
Control Word	863.6	168.9	21.4	9.9

MANOVAs with solution state (solved versus unsolved) and trial delays (one, four, and seven) as within-subject factors were computed to test for interactions in the amount of facilitation for solved versus unsolved definitions over the trial delays. A solution state by trial delay computation of the facilitation in RT revealed a main effect of solution state [ $F(1,49) = 21.7$ ,  $MS_e = 16829.7$ ,  $p < .05$ ] and a main effect of delay [ $F(2,98) = 21.7$ ,  $MS_e = 12787.6$ ,  $p < .0001$ ], but a nonsignificant solution state x delay interaction [ $F(2,98) =$

1.1,  $MS_e = 19283.3$ ,  $p < .32$ ]. It is important to note, however, that the power for this analysis was very low (.24).

A solution state  $\times$  delay computation of facilitation in error rates again indicated a main effect of solution category [ $F(1,62) = 114.4$ ,  $MS_e = 280.1$ ,  $p < .0001$ ], but no main effect of the delay factor [ $F(2,124) = 1.5$ ,  $MS_e = 132.8$ ,  $p < .22$ ]. The solution  $\times$  delay interaction was significant, however [ $F(2,124) = 5.0$ ,  $MS_e = 118.8$ ,  $p < .008$ ]. Given the significance of this latter interaction and the low power associated with the analysis based on RT, individual contrasts for each of the three solution states were completed, as planned.

#### Correctly Solved Definitions

Overall, responses to lexical decision words that had been previously solved were made faster [ $F(1,43) = 23.1$ ,  $MS_e = 3292.2$ ,  $p < .0001$ ] and more accurately [ $F(1,90) = 114.1$ ,  $MS_e = 106.9$ ,  $p < .0001$ ] than responses to the matched control words. MANOVA contrasts were also computed to compare differences in responding to target and control stimuli at each of the individual delay periods. No significant differences between solved and control words in speed of responding were indicated when the solved and matched control word appeared on the very next trial, that is, one trial later [ $F(1,45) < 1$ ,  $MS_e = 10335.6$ ,  $p < .37$ ]. Significant differences in RT were indicated, however, when the associated stimuli were presented for lexical decision four trials [ $F(1,44) = 30.6$ ,  $MS_e = 5897.6$ ,  $p < .0001$ ] and seven trials [ $F(1,44) = 21.8$ ,  $MS_e = 9967.7$ ,  $p < .0001$ ] after originally solving the definitions, with responses to the target words occurring faster than responses to control words. Finally, facilitation in responding to target words in the

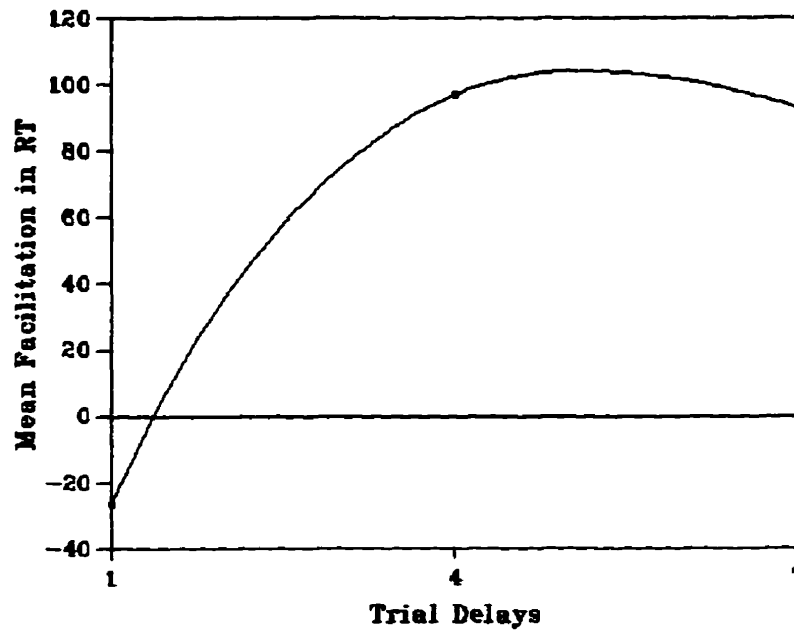
recognition task was similarly evaluated by comparing RTs to make Old/New decisions about target and control words and indicated faster responding to previously solved definition words than to controls [ $F(1,87) = 163.2$ ,  $MS_e = 4368.4$ ,  $p < .0001$ ].

Facilitation in the form of error rates was also compared at each delay.

Significantly fewer errors were made in decisions about the word/nonword status or old/new status of previously solved words than of matched controls at the one [ $F(1,88) = 50.0$ ,  $MS_e = 202.9$ ,  $p < .0001$ ], four [ $F(1,79) = 98.8$ ,  $MS_e = 131.5$ ,  $p < .0001$ ] and seven [ $F(1,77) = 39.7$ ,  $MS_e = 200.5$ ,  $p < .0001$ ] trial delays, and in the recognition task [ $F(1,90) = 273.2$ ,  $MS_e = 82.9$ ,  $p < .0001$ ].

To test predictions about the persistence of residual activation over time, trend analyses were completed to compare the degree and pattern of facilitation over the one-, four- and seven-trial delays. Facilitation was computed as the difference between responses to the target answer words and matched controls, with positive values always indicating superior performance on the target stimuli. A MANOVA contrast of the mean facilitation in RT across the trial delays of previously solved definitions indicated a significant effect of delay [ $F(2,102) = 14.0$ ,  $MS_e = 18346.2$ ,  $p < .0001$ ]. Here, a quadratic trend was significant, [ $t = -3.5$ ,  $p < .0001$ ] (see Figure 4a). Further contrasts indicated a significant difference between the one- and four-trial delays [ $t = -4.7$ ,  $p < .0001$ ], with a greater amount of facilitation in the four- than one-trial delay, but no significant difference between the four- and seven-trial delay conditions [ $t < 1$ ,  $p < .85$ ].

A MANOVA of facilitation in error rates over the trial delays revealed a significant delay effect for solved definitions [ $F(2,128) = 4.0$ ,  $MS_e = 64.2$ ,  $p < .02$ ]. Similar to the



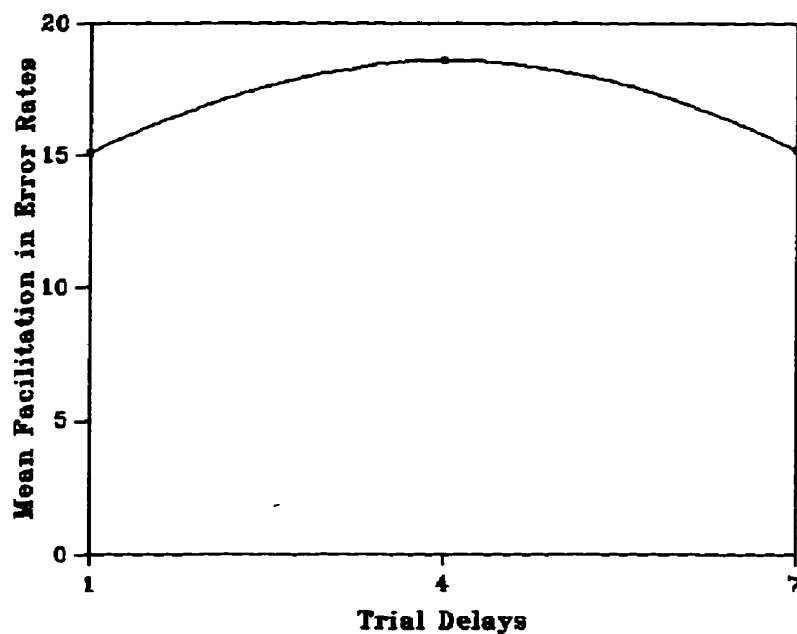
**Figure 4a. Trend of mean facilitation in RT over trial delays for solved definitions.**

trend data for RT, a quadratic trend was also significant for the mean facilitation in error rates for previously solved definitions [ $t = 3.3$ ,  $p < .002$ ] (see Figure 4b). Further contrasts revealed no significant differences in facilitation between the one- and four-trials delays [ $t = 1.4$ ,  $p < .17$ ], but significantly reduced facilitation at the seven-trial delay from the four-trial delay [ $t = -2.6$ ,  $p < .01$ ].

#### Unsolved Definitions

Similar to the solved definition words, overall, lexical decisions to previously unsolved definition words were made significantly faster than decisions about the matched control words [ $F(1,44) = 6.1$ ,  $MS_e = 2757.2$ ,  $p < .02$ ]. However, responses were slightly





**Figure 4b. Trend of mean facilitation in error rates over trial delays for solved definitions.**

less accurate to target words than to control words [ $F(1,89) = 4.4$ ,  $MS_e = 82.7$ ,  $p < .04$ ] when left unsolved.

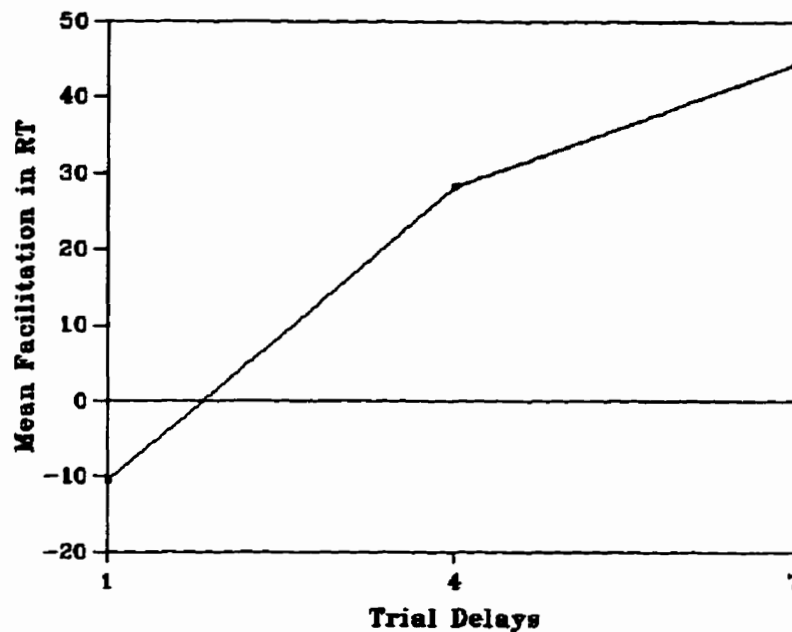
Again, MANOVA contrasts compared differences in responding to the unsolved target and control words at each of the delay periods. Similar to the results with previously solved definitions, no significant differences in speed of responding between unsolved and control words were indicated at the one-trial delay [ $F(1,45) < 1$ ,  $MS_e = 10829.4$ ,  $p < .38$ ]. At the four-trial delay point, responses to unsolved target words were significantly faster than responses to matched control words [ $F(1,44) = 10.5$ ,  $MS_e = 5761.1$ ,  $p < .002$ ]. Decisions to target words in the seven-trial delay were also faster than those to matched controls and this difference closely approached significance [ $F(1,45) =$

3.6,  $MS_e = 9127.0$ ,  $p < .06$ ]. However, no significant differences in RT were indicated on the recognition task in making Old/New judgements about previously seen but unsolved definition words versus control words [ $F(1,87) < 1$ ,  $MS_e = 4451.3$ ,  $p < .74$ ].

Results concerning the accuracy of responding indicated a higher proportion of errors when responding to unsolved target words than to control words at the one-trial delay [ $F(1,89) = 6.6$ ,  $MS_e = 185.9$ ,  $p < .01$ ] and four-trial delay [ $F(1,89) = 7.0$ ,  $MS_e = 199.8$ ,  $p < .01$ ]. No differences in accuracy of responding to unsolved versus control lexical stimuli were found at the seven-trial delay [ $F(1,89) < 1$ ,  $MS_e = 158.8$ ,  $p < .51$ ]. On the recognition task, participants made fewer errors when making judgements about unsolved target words than control words [ $F(1,89) = 4.2$ ,  $MS_e = 85.9$ ,  $p < .05$ ].

Again, the hypotheses regarding the rate of decline of activation related to unsolved problems were evaluated using trend analyses. A MANOVA contrast of the facilitation in RT over the one-, four- and seven-trial delay conditions for unsolved definitions indicated a significant effect due to delay [ $F(2,72) = 3.6$ ,  $MS_e = 19115.2$ ,  $p < .03$ ]. A trend analysis of unsolved definitions indicated a significant linear, but not quadratic function, [ $t = 2.5$ ,  $p < .01$ ] (see Figure 5a). Further contrasts revealed a significant increase in facilitation from the one-trial to four-trial delays [ $t = -2.4$ ,  $p < .02$ ]; the difference between the four- and seven-trial delays did not reach significance, however [ $t = -.85$ ,  $p < .40$ ].

Similar results were indicated in a trend analysis of the error data. A MANOVA contrast of the facilitation in error rates over the trial delays revealed a significant delay effect [ $F(2,172) = 7.9$ ,  $MS_e = 193.7$ ,  $p < .001$ ]. Here again, a linear, but not quadratic function was significant [ $t = -3.7$ ,  $p < .0003$ ] (see Figure 5b). Contrasts revealed greater

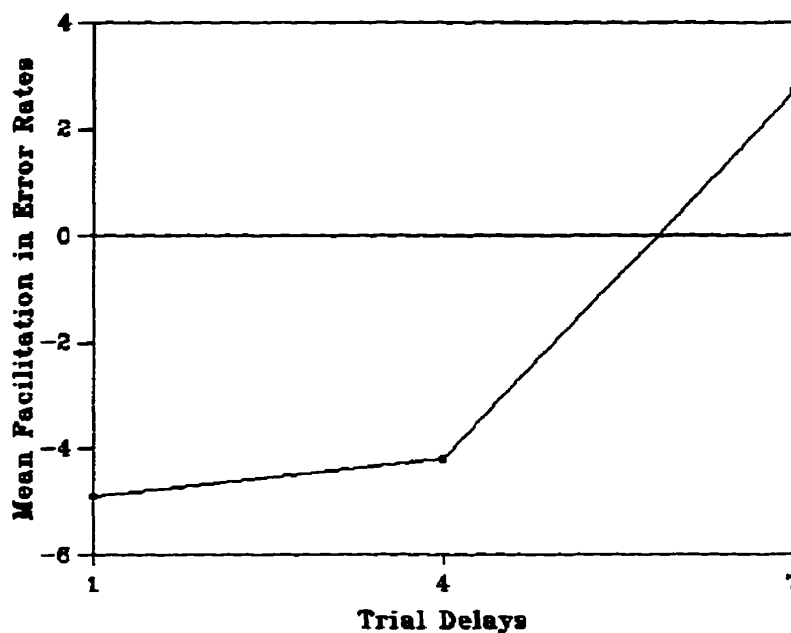


**Figure 5a. Trend of mean facilitation in RT over trial delays for unsolved definitions.**

facilitation in the four-trial than one-trial delay [ $t = 2.3, p < .02$ ] and in the seven-trial than four-trial delay [ $t = 3.2, p < .002$ ] in responding accurately to the unsolved lexical decision target words.

#### Incorrectly Solved Problems

Overall, lexical decisions to words whose definitions were completed with an incorrect word were no faster [ $F(1,44) = 1.6, MS_e = 5006.7, p < .21$ ] and had a tendency to have higher error rates [ $F(1,90) = 3.1, MS_e = 65.5, p < .08$ ] than decisions made to matched control words. In the one-trial delay condition, a difference between RTs to incorrectly solved words and control words approached significance [ $F(1,45) = 2.9, MS_e =$



**Figure 5b. Trend of mean facilitation in error rates over trial delays for unsolved definitions.**

11999.6,  $p < .10$ ]. No significant facilitation for target words was indicated in either the four- [ $F(1,44) < 1$ ,  $MS_e = 15095.6$ ,  $p < .65$ ] or seven- [ $F(1,45) < 1$ ,  $MS_e = 4809.4$ ,  $p < .72$ ] trial delays for speed of responding. However, significant facilitation in RT for target words over controls was found for previously incorrectly completed definitions on the recognition task [ $F(1,87) = 8.3$ ,  $MS_e = 5094.6$ ,  $p < .005$ ].

With respect to the accuracy data, decisions to target words originally incorrectly completed were more accurate than those to matched controls in the one-trial delay target [ $F(1,87) = 9.9$ ,  $MS_e = 140.8$ ,  $p < .003$ ]. However, decisions to incorrectly-completed words were less accurate [ $F(1,89) = 25.0$ ,  $MS_e = 210.7$ ,  $p < .0001$ ] or no different [ $F(1,88)$

$< 1$ ,  $MS_e = 133.1$ ,  $p < .95$ ] than those to controls in the four- and seven-trial delays, respectively. Similar to the RT data, however, significant facilitation of target over control words was found on the recognition task for incorrectly solved definitions [ $F(1,90) = 5.9$ ,  $MS_e = 82.2$ ,  $p < .02$ ].

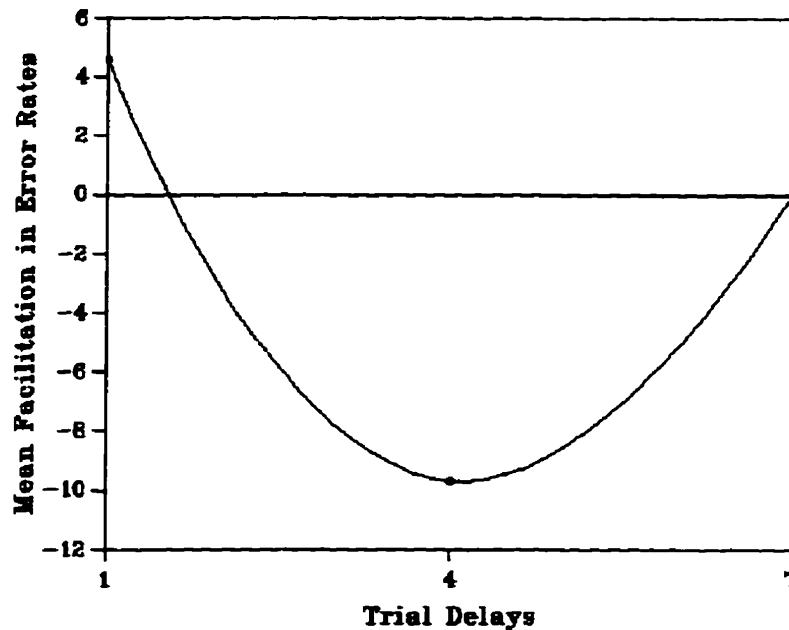
A MANOVA contrast of RT facilitation over the trial delays for definitions originally incorrectly completed indicated no significant effects due to delay [ $F(2,156) = 2.2$ ,  $MS_e = 27150.3$ ,  $p < .11$ ]. A significant effect in delay was indicated for the accuracy data here [ $F(2,166) = 18.8$ ,  $MS_e = 240.1$ ,  $p < .0001$ ]. Trend analyses of the error data revealed a significant quadratic trend for the accuracy facilitation data [ $t = -5.6$ ,  $p < .0001$ ] (see Figure 6). Further contrasts revealed a significant decrease in facilitation from the one- to four-trial delay [ $t = -4.6$ ,  $p < .0001$ ], but a significant increase in facilitation in the seven-trial over the four-trial delay [ $t = 4.0$ ,  $p < .0001$ ].

### Discussion

The results concerning activation related to solved, unsolved, and incorrectly solved definitions can be discussed in terms of the strength of activation indicated and the trend of activation across time.

#### Strength of Activation

Clearly, activation stemming from previously solved definitions was quite strong. Facilitation in terms of the speed of responding to a solved target word over matched controls was strongly indicated in all trial delays except the first, as well as in the recognition task. Facilitation in terms of the accuracy of responding was also strongly indicated at all delays. These results replicate Yaniv and Meyer's findings and are rather



**Figure 6. Trend of mean facilitation in error rates over trial delays for incorrectly solved definitions.**

unsurprising. Although participants were prevented from actually seeing the solution word by having asterisks displayed instead of the word letters, they nevertheless generated the word and entered it via the keyboard. Further, after some time on the task, participants likely began to anticipate the later appearance of the solution word in the lexical decision trials. When asked during debriefing whether they noticed any relation between the definition task and lexical decision trials, almost all participants spontaneously reported that the answers to some of the definitions appeared later on such trials. Thus, it is not unlikely that participants “held” their solutions to the definitions at some level of active memory, expecting their re-emergence later in the experiment. Having a stimulus “held” at some level of memory would be expected to speed its later identification. Thus, the

strength of activation relating to previously solved definition words would seem to be accounted for by participants' acts of generating the solution word, typing in the word, and their cognitive expectancies for its later presentation.

Evidence was also indicated for the presence of residual activation relating to previously unsolved definitions, although perhaps to a lesser extent than that for solved definitions. Facilitation in the speed of responding to a definition word that had previously been left blank was indicated in the four- and seven-trial delay conditions, but not on the recognition task. This last finding represents a failure to replicate Yaniv and Meyer, who did find facilitation in responses to unsolved definition words on a recognition task; the reasons for this failure are unclear. Furthermore, the results of the accuracy data do not consistently indicate facilitation in responding to the unsolved target word over matched controls. In fact, in the one- and four-trial delay conditions, the reverse is true: Participants made slightly more errors in responding to the unsolved definition word. Given this finding, it is important to consider whether the facilitation effects in speed that were found on some trial delays are simply the result of a speed-accuracy trade-off. On closer inspection, however, this does not appear to be the case. In the one-trial delay condition, no facilitation effects in speed were found although more errors in responding to target words were made. Moreover, in the seven-trial delay, facilitation in speed was indicated although no differences in error rates between target and control words were found. Furthermore, a facilitation in accuracy was indicated in the recognition task despite no difference in the speed of responding to target and control words being found here. In only one condition, the four-trial delay, was a significant facilitation in speed of

responding to target words combined with a significant increase in errors in responding to those target words.

Although, unsurprisingly, the data from responses to unsolved definitions do not match the degree of facilitation seen with solved definitions, they do indicate a significant level of continuing activation in several conditions, a counter-intuitive finding that replicates Yaniv and Meyer's (1987) and Shames' (cf. Dorfman et al., 1996) results. In the present study, participants would have worked for one minute on the definition and then gone on, unable to retrieve the correct word. Later, however, on viewing the word, they were able to respond faster or more accurately to it. One might explain these findings by proposing that participants did indeed have the correct solution to the definition, but refrained from entering it due to an uncertainty about its veracity, or that they solved the definition moments after the trial had ended. Although possible, such explanations would not explain the failure to find facilitation effects for unsolved words in the recognition task. If participants had actually solved the definition at some point, residual activation from the solved word, combined with the cognitive expectation for its re-appearance later, should have resulted in facilitation at all delays, including the recognition delay, similar to that found with solved words. Moreover, this account cannot explain the differential trends of activation over time found for solved versus unsolved definitions (see below). Thus, it would seem that residual traces remaining from the spread of activation initiated during initial work on the definition are indicated, even when the problem is not originally solved. Additionally, the activation persisting from unsolved definitions differs than that from solved definitions, as it is not the result of generating the words themselves or of



specific cognitive expectancies for particular words to be presented later, given that, for unsolved definitions, the exact words were not generated in the first place.

The results concerning definitions answered incorrectly seem to indicate minimal levels of any continuing activation resulting from original work on the definitions. A significant facilitation in speed was indicated here only in the recognition task, while facilitation in responding to target over control words in accuracy was found in the one-trial and recognition conditions. The fact that facilitation was found primarily in the recognition task here might suggest that viewing the target word, when presented during the lexical decision trials, triggered participants to its solution value for a previous definition they had answered with a different word, and then served to facilitate its identification on the subsequent recognition task.

#### Activation Over Time

Questions regarding the trend of activation across time differ from tests of its overall strength and are the important analysis for evaluating predictions about the rates of decline of activation of solved versus unsolved problems. I predicted that residual activation from unsolved definitions would persist longer over time, whereas such activation from solved definitions would “die off” more quickly.

A significant interaction between solution state (solved versus unsolved) and delay was indicated for error rates, although not for RT, possibly due to low power. Separate trend analyses for solved, unsolved, and incorrectly solved definitions were illuminating in testing the changes in the degree of facilitation over time within each of these solution states, however. Three equal-interval trial delays were represented in these analyses,

namely, the one-, four- and seven-trial delays. Because a trial took, on average, about one minute to complete, the analyses represent the pattern of activation occurring from one to seven minutes after initial work on the definition.

A trend analysis for solved definitions indicated a quadratic function as the best fit for both the RT and the accuracy data. Here, facilitation either increased or was maintained initially over time and then levelled off or began to decline at later time intervals. In contrast, activation over the trial delays for unsolved problems was best represented by an increasing linear function, again, for both the speed and accuracy data. Here, the degree of facilitation continued to increase over the entire seven minute period, without levelling off or declining. Results from incorrectly solved definitions were mixed and present no clear picture. Trend analyses of the RT data indicated no significant linear or quadratic function; in contrast, the accuracy data revealed a quadratic function with activation initially declining and later increasing. These mixed results may reflect a rather diverse response style in this condition. Some of the incorrect responses likely represent participants who thought at some length about the definition and approached the target word, but substituted a similar but non-target word in its place. Other entries may reflect an impulsive “shot-in-the-dark” response to avoid the frustration of spending prolonged periods of time attempting to recall words when there was little confidence in being able to retrieve them. Recall that participants were prevented from prematurely ending the trial with no response.

Consistent with the predictions, residual activation relating to solved and unsolved definitions did indicate some evidence of differential trends over time. The trend analyses

indicated that, despite the strength of activation of solved definitions due to actually generating the solution word and expecting its later presentation, the degree of such activation levelled off, or began declining, over time. In contrast, remaining traces of unsolved definitions did not appear to decline as quickly, or at all, in the space of seven minutes. In fact, the predictions about the decline of activation were unsupported by the trend data of unsolved definitions. Over the seven-minute period, such traces did not decline but rather, somewhat counter-intuitively, increased. Supporting the role of autonomous activation in the incubation effect, perhaps it is the case that, for unsolved problems, longer periods of time off task allow for a continued spread and build-up of activation that more approaches nodes relevant to the solution.

## General Discussion

### Summary of Findings

Given its unreliable demonstration in the laboratory, this thesis began by questioning whether the incubation effect in problem solving, the idea that problem performance can actually improve with an interpolated period of time off task, actually does exist, or whether anecdotal accounts of its effects given by great minds and lay people alike are a result of cognitive illusions, such as selective remembering and forgetting. If indeed such a phenomenon exists, the question of what mechanisms the effect may operate through was also raised. The two above questions were united in this thesis to evaluate the existence of incubation by employing distinct methodologies to specifically investigate different proposed mechanisms of incubation. To date, three main explanations of incubation have been proposed in the literature: the forgetting fixation hypothesis, the implicit clue hypothesis, and the role of unconscious spreading activation.

Experiment I investigated the role that fixation and encounters with implicit clues, and any interaction among these factors, might play in the incubation effect. Participants were either correctly or incorrectly fixated on word fragments, received an incubation period or no incubation, and were exposed to implicit clues to the fragments or non-clue nonwords in a lexical decision task. It was predicted that the incubation period should be particularly helpful when participants were incorrectly fixated, as opposed to correctly fixated, on the fragments, and that the implicit clue would be most helpful for incorrectly fixated fragments after incubation. Results indicated a fixation  $\times$  incubation interaction, but not in the way predicted. The break from the problem failed to increase performance

on incorrectly fixated fragments, but did significantly reduce the number of correctly fixated fragments solved. The failure to demonstrate improved performance after incubation for incorrectly fixated fragments was discussed with respect to the possibility that incorrect fixation was never successfully manipulated. Results concerning the role of implicit clues indicated that presenting an implicit clue word to a word fragment significantly improved the percentage of fragments solved, regardless of fixation or whether an incubation period occurred or not.

Experiment II continued to investigate the forgetting fixation and implicit clue hypotheses, but replaced the multi-item task of Experiment I with three insight-type problems: the Candle problem, the Radiation problem, and a series of ten RAT items. Participants attempted to solve two correctly fixated and one incorrectly fixated problems. Each problem was also presented in one of three incubation conditions, namely, no incubation, clue incubation, an incubation period in which participants worked at a task containing helpful information to the problem, and no clue incubation, in which the incubation period was filled with work on a task unrelated to the problem being attempted. According to the forgetting fixation hypothesis, the no clue incubation should improve performance on the incorrectly fixated problems, but be less helpful for correctly fixated cases. The implicit clue hypothesis would predict that the clue incubation period would benefit problem solving, regardless of the fixation condition. Results indicated that performance was not benefited on any of the problems by the no clue incubation period, regardless of fixation. However, the no clue incubation did significantly impair performance on the Candle problem when participants were correctly fixated. Results

concerning the implicit clue hypothesis indicated that the clue incubation improved performance on all three problems; however, the benefit was circumscribed to either the correct or incorrect fixation version of the problem in each case. Because each problem differed with respect to whether incubation was most helpful in the correctly or incorrectly fixated condition, it appeared that the effect of an implicit clue varied with problem difficulty, with medium-level problems most likely to benefit.

In Experiment III the investigation of the mechanisms underlying incubation took a turn and began to focus on the third proposed explanation, namely, the 'autonomous activation' or 'spreading activation' hypothesis. Specifically, this study was a test of Yaniv & Meyer's (1987) 'Memory Sensitization' hypothesis, the idea that memory traces partially activated through initial work on a problem sensitize a person to encounters with information relevant to these traces, and therefore the problem, during an incubation period. The interaction between the partial activation and related information in the environment can result in a conscious representation of the problem solution. Although this account identifies the role of the implicit clue, it recognizes the effects of incubation as due to more than the influence of a clue on performance. Indeed, ensuing problem-related partial activation over the incubation period also plays a significant role. It follows from this that an implicit clue would have varying effects on performance depending on the timing of its presentation, that is, before or after partial problem-related activation exists. In a within-subjects design, Experiment III had participants attempt the Two-String, Hatrack, and Radiation problems. Each problem was attempted in one of three conditions: (1) clue before, where participants worked on a separate task with an

embedded clue before attempting the problem, (2) clue after, in which participants worked on the task with an embedded clue after spending some initial time on the problem, and (3) no clue, where no clue activity preceded or followed the problem. It was expected that problem performance would benefit most from an implicit clue when given after, rather than before, the initial problem presentation. Results indicated that when presented with a clue after initial work on the problem, participants solved the problems significantly faster than when introduced to the same clue before their work began, or when no clue was presented at any point of problem solving. Furthermore, when presented after, rather than before, initial problem presentation, an implicit clue was significantly more likely to be recognized as a clue, and there was a significant relation between recognizing the 'after clue' as a clue and problem performance, whereas there was no such relation with clues presented before the problem.

Finally, Experiment IV investigated the presence of problem-related activation that continues after termination of work on a problem and its role in the incubation effect. Similar to Yaniv & Meyer (1987), participants completed a rare-word definition task where they attempted to generate a rare word given its definition, and then made lexical decisions to solution words from the task as well as matched controls and other unrelated words and nonwords. Different from Yaniv and Meyer, participants in Experiment IV made these lexical decisions after varying amounts of time after terminating their work on the definition. If an autonomous spreading activation process is involved in the incubation effect, it would be expected that sub-threshold automatic activation would persist longer for unsolved than for solved items. Thus, I predicted a differential rate of decline of

activation for solved versus unsolved definitions, with activation of unsolved definitions persisting longer over time and activation relating to solved definitions dying off more quickly. Trend analyses were completed to compare the degree and pattern of facilitation over time (one, four and seven minutes after work on the definition) for solved and unsolved definitions. Although the trend analyses for solved definitions indicated a quadratic function as the best fit to the data, the trend of unsolved definitions was best represented by an increasing linear function. Thus, activation related to solved problems appeared to level off or decline over time, whereas such activation for unsolved problems increased without levelling off or declining.

### Conclusions and Implications

Little empirical support for the forgetting fixation hypothesis was indicated in the present thesis. Possible difficulties in manipulating incorrect fixation may have contributed to this result in some cases. Given these potential difficulties and the previous empirical demonstration of the role of forgetting fixation in incubation by other investigators (Smith & Blankenship, 1989, 1991; Smith & Vela, 1991; Smith, et al., 1993 cf. Smith, 1995), I cannot make any conclusions about the forgetting fixation hypothesis based on failures to indicate such effects in this thesis. However, the possibility that there is a role of other mechanisms of incubation, besides that of forgetting one's initial incorrect fixation, became introduced.

In contrast to the failure to validate the effects of incorrect fixation on the benefit of incubation, more strongly indicated here were the debilitating effects of incubation when the problem solver is correctly fixated, an observation that has not been previously noted



in the literature. On some of the problems studied, providing an incubation period after initially correctly fixating participants significantly decreased performance, compared to participants permitted to work continuously on the problem, with no interjected breaks. This suggests one possible explanation of the many previous failures to empirically demonstrate significant differences between incubation and no incubation control groups. On problems where fixation is left unmanipulated, participants will naturally vary from being incorrectly to correctly fixated. Although a break from the problem may be beneficial to participants with incorrect representations of the problem, the same period off task may actually impair the performance of those who had been correctly fixated. In merging these two groups of participants, the end result of no difference between groups would be indicated, and would appear to incorrectly indicate that incubation has no effect on performance.

A second proposed mechanism of incubation, the implicit clue hypothesis, received fairly strong support in the present studies. Although intuitively it would seem very likely that being presented with a clue to a problem, even if implicit, would benefit performance, such a prediction was certainly not guaranteed based on results of the spontaneous transfer literature (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983; Landrum, 1990; Perfetto et al., 1983; Weisberg et al., 1978). Nonetheless, it would appear that when people “bump into” related information after some initial period of work, they can pick up on this information and make use of it on return to problem solving. Note, however, that we are still limited in what we can conclude about the ‘real-world’ incubation setting. At present, we can conclude that, under some conditions, people can make use of implicit

information available in their environment after some preliminary work on a problem has occurred. It is difficult to know, however, whether such clues are readily available in the natural environment and how much of the anecdotal incubation experiences can be accounted for by this finding. Indeed, if clues or related information are not readily available in the problem solver's surroundings, it makes little difference whether s/he can spontaneously notice and transfer them to the problem.

Implicit clues were found to be of most help on medium-level difficulty problems. This finding would seem to stand in contrast to anecdotal reports of incubation in which the problem solver is working on very difficult, innovative and indeed previously 'unsolved' problems. We must be careful to consider the context surrounding each of these observations, however. The real-world problem solver has likely spent months thinking over the complexities of his/her situation, has a well-developed knowledge base in the problem area, is very motivated to solve the problem, and may have incubated for days on end. Our laboratory participants, of course, come with no specialized expertise in the problem area, some, but minimal, motivation to successfully solve the problems we administer, and spend minutes initially working and incubating before we measure their success. Here, then, medium-difficulty level problems provide a more sensitive measure of the effect, an important component to laboratory investigations of incubation.

The impact of the implicit clue does not appear to depend entirely on participants' conscious recognition and report of its relation to the problem at hand. In two of the studies (Experiment I and II), benefits on performance were observed regardless of whether participants reported noticing the hint value of the clue. Such participants can be

considered to be unconsciously influenced with respect to a second order consciousness (Bowers, 1987). Although performance can benefit from an 'unrecognized' clue, it is still the case, however, that an explicit awareness of the clue as a clue benefits performance to a greater extent. Previous research on spontaneous transfer has indeed noted the great discrepancy in solution rates of participants explicitly told of the clue compared to those receiving only its implicit presentation (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980; Landrum, 1990; Perfetto et al, 1983; Weisberg et al, 1978). Further, Experiment III here indicated that one of the primary advantages of initializing problem-related activation before versus after contact with an implicit clue is the role such activation plays in sensitizing the problem solver to the clue, helping him or her to notice it and its relation to the problem; in other words, making the clue more explicit.

A third and final incubation mechanism under study here was the 'autonomous activation' hypothesis (Dorfman et al., 1996), which is the conceptualization of incubation most akin to the 'unconscious processes' hypothesis, and involves the idea that 'work' or problem-related activation continues during a period of time when the task is no longer consciously considered. To my knowledge, this mechanism of incubation has never been directly tested. Indeed, the idea of testing for the presence of unconscious processes or unconscious spreading activation seems somewhat daunting. How can such internal processes be evaluated? I would argue that more sensitive measurement techniques are required for its investigation in the laboratory. As noted above, the typical incubation laboratory setting has not been very representative of real-world incubation experiences, meaning that what effects are present will be smaller or weaker in the laboratory.

Attempting to measure continuing problem-related autonomous activation by exposing participants to a problem, interrupting their performance with a break, returning them to task and thereafter measuring their success dichotomously, in terms of solved or not solved, is thus too blunt an instrument. Such a procedure assumes that residual activation always leads to the successful solution to a problem, and does so in a matter of about ten minutes, the average incubation time in such experiments. Instead, it may be that residual activation relating to a problem often exists, but sometimes in a weak form, not strong enough to eventually converge on the problem solution. As well, it may take a greater amount of time than often permitted for such spreading activation to lead to the final solution.

Experiments III and IV attempted to employ more specific and sensitive measures of autonomous activation. In Experiment III, residual activation on a problem interacted with an implicit clue before its success was measured on completing insight problems. Here, the effects of partial activation and a hint were compared to the effects of a hint alone, and findings indicated that residual problem-related activation continuing over the incubation period adds significantly to success in problem solving.

In Experiment IV, reaction-time data from lexical decisions to solution words of previously attempted definitions provided a more sensitive test of the role of autonomous activation over time. Here, rather than measuring whether a problem is eventually solved or not, I tested directly for the presence of continued activation. Evidence of such activation was indicated by greater facilitation in responding to unsolved target (solution) words relative to control words. Moreover, the relevance of such continuing activation to

the incubation effect was tested by examining the trend of continuing activation over time for solved versus unsolved definitions. Activation for unsolved definitions appeared to actually increase linearly over time, in a way one might expect when a solution is being approached. As well, the trend for unsolved activation differed from that in which the definitions were originally solved; here activation levelled off or declined.

One might question whether the results of Experiment III and IV can be explained or represented in terms of explanations of incubation other than continuing autonomous activation that are more “testable,” for example, the forgetting fixation hypothesis, as per Woodworth & Schlosberg’s (1954) early warning. However, the results of Experiment III do not appear to be predictable from this framework; indeed, if anything, the reverse finding might be expected to occur. If one conceptualizes the implicit clue presented before contact with the problem as a type of implicit manipulation of correct fixation, then performance in the ‘clue before’ condition should exceed that of the ‘clue after’ condition because participants are expected to be more successful when correctly fixated. Experiment III, however, found that a clue presented after some preliminary work on the problem improved performance, whereas the same clue presented before the problem presentation did not. In Experiment IV, facilitation in identifying the target solution word occurred even when that word was previously not generated by the participant. According to the forgetting fixation hypothesis, an incubation period improves performance by moving the problem solver away from an incorrect set. This hypothesis would not predict, however, that the problem solver moves towards the correct set in any way due to the incubation period; instead s/he might be best understood as being back at a ‘no set’ or neutral starting point. Thus, the forgetting fixation hypothesis does not predict or explain

the trend of increased facilitation for unsolved definitions indicating an approaching of solution-associated nodes. Therefore, although the forgetting fixation hypothesis cannot be refuted based on any results from the present studies, due to methodological difficulties in some conditions and the clear empirical validation it has received in other experiments, the present work would seem to indicate the role of possible additional mechanisms of incubation, including a continuing spread of autonomous activation.

Caution must be advised in applying the results of Experiment IV directly to the problem solving context, however. The word definition task in Experiment IV is better conceptualized as a memory test than as a problem, and there are likely important differences between tests of memory and true problem solving situations. The results of Experiment IV therefore need to be replicated using a 'true' problem set. The RAT items that have been previously employed by Shames (1994; cf. Dorfman et al., 1996) using a Yaniv and Meyer type procedure, might constitute a viable alternative set of materials for replication of the present work.

It may also be helpful for further research on incubation to be very mindful of the less than optimal laboratory representation of the real-world incubation setting, as discussed above, and to implement procedures to address the differences between these two contexts. In the laboratory, more sensitive measurement techniques to assess specific incubation mechanisms will increase the 'testability' of different proposed processes of incubation. In addition, paralleling the laboratory incubation setting more closely with real-world settings may help to increase effect sizes, if the effects of incubation are related to having expertise areas, high levels of motivation and long periods of time struggling with problems. Experimenters might make more use of participants with specialized

expertise in knowledge areas who would be expected to have well-developed networks of associations specific to the problem. Methods of motivating laboratory participants, such as paying people for problems solved, might be developed and employed. Longer periods of working and incubating could be used. Of course, another way to gain some advantages of the real-world setting is to design ways to study incubation in its natural environment.

Another aspect likely very important to the study of incubation, but overlooked by the present work, is that of individual differences. It is possible that people differ in the extent of the benefit they receive from taking a break from their work and that these differences correlate with other important cognitive and personality variables. To my knowledge, there has been little work investigating such individual differences in incubation. Murray & Denny (1969), Dominowski & Jenrick (1972) and Patrick (1986) investigated the effects of incubation for low- and high-ability participants, but the results were mixed. Furthermore, there has been no more recent work examining other important variables. It may also be the case that different types of individuals benefit from incubation in different ways, for example, through a forgetting of their initial fixation, by being open to and making use of related information they find in their environment, or through a residual autonomous spreading of activation. Thus, studying individual differences in incubation would seem to be a particularly productive area of research not only by providing, again, a more sensitive method of investigating mechanisms of incubation, by perhaps eliminating unrelated variance, but also by furthering our understanding of the phenomenon with respect to what type of individuals might benefit most from incubation and how individuals with varying characteristics profit from it.

In conclusion, the results of four experiments reported here indicate support for the implicit clue and autonomous activation hypotheses of the incubation effect in problem solving. When presented with an implicit clue after some initial work on a problem, the clue was spontaneously noticed and benefitted performance, most often without participants' awareness of its impact. Results also supported the notion that an autonomous problem-related sub-threshold spreading of activation continues after direct conscious work on a problem has been temporarily discontinued. On some occasions such activation may interact with implicit information available in the problem solver's surroundings. In this case, the role such activation may play is to sensitize the person to the problem related input in his/her environment, so that such information can implicitly inform the problem solving, a la implicit clue hypothesis. On other occasions, the problem related spreading of activation may continue and converge on solution associated nodes without help from an external implicit stimulus. It would appear from the results of the above experiments, however, that, although present, the magnitude of such continuing activation may often be weak. Thus, it may be the case that autonomous activation most often interacts with other mechanisms involved in incubation before it reaches sufficient intensity to cross the awareness threshold.



## References

Anderson, B.F. (1975). Cognitive psychology: The study of knowing, learning and thinking. New York: Academic Press.

Anderson, J.R. (1983). A spreading activation theory of memory. Journal of Verbal Learning and Verbal Behavior, 22, 261-295.

Anderson, J.R. (1990). Cognitive psychology and its implications (3rd ed.). New York: W.H. Freeman and Company.

Antonietti, A., Cerana, P., & Scafidi, L. (1994). Mental visualization before and after problem presentation: A comparison. Perceptual and Motor Skills, 78, 179-189.

Beveridge, M., & Parkins, E. (1987). Visual representation in analogical problem solving. Memory & Cognition, 15, 230-237.

Bowden, E.M. (1985). Accessing relevant information during problem solving: Time constraints on search in the problem space. Memory & Cognition, 13, 280-286.

Bowers, K.S. (1987). Revisioning the unconscious. Canadian Psychology, 28, 93-132.

Bowers, K.S., Regehr, G., Balthazard, C., & Parker, K. (1990). Intuition in the context of discovery. Cognitive Psychology, 22, 72-110.

Browne, B.A., & Cruse, D.F. (1988). The incubation effect: Illusion or illumination? Human Performance, 1, 177-185.

Burke, R.J., Maier, N.R.F., & Hoffman, L.R. (1966). Functions of hints in individual problem-solving. American Journal of Psychology, 79, 389-399.

Campbell, D.T. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. Psychological Review, 67, 380-400.

Catrambone, R., & Holyoak, K.J. (1989). Overcoming contextual limitations on problem-solving transfer. Journal of Experimental Psychology: Learning, Memory, and cognition, 15, 1147-1156.

Collins, A.M., & Loftus, E.F. (1975). A spreading-activation theory of semantic processing. Psychological Review, 82, 407-428.

Dominowski, R.L., & Jenrick, R. (1972). Effects of hints and interpolated activity on solution of an insight problem. Psychonomic Science, 26, 335-337.

Dominowski, R.L. (1995). Productive problem solving. In S.M. Smith, T.B. Ward, & R.A. Finke, (Eds.), The creative cognition approach. Cambridge, MA: MIT Press.

Dorfman, J., Shames, V.A., & Kihlstrom, J.F. (1996). Intuition, incubation, and insight: Implicit cognition in problem solving. In G. Underwood (Ed.), Implicit cognition. Oxford: Oxford University Press.

Dreistadt, R. (1968). An analysis of the use of analogies and metaphors in science. Journal of Psychology, 68, 97-116.

Dreistadt, R. (1969). The use of analogies and incubation in obtaining insights in creative problem solving. Journal of Psychology, 71, 159-175.

Duncker, K. (1945). On problem solving. Psychological Monographs, 58(5, Whole No 270).

Fulgosi, A., & Guilford, J.P. (1968). Short-term incubation in divergent production. American Journal of Psychology, 81, 241-246.

Gall, M., & Mendelsohn, G.A. (1967). Effects of facilitating techniques and subject-experimenter interaction on creative problem solving. Journal of Personality and social Psychology, 5, 211-216.

Gardner, M. (1978). Aha! Insight. New York: W.H. Freeman.

Ghiselin, B. (Ed.) (1952). The creative process. Berkeley, CA: University of California Press.

Gibson, J.M., & Watkins, M.J. (1988). A pool of 1,086 words with unique two-letter fragments. Behavior Research Methods, Instruments, & Computers, 20, 390-397.

Gick, M.L., & Holyoak, K.J. (1980). Analogical problem solving. Cognitive Psychology, 12, 306-355.

Gick, M.L., & Holyoak, K.J. (1983). Schema induction and analogical transfer. Cognitive Psychology, 15, 1-38.

Glucksberg, S., & Weisberg, R.W. (1966). Verbal behavior and problem solving: Some effects of labelling in a functional fixedness problem. Journal of Experimental Psychology, 71, 659-664.

Goldman, W.P., Wolters, N.C.W., & Winograd, E. (1992). A demonstration of incubation in anagram problem solving. Bulletin of the Psychonomic Society, 30, 36-38.

Holyoak, K.J., & Koh, K. (1987). Surface and structural similarity in analogical transfer. Memory & Cognition, 15, 332-340.

Judson, A.J., Cofer, C.N., & Gelfand, S. (1956). Reasoning as an associative process: II. "Direction" in problem solving as a function of prior reinforcement of relevant responses. Psychological Reports, 2, 501-507.

Landrum, R.E. (1990). Maier's (1931) two-string problem revisited: Evidence for spontaneous transfer? Psychological Reports, 67, 1079-1088.

Lockhart, R.S., Lamon, M., & Gick, M.L. (1988). Conceptual transfer in simple insight problems. Memory & Cognition, 16, 36-44.

Maier, N.R.F. (1931). Reasoning in humans. II. The solution of a problem and its appearance in consciousness. Journal of Comparative Psychology, 12, 181-194.

Maier, N.R.F., & Burke, R.J. (1967). Influence of timing of hints on their effectiveness in problem solving. Psychological Reports, 20, 3-8.

Mandler, G. (1995). Origins and consequences of novelty. In S.M. Smith, T.B. Ward, & R.A. Finke, (Eds.), The creative cognition approach. Cambridge, MA: MIT Press.

Marcel, T. (1980). Conscious and preconscious recognition of polysemous words: Locating the selective effects of prior verbal context. In R.S. Nickerson (Ed.), Attention and Performance VIII. Hillsdale, NJ: Erlbaum.

Mednick, M.T., Mednick, S.A., & Mednick, E.V. (1964). Incubation of creative performance and specific associative priming. Journal of Abnormal and Social Psychology, 69, 84-88.

Murray, H.G., & Denny, J.P. (1969). Interaction of ability level and interpolated activity (opportunity for incubation) in human problem solving. Psychological Reports, 24, 271-276.

Neisser, U. (1967). Cognitive psychology. New York: Appleton.

Olton, R.M. (1979). Experimental studies of incubation: Searching for the elusive. Journal of Creative Behavior, 13, 9-22.

- Olton, R.M., & Johnson, D.M. (1976). Mechanisms of incubation in creative problem solving. American Journal of Psychology, 89, 617-630.
- Palermo, D.S., & Jenkins, J.J. (1964). Word association norms. Minneapolis: University of Minnesota Press.
- Patrick, A.S. (1986). The role of ability in creative 'incubation'. Personality & Individual Differences, 7, 169-174.
- Perfetto, G.A., Bransford, J.D., & Franks, J.J. (1983). Constraints on access in a problem solving context. Memory & Cognition, 11, 24-31.
- Peterson, C. (1974). Incubation effects in anagram solution. Bulletin of the Psychonomic Society, 29-30.
- Posner, M.I. (1973). Cognition: An introduction. Glenview, IL: Scott, Foresman and Company.
- Posner, M.I., & Snyder, C.R.R. (1975). Attention and cognitive control. In R.L. Solso (Ed.), Information processing and cognition. Hillsdale, NJ: Erlbaum.
- Postman, L., & Keppel, G. (1970). Norms of word association. New York: Academic Press.
- Shiffrin, R.M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. Psychological Review, 84, 127-190.
- Smith, S.M. (1995). Fixation, incubation, and insight in memory and creative thinking. In S.M. Smith, T.B. Ward, & R.A. Finke (Eds.), The creative cognition approach. Cambridge, MA: MIT Press.
- Smith, S.M., & Blankenship, S.E. (1989). Incubation effects. Bulletin of the Psychonomic Society, 27, 311-314.
- Smith, S.M., & Blankenship, S.E. (1991). Incubation and the persistence of fixation in problem solving. American Journal of Psychology, 104, 61-87.
- Smith, S.M., & Vela, E. (1991). Incubated reminiscence effects. Memory & Cognition, 19, 168-176.
- Spence, D.P. (1964). Conscious and preconscious influences on recall: Another example of the restricting effects of awareness. Journal of Abnormal and Social Psychology, 68, 92-99.

Spence, D.P., & Holland, B. (1962) The restricting effects of awareness: A paradox and an explanation. Journal of Abnormal and Social Psychology, 64, 163-174.

Stolz, J.A., & Neely, J.H. (1995). When target degradation does and does not enhance semantic context effects in word recognition. Journal of Experimental Psychology: Learning, Memory, & Cognition, 21, 596-611.

Tulving, E., Schacter, D.L., & Stark, H.A. (1982). Priming effects in word-fragment completion are independent of recognition memory. Journal of Experimental Psychology, 8, 336-342.

Van Selst, M., & Jolicoeur, P. (1994). A solution to the effect of sample size on outlier elimination. Quarterly Journal of Experimental Psychology, 47A, 631-650.

Weisberg, R., DiCamillo, M., & Phillips, D. (1978). Transferring old associations to new situations: A nonautomatic process. Journal of Verbal Learning and Verbal Behaviour, 17, 219-228.

Woodworth, R.S., & Schlosberg, H. (1954). Experimental psychology. New York: Holt, Rinehart and Winston.

Yaniv, I., & Meyer, D.E. (1987). Activation and metacognition of inaccessible stored information: Potential bases for incubation effects in problem solving. Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, 187-205.

**APPENDICES**

**Appendix A**

**Word Fragments, Associate Words, and Clues used in Experiment I**

<u>Fragment</u>	<u>Solution</u>	<u>Associated Word</u>	<u>Misleading Word</u>	<u>Clue Word</u>	<u>Non-Clue Nonword</u>
_l_r_et	clarinet	flute	stand	reed	memorzie
_at_l_c	catholic	protestant	snake	orthodox	resaerch
_w_i_n	hawaiian	island	yellow	vacation	gradaute
_n_bt_d	indebted	owing	control	grateful	nihgtime
_f_c	traffic	highway	house	transportation	friut
_r_i_l_r_	artillery	bomb	rattle	war	contagiuos
_i_amo_	cinnamon	spice	temper	flavour	mudrer
_a_l_r_a_	railroad	tracks	sister	crossing	medcinie
_r_si__t	president	prime-minister	woman	boss	einstien
_m_a_ds	emeralds	sapphire	shower	stone	propreitor
_a_pe_te_	carpenter	hammer	basket	trade	hopsital
c__a_n_r	container	carton	round	jar	lonely
_rg_i_a__n	organization	group	table	club	empty
j_i__l	judicial	lawful	tower	trial	orhpan
_m_r_as	embarrass	blush	friend	shame	orgnaic
_e_i_p_e_	helicopter	plane	window	hover	supplemet
_erc_n_	percent	ratio	planet	hundredth	operatoin
_ldi_r_	soldiers	fight	alley	command	adbomen
b_e_s_	blemish	scar	teeth	mark	lihgt
_o_le_b__	volleyball	game	dog	beach	enegry
_ac_o_y_	factory	manufacture	dishes	industrial	aluminum
_hn_it_	ethnicity	native	cotton	chinese	elemnt
_a_ro_	sparrow	finch	circus	nest	Chirstmas
t__ta_en	testament	covenant	wave	bible	butterlfy
_g_ge_n_	engagement	ring	silent	wedding	troulbe
_opi__	tropical	resort	peace	hot	enevelope
_p_g_e_	spaghetti	noodle	smoke	italian	annial
_ho_de_	shoulder	arm	dance	shrug	metropolis
_es_ur_n_	restaurant	chef	mouse	service	antleope
_d_he_	headache	splitting	sweating	worry	mytsery
_ex_le_	flexible	rigid	climb	elastic	brococli
_h_ra_t_	character	actor	fear	letter	carnvial
_ce_a_k	racetrack	indy	london	horses	carbdoard
_g_e_n_	agreement	pact	throne	settle	sercetary
_ar_st_c_	yardstick	measure	string	ruler	alochol
pu_i_n_	puritan	strict	angel	godly	sheirff
_eh_c_e_	vehicle	motor	snow	drive	agaisnt
_p_et_	operetta	musical	dollar	theatre	laydbug
_a_gs_r_	gangster	steal	leather	attack	contsruct
_f_n_r_	offender	criminal	waste	juvenile	fatigieue
_u_y_g_	studying	exams	milk	library	pithcer
_a_px_	smallpox	mumps	organ	rash	telehpone
_o_e_n_nt	government	bureaucracy	mine	federal	brigde
_a_dr_e_	wardrobe	garment	seal	dress	histroy
_a_h_m_ti_	mathematics	algebra	puzzle	numbers	impossbile
_b_n_o_d_	abandoned	forgotten	lead	desert	banquet
o_o_ke_	onlooker	watch	herd	witness	treasrue
_a_fb_c_	halfback	sport	wire	catch	entertian
_e_fh_	twelfth	eleventh	moon	placement	califonria
_i_il_r_	similar	alike	forest	twin	thristy



**Appendix B**

**Information Letter and Consent Form for Experiment I**

### **INFORMATION CONSENT LETTER**

The following study investigates factors involved in problem-solving. The problem-solving task employed here is word-fragment completion. The study is being conducted by Ms. Julie Torrance Perks under the supervision of Dr. Ken Bowers of the Department of Psychology at the University of Waterloo.

You will be asked to complete 50 word-fragments, which will involve typing in missing letters to the fragment of a word to generate the whole word. Before each word fragment is presented you will see an associate of, or word related to, the solution to the fragment. The completion of these tasks will require approximately one hour, for which you will receive partial credit towards your Introductory Psychology course.

There is little or no risk associated with participation in this study. All information collected as a result of your participation in the study will be used for teaching or research publication purposes. In either case, your anonymity is guaranteed. However, consent to participate, or for the use of the information you provided, may be withdrawn at any time by indicating this to the researcher.

**CONSENT FORM**

This study has been reviewed and approved for ethics through the Office of Human Research & Animal Care at the University of Waterloo. However, if you have any questions or concerns resulting from your participation in this study, please contact this office at 885-1211, ext. 6005.

I grant permission to Julie Torrance Perks to collect data from my participation in this research being conducted by Dr. Ken Bowers.

I understand that the study will involve completing 50 word fragments.

I understand that all information gathered in this study will be used for research purposes only and that my anonymity will be protected. I understand that I may withdraw this permission at any time and that recordings of my participation will be destroyed at my request.

**Name (Please print):**

---

**Signature:**

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**Date:**

---

**Appendix C**  
**Written Feedback for Experiment I**

### **Factors Involved in the Incubation Effect**

This study investigates the "incubation effect" in problem solving, a condition in which taking one's mind off a difficult problem that one had been previously trying to solve is followed by the successful solution to the problem. This study investigated the incubation period by giving half of the subjects a 10 minute rest period when solving word fragments while the remaining half received no 10 minute rest period. We expect subjects who get a rest period in the middle of their problem solving to solve more word fragments after this rest period than subjects who did not receive any such incubation period.

The study also investigates the reasons why an incubation period might be helpful. One proposed explanation of the incubation effect suggests that one thing that may happen when people attempt to solve a difficult or unique problem is that they get "stuck" in old and incorrect ways of viewing the problem. This prevents them from coming up with different ways to view and therefore solve the problem. The incubation period, then, is helpful because it allows old ways of thinking about the problem to die off, permitting the person to return to problem solving with a fresh mind. To investigate whether an incubation period would be more helpful when people are thinking of the problem in the wrong way, we attempted to get participants "stuck" in the wrong way of viewing a word fragment by occasionally giving them misleading words as the associate word to word fragments.

Another explanation of the incubation effect proposes that when a person takes their mind off a problem, this allows them to come in contact with information in their environment that may actually be helpful or related to solving the problem. Thus, in this study, we also investigated whether implicit information related to the problem might better problem-solving performance, even when participants were not told of any direct relation between this information and the problem. Half of the participants were required to make word/nonword decisions about words that were flashed on the screen while they worked on the word fragment. Some of these flashed words were words related to the particular fragment solution.

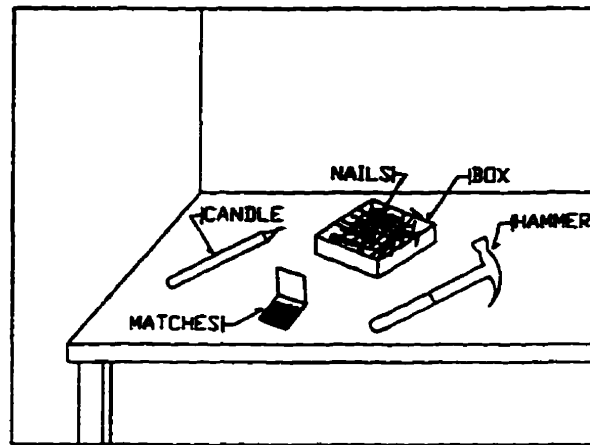
We predict that the implicit information received through responding to flashed words will be more helpful when participants who were previously stuck in the wrong way of thinking about the word fragment because of a misleading associate word receive an incubation, or rest, period than when such participants receive no rest period. Having an incubation period allows old ways of thinking about the problem to die off, and permits the person to return to problem solving with a fresh mind. With a fresh mind, the helpful implicit information may lead the problem-solver to a new way of thinking about the problem and the correct solution. Without an incubation period, it is expected that the implicit information received through the flashed words will be simply integrated into the old, incorrect way of thinking about the problem.

**Appendix D**

**Candle Problem – Correct fixation Version**

### Candle Problem

Below is a picture of some common household objects. You are to affix the candle to the wall so that it will burn properly, using only the objects in this picture. The problem is considered solved when the candle can be firmly affixed to the wall, burns properly and does not drip wax on the table or on the floor.



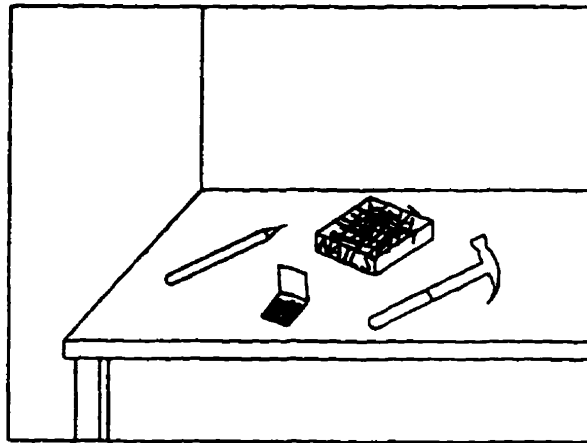
**Appendix E**

**Candle Problem – Incorrect fixation Version**



**Candle Problem**

Below is a picture of some common household objects. You are to affix the candle to the wall so that it will burn properly, using only the objects in this picture. The problem is considered solved when the candle can be firmly affixed to the wall, burns properly and does not drip wax on the table or on the floor.

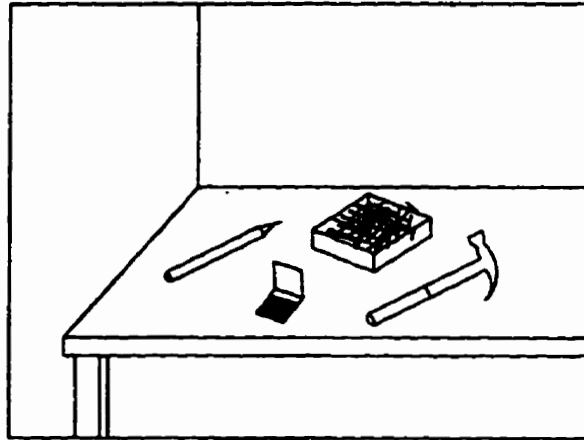


**Appendix F**

**Candle Problem -- Neutral Version**

### Candle Problem

Below is a picture of some common household objects. You are to affix the candle to the wall so that it will burn properly, using only the objects in this picture. The problem is considered solved when the candle can be firmly affixed to the wall, burns properly and does not drip wax on the table or on the floor.



**Appendix G**

**RAT Items – Correct fixation Version**

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

LICK  
SPRINKLE  
MINES

**Solution:** s

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

BREAK  
TRAIN  
BATTLE

**Solution:** s

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

HEARTED  
FEET  
BITTER

**Solution:** c

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

WORM  
SCOTCH  
RED

**Solution:** t

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

RIVER  
NOTE  
BLOOD

**Solution:** b

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

FAMILY  
APPLE  
HOUSE

**Solution:** t

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

CAT  
SLEEP  
BOARD

**Solution:** w

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

ATTORNEY  
SELF  
SPENDING

**Solution:** d

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

WIDOW  
BITE  
MONKEY

**Solution:** s

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
Note that the first letter of the solution word is provided.

TRAIN  
PONY  
SORROW

**Solution:** e



**Appendix H**

**RAT Items – Incorrect fixation Version**

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
The words in parentheses are examples of correct solutions to the problem.

(Tongue) LICK  
(Rain) SPRINKLE  
(Gold) MINES

**Solution:**

-----

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
The words in parentheses are examples of correct solutions to the problem.

(Coffee) BREAK  
(Toilet) TRAIN  
(Fight) BATTLE

**Solution:**

-----

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
The words in parentheses are examples of correct solutions to the problem.

(Broken) HEARTED  
(Inches) FEET  
(Sweet) BITTER

**Solution:**

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words. The words in parentheses are examples of correct solutions to the problem.

(Bug) WORM  
(Whiskey) SCOTCH  
(Green) RED

**Solution:**

-----

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words. The words in parentheses are examples of correct solutions to the problem.

(Lake) RIVER  
(Music) NOTE  
(Wound) BLOOD

**Solution:**

-----

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words. The words in parentheses are examples of correct solutions to the problem.

(Mother) FAMILY  
(Pie) APPLE  
(Home) HOUSE

**Solution:**

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
The words in parentheses are examples of correct solutions to the problem.

(Nap) CAT  
(Night) SLEEP  
(Wood) BOARD

**Solution:**

-----

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
The words in parentheses are examples of correct solutions to the problem.

(Lawyer) ATTORNEY  
(Me) SELF  
(Shopping) SPENDING

**Solution:**

-----

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
The words in parentheses are examples of correct solutions to the problem.

(Woman) WIDOW  
(Chew) BITE  
(Wrench) MONKEY

**Solution:**

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.  
The words in parentheses are examples of correct solutions to the problem.

(Toilet) TRAIN  
(Horse) PONY  
(Regret) SORROW

**Solution:**

**Appendix I**

**RAT Items -- Neutral Version**

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

LICK  
SPRINKLE  
MINES

**Solution:**

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

BREAK  
TRAIN  
BATTLE

**Solution:**

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

HEARTED  
FEET  
BITTER

**Solution:**

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

WORM  
SCOTCH  
RED

**Solution:**

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

RIVER  
NOTE  
BLOOD

**Solution:**

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

FAMILY  
APPLE  
HOUSE



**Solution:**

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

CAT  
SLEEP  
BOARD

**Solution:**

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

ATTORNEY  
SELF  
SPENDING

**Solution:**

---

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

WIDOW  
BITE  
MONKEY

**Solution:**

**Remote Associates Task**

Following are three words. Find the word that is related to all three of these words.

TRAIN  
PONY  
SORROW

**Solution:**

**Appendix J**

**Radiation Problem – Correct fixation Version**

**Radiation Problem**

Suppose you are a doctor faced with a patient who has a malignant tumour in his stomach. It is impossible to operate on the patient, but unless the tumour is destroyed the patient will die. There is a kind of ray that can be used to destroy the tumour. If the rays reach the tumour all at once at a sufficiently high intensity, the tumour will be destroyed. Unfortunately, at this intensity, the healthy tissue that the rays pass through on the way to the tumour will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumour either. What type of procedure might be used to destroy the tumour with the rays, and at the same time avoid destroying the healthy tissue?

**Think of:**            Multiple

**Appendix K**

**Radiation Problem -- Incorrect fixation Version**

### **Radiation Problem**

Suppose you are a doctor faced with a patient who has a malignant tumour in his stomach. It is impossible to operate on the patient, but unless the tumour is destroyed the patient will die. There is a kind of ray that can be used to destroy the tumour. If the rays reach the tumour all at once at a sufficiently high intensity, the tumour will be destroyed. Unfortunately, at this intensity, the healthy tissue that the rays pass through on the way to the tumour will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumour either. What type of procedure might be used to destroy the tumour with the rays, and at the same time avoid destroying the healthy tissue?

**Think of:** Intensity

**Appendix L**

**Radiation Problem -- Neutral Version**

### **Radiation Problem**

Suppose you are a doctor faced with a patient who has a malignant tumour in his stomach. It is impossible to operate on the patient, but unless the tumour is destroyed the patient will die. There is a kind of ray that can be used to destroy the tumour. If the rays reach the tumour all at once at a sufficiently high intensity, the tumour will be destroyed. Unfortunately, at this intensity, the healthy tissue that the rays pass through on the way to the tumour will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumour either. What type of procedure might be used to destroy the tumour with the rays, and at the same time avoid destroying the healthy tissue?



**Appendix M**

**Clue Paired Associates Incubation Task  
for Candle Problem**

**Paired- Associates Task**

Table	--	Chair
Bread	--	Butter
Doctor	--	Nurse
Black	--	White
Start	--	Stop
Thread	--	Needle
Man	--	Woman
Mouth	--	Lip
Sheep	--	Wool
Church	--	Tower
Cow	--	Milk
Rain	--	Wet
Pastor	--	Priest
Dove	--	Peace
Pan	--	Cook
Dog	--	Bone
Web	--	Spider
Nest	--	Bird
Grass	--	Green
Candle	--	Box

**Appendix N**

**No Clue Paired Associates Incubation Task  
for Candle Problem**

**Paired- Associates Task**

Table	--	Chair
Bread	--	Butter
Doctor	--	Nurse
Black	--	White
Start	--	Stop
Thread	--	Needle
Man	--	Woman
Mouth	--	Lip
Sheep	--	Wool
Church	--	Tower
Cow	--	Milk
Rain	--	Wet
Pastor	--	Priest
Dove	--	Peace
Pan	--	Cook
Dog	--	Bone
Web	--	Spider
Nest	--	Bird
Grass	--	Green
Candle	--	Paper

**Appendix O**

**Clue Story Incubation Task  
for Radiation Problem**

**Read over the following, keeping the main points of in mind. You will be asked to recall and summarize the situation after reading it.**

### **The General**

A small country was ruled from a strong fortress by a king. The fortress was situated in the middle of the country surrounded by farms and villages. Many roads radiated outward from the fortress like spokes on a wheel. A rebel general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads. However, the general learned that the king had planed mines on each of the roads. The mines were set so that small bodies of men could pas over them safely, since the king needed to move his troops and workers to and from the fortress. However, any large force would detonate the mines. Not only would this blow up the road and render it impassable, but it would also destroy many neighbouring villages. It therefore seemed impossible to mount a full-scale attack on the fortress.

The general, however, knew just what to do. He divided his army up into small groups and dispatched each group to the head of a different road. When all was ready he gave the signal and each group marched down a different road. Each group continued down its road to the fortress at the same time. The fortress fell and the king was forced to flee into exile.

**Please give a summary of the story you just read, in your own words.**

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**On a scale of 1 to 7, rate this story's plausibility.**

1-----2-----3-----4-----5-----6-----7  
Low High

**On a scale of 1 to 7, rate this story's comprehensibility.**

1-----2-----3-----4-----5-----6-----7  
Low High

**Appendix P**

**No Clue Story Incubation Task  
for Radiation Problem**



**Read the following story, keeping the main points of the story in mind. You will be asked to recall and summarize the story after reading it.**

### **The Identical Twins**

Once there were identical twins who were continually playing pranks on their family, friends, and teachers. The annual school picnic was always a big event for the twins. There were races and other athletic events in which the twins won lots of prizes. One year a new student arrived who was a star runner. The twins wanted to win the main event: the 2-mile race through the woods behind the school. So they secretly devised a plan which would enable them to outdo the newcomer.

The day of the race arrived. Each runner was to pick his own path through the woods to a clearing, where a teacher stood posted to determine the winner. One twin entered the race, while the other excused himself on the grounds that he had hurt his leg in an earlier broadjumping event. The race began and the students rushed into the woods. The twin rushed into the woods and waited until the others had passed out of sight. Then he went back to the school using a path hidden from the picnic area. Shortly after, the other twin, who had been hiding behind a rock near the finish line of the race, burst out and ran into the clearing ahead of the other runners. The teacher named him the winner and marvelled at the speed of his running. Next year the twins switched places and thereafter maintained their status of this event.

**Appendix Q**  
**Clue Analogy Incubation Task**  
**for RAT Items**

**Analogy Task**

In each of the following, fill in the blank with the appropriate word to complete the analogy. An example of an analogy is "Mother : Father as Sister: Brother." In the space underneath, please briefly indicate your reasoning for the word choice.

SLEEP : BED as SIT : \_ \_ \_ \_ \_

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BLACK : WHITE as PEPPER : \_ \_ \_ \_

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TELEVISION : CHANNEL as RADIO : \_ \_ \_ \_ \_

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SUMMER : WINTER as HOT : \_ \_ \_ \_

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OUTLET : ELECTRICITY as FAUCET : \_ \_ \_ \_ \_

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PHONOGRAPH : RECORD as RECORDER : \_ \_ \_ \_ \_

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MONEY : WALLET as SAVINGS : \_ \_ \_ \_ \_

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LIMB : BODY as BRANCH : \_ \_ \_ \_ \_

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CHALK : PENCIL as BLACKBOARD : \_ \_ \_ \_ \_

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GALLOP : TROT as RUN : \_ \_ \_ \_ \_

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---

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ATTACK : PROTECT as OFFENSE : \_ \_ \_ \_ \_

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NEST : BIRD as WEB : \_ \_ \_ \_ \_

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SAD : CRY as FEELINGS : \_ \_ \_ \_ \_

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SCISSORS : HAIR as MOWER : \_ \_ \_ \_ \_

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SHAMPOO: TOOTHPASTE as HAIR : \_ \_ \_ \_ \_

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DIG : SWEEP as SHOVEL : \_ \_ \_ \_ \_

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FOOT : SHOE as HAND : \_ \_ \_ \_ \_

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PLIERS : SCISSORS as HOLD : \_ \_ \_

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PLANTS : EARTH as FISH : \_ \_ \_ \_ \_

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**Appendix R**

**No Clue Analogy Incubation Task  
for RAT Items**

**Analogy Task**

In each of the following, fill in the blank with the appropriate word to complete the analogy. An example of an analogy is "Mother : Father as Sister: Brother." In the space underneath, please indicate your reasoning for the word choice.

SLEEP : BED as SIT : \_ \_ \_ \_ \_

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DIAMOND : HEART as SPADE : \_ \_ \_ \_ \_

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COAT : WEAR as APPLE : \_ \_ \_

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DROPS : RAIN as FLAKES : \_ \_ \_ \_ \_

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RUN : FAST as WALK : \_ \_ \_ \_ \_

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PEN : INK as PENCIL : \_ \_ \_ \_

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CAN : METAL as BOTTLE : \_ \_ \_ \_

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OUTLET : ELECTRICITY as FAUCET : \_ \_ \_ \_

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COLLAR : NECK as WATCH : \_ \_ \_ \_

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AUTHOR : BOOK as JOURNALIST : \_ \_ \_ \_

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PLIERS : SCISSORS as HOLD : \_ \_ \_

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PLANTS : EARTH as FISH : \_ \_ \_ \_ \_

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CHALK : PENCIL as BLACKBOARD : \_ \_ \_ \_ \_

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CAR : ROAD as TRAIN : \_ \_ \_ \_ \_

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---

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DIG : SWEEP as SHOVEL : \_ \_ \_ \_ \_

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FOOT : SHOE as HAND : \_ \_ \_ \_ \_

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SCISSORS : HAIR as MOWER : \_ \_ \_ \_ \_

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SHAMPOO: TOOTHPASTE as HAIR : \_ \_ \_ \_ \_

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**Appendix S**  
**Counterbalanced Order of Administration --**  
**Experiment II**

- I.
  1. Radiation Problem -- Correct Fixation; No Incubation
  2. Candle Problem -- Correct Fixation; No Clue Incubation
  3. RAT Problems -- Incorrect Fixation; Clue Incubation
  
- II.
  1. RAT Problems -- Correct Fixation; No Clue Incubation
  2. Radiation Problem -- Correct Fixation; Clue Incubation
  3. Candle Problem -- Incorrect Fixation; No Incubation
  
- III.
  1. Candle Problem -- Correct Fixation; Clue Incubation
  2. RAT Problems -- Correct Fixation; No Incubation
  3. Radiation Problem -- Incorrect Fixation; No Clue Incubation
  
- IV.
  1. Radiation Problem -- Correct Fixation; Clue Incubation
  2. Candle Problem -- Correct Fixation; No Incubation
  3. RAT Problems -- Incorrect Fixation; No Clue Incubation
  
- V.
  1. RAT Problems -- Correct Fixation; No Incubation
  2. Radiation Problem -- Correct Fixation; No Clue Incubation
  3. Candle Problem -- Incorrect Fixation; Clue Incubation
  
- VI.
  1. Candle Problem -- Correct Fixation; No Clue Incubation
  2. RAT Problems -- Correct Fixation; Clue Incubation
  3. Radiation Problem -- Incorrect Fixation; No Incubation
  
- VII.
  1. Radiation Problem -- Correct Fixation; No Clue Incubation
  2. Candle Problem -- Correct Fixation; Clue Incubation
  3. RAT Problems -- Incorrect Fixation; No Incubation
  
- VIII.
  1. RAT Problems -- Correct Fixation; Clue Incubation
  2. Radiation Problem -- Correct Fixation; No Incubation
  3. Candle Problem -- Incorrect Fixation; No Clue Incubation
  
- IX.
  1. Candle Problem -- Correct Fixation; No Incubation
  2. RAT Problems -- Correct Fixation; No Clue Incubation
  3. Radiation Problem -- Incorrect Fixation; Clue Incubation

**Appendix T**

**Information Letter and Consent Form for Experiment II**

## INFORMATION CONSENT LETTER

The following study investigates factors involved in problem-solving. The study is being conducted by Ms. Julie Torrance Perks under the supervision of Dr. Ken Bowers of the Department of Psychology at the University of Waterloo.

You will be asked to solve three different problems. On some of the problems, you will be given a hint about how to think about the problem in order to solve it. The completion of these tasks will require approximately one hour, for which you will receive partial credit towards your Introductory Psychology course.

There is little or no risk associated with participation in this study. All information collected as a result of your participation in the study will be used for teaching or research publication purposes. In either case, your anonymity is guaranteed. However, consent to participate, or for the use of the information you provided, may be withdrawn at any time by indicating this to the researcher.

**CONSENT FORM**

This study has been reviewed and approved for ethics through the Office of Human Research & Animal Care at the University of Waterloo. However, if you have any questions or concerns resulting from your participation in this study, please contact Dr. Susan Sykes, Office of Human Research, University of Waterloo, 888-4567, ext. 6005.

I grant permission to Julie Torrance Perks to collect data from my participation in this research being conducted by Dr. Ken Bowers.

I understand that the study will involve solving three different problems.

I understand that all information gathered in this study will be used for research purposes only and that my anonymity will be protected. I understand that I may withdraw this permission at any time and that recordings of my participation will be destroyed at my request.

**Name (Please print):**

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**Signature:**

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**Date:**

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**Appendix U**  
**Written Feedback for Experiment II**

### **Factors Involved in the Incubation Effect**

This study investigates factors that may be involved in the "incubation effect" in problem solving. The incubation effect occurs when taking one's mind off a difficult problem that one had been previously trying to solve is followed by the successful solution to the problem. Participants in the study attempted to solve three insight-type problems. The study investigated the incubation period by giving participants an incubation period for two of the problems they worked on and no incubation period for one of the problems.

One proposed explanation of the incubation effect suggests that one thing that may happen when people attempt to solve a difficult or unique problem is that they get "stuck" in old and incorrect ways of viewing the problem. This prevents them from coming up with different ways to view and therefore solve the problem. The incubation period, then, is helpful because it allows old ways of thinking about the problem to die off, permitting the person to return to problem solving with a fresh mind. To investigate whether an incubation period would be more helpful when people are thinking of the problem in the wrong way, we attempted to get participants "stuck" in the wrong way of thinking about a problem by giving them a misleading hint to one of the problems they attempted to solve.

Another explanation of the incubation effect proposes that when a person takes their mind off a problem, this allows them to come in contact with information in their environment that may actually be helpful or related to solving the problem. Thus, in this study, we also investigated whether implicit information related to the problem might better problem-solving performance, even when participants were not told of any direct relation between this information and the problem. During one of the two incubation periods that each participant received, they completed a task which contained information that could be helpful for solving the problem they were working on.

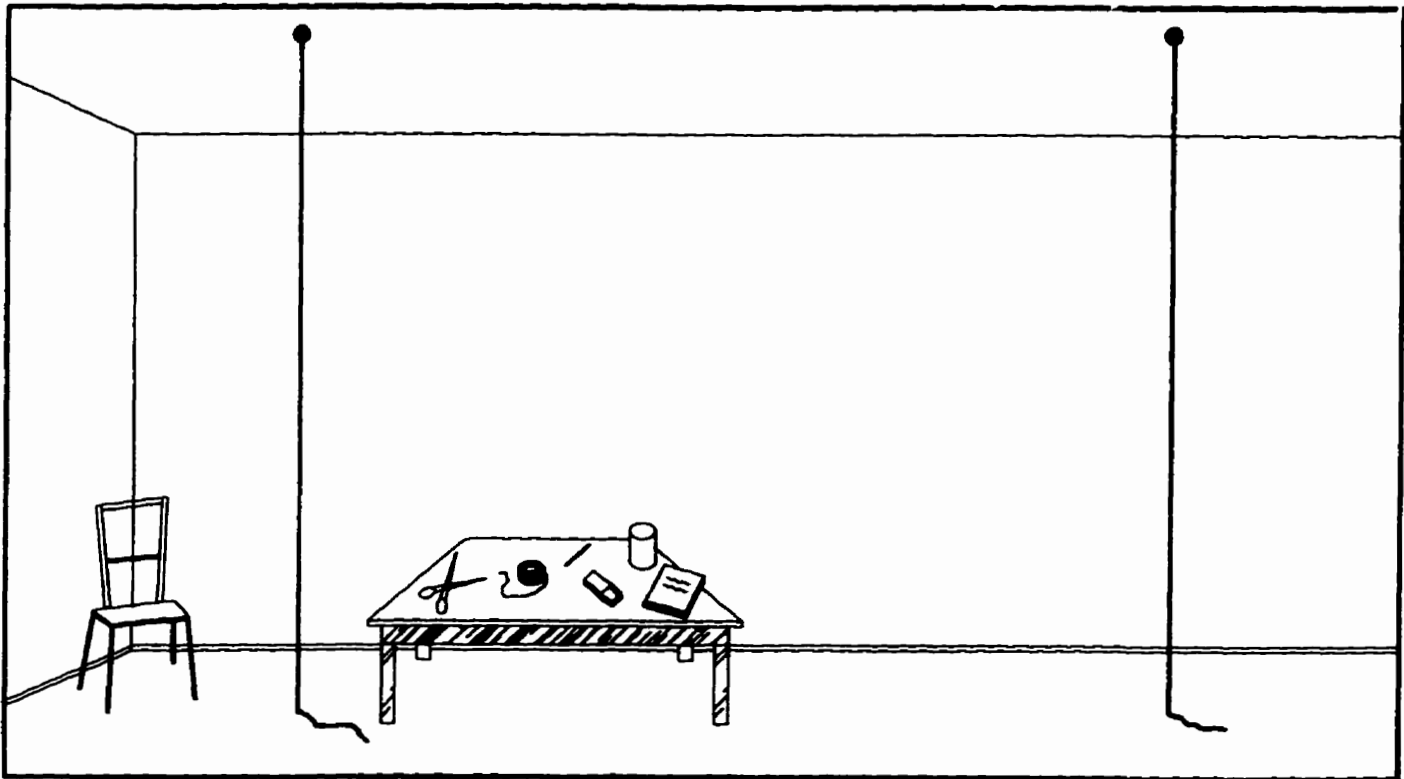
We predict the beneficial effects of the incubation period alone will be most evident for problems where participants were previously stuck in the wrong way of thinking about the problem because of the original misleading hint. Having an incubation period allows old ways of thinking about the problem to die off, and permits the person to return to problem solving with a fresh mind. The incubation period alone may have no effect on performance in cases where participants were correctly thinking about the problem, due to the helpful hint, or incubation may actually be unhelpful in this case because it interrupts a person when they are on the right track to solving the problem. Finally, we would expect incubation to be helpful for both cases where people were thinking about the problem in correct and incorrect ways when the incubation period also included implicit helpful information for solving the problem.

Thank you very much for participating in this study. If you have any further questions about the study, feel free to contact Julie Torrance Perks, 885-1211, x2813. If you have any concerns resulting from your participation in this study, please contact Dr. Susan Sykes, Office of Human Research, University of Waterloo, 888-4567, ext 6005.

**Appendix V**  
**Two-String Problem**

### Two String Problem

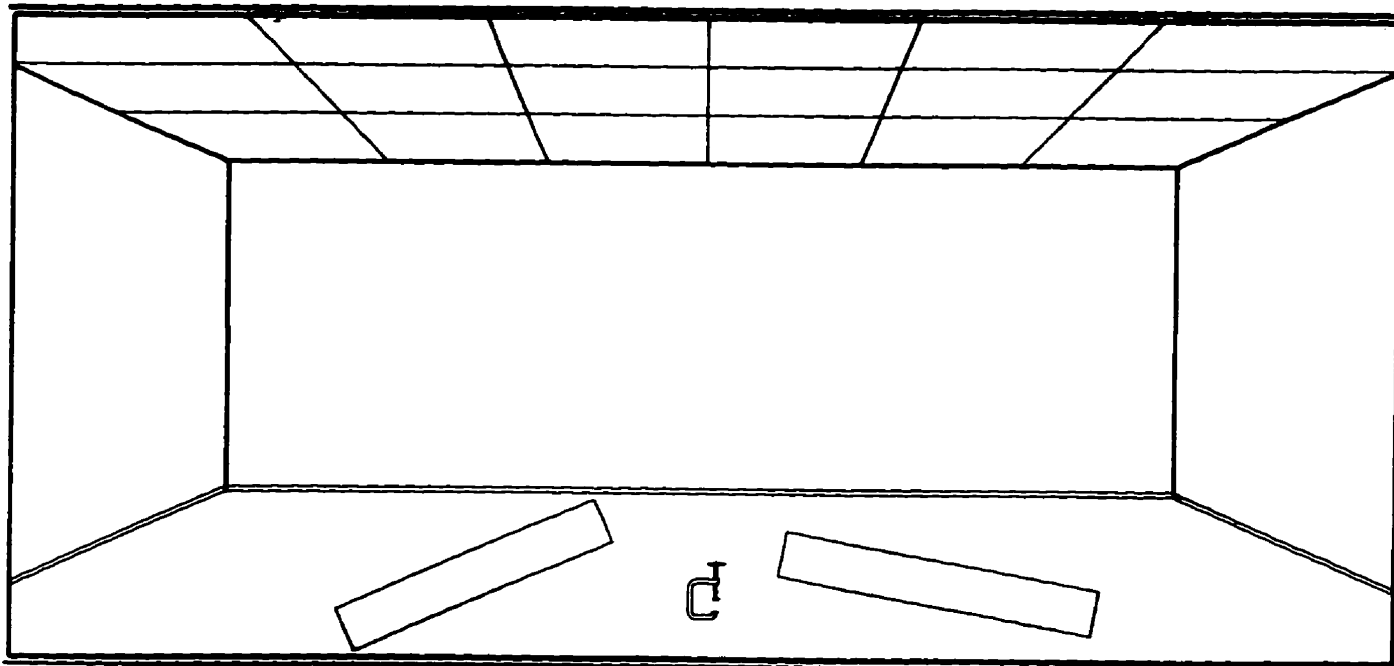
Below is a picture of two strings hanging from the ceiling. Your task is to tie together the two strings. When you try to do this, you find that the strings are hung too far apart to allow one to be reached when the other is grasped. Find a way to tie the two strings together. You may use anything in the picture to help you do so.



**Appendix W**  
**Hatrack Problem**

### Coat-Rack Problem

In the room below are two boards and a C clamp. You are to construct a stable coat-rack (i.e., something to hang a coat on) using these objects. One board is 4.5 feet long and the other is 4 feet long. The boards are both 5 inches wide and 1 inch thick. The C clamp is capable of opening to 4 inches wide. The room is 20 feet by 20 feet square and 8 feet from ceiling to floor. Construct the coat-rack in the centre of the room. The coat-rack must be strong enough to support a coat. Therefore, it cannot be balanced in some flimsy way; it must be quite sturdy.



**Appendix X**

**Analogy Task --  
Clue to Two-String Problem**

**Analogy Problem**

In each of the following, fill in the blank with the appropriate word to complete the analogy. An example of an analogy is "Mother : Father as Sister: Brother." In the space underneath, please briefly indicate your reasoning for the word choice.

SINGLE : DOUBLE as ONE : \_ \_ \_ \_

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DROPS : RAIN as FLAKES : \_ \_ \_ \_

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BOW : RIBBON as KNOT : \_ \_ \_ \_ \_

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---

---

DIAMOND : HEART as SPADE : \_ \_ \_ \_

---

---

---

GUN : SHOOT as NOOSE : \_ \_ \_ \_

---

---



LIMB : BODY as BRANCH : \_ \_ \_ \_ \_

---

---

---

ZIPPER : FASTEN as SHOELACE : \_ \_ \_ \_

---

---

---

BELL: RING as PENDULUM : \_ \_ \_ \_ \_

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---

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ROLEX : WATCH as GRANDFATHER : \_ \_ \_ \_ \_

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SAND : SANDBOX as SWING : \_ \_ \_ \_ \_

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**Appendix Y**

**Paired Associates Rating Task --  
Clue to Hatrack Problem**

**Please rate the degree of relatedness of each of the following pairs of words.**

Table -- Chair	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Black -- White	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
House -- Pet	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Dog -- Bone	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Start -- Stop	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Pan -- Cook	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Telephone -- Book	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Dove -- Peace	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Thread -- Needle	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Doctor-- Nurse	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Nest -- Bird	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Rain -- Thunder	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Grass -- Green	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Spider -- Web	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related
Boards -- Ceiling	1 ---- 2 ---- 3 ---- 4 ---- 5 ---- 6 ---- 7 Not related Very related

**Appendix Z**

**Counterbalanced Order of Administration --  
Experiment III**

**Order One**

1. Hatrack Problem - No Hint
2. Radiation Prob. - Hint Before
3. Two-String Prob. - Hint After

**Order Two**

1. Hatrack Problem - Hint After
2. Radiation Prob. - No Hint
3. Two-String Prob. - Hint Before

**Order Three**

1. Hatrack Problem - Hint Before
2. Radiation Prob. - Hint After
3. Two-String Prob. - No Hint

**Order Four**

1. Two String Prob. - No Hint
2. Hatrack Problem - Hint Before
3. Radiation Prob. - Hint After

**Order Five**

1. Two String Prob. - Hint After
2. Hatrack Problem - No Hint
3. Radiation Prob. - Hint Before

**Order Six**

1. Two String Prob. - Hint Before
2. Hatrack Problem - Hint After
3. Radiation Prob. - No Hint

**Order Seven**

1. Radiation Prob. - No Hint
2. Two-String Prob. - Hint Before
3. Hatrack Problem - Hint After

**Order Eight**

1. Radiation Prob. - Hint After
2. Two-String Prob. - No Hint
3. Hatrack Problem - Hint Before

**Order Nine**

1. Radiation Prob. - Hint Before
2. Two-String Prob. - Hint After
3. Hatrack Problem - No Hint

**Appendix AA**

**Information Letter and Consent Form for Experiment III**

## **INFORMATION CONSENT LETTER**

The following study investigates factors involved in problem-solving. The study is being conducted by Ms. Julie Torrance Perks under the supervision of Dr. Ken Bowers of the Department of Psychology at the University of Waterloo.

You will be asked to work on several different types of problems. Included with these are some tasks which are being used to collect normative data to develop problems for future research. In all there are five tasks. The completion of these will require approximately one hour, for which you will receive partial credit towards your Introductory Psychology course.

There is little or no risk associated with participation in this study. All information collected as a result of your participation in the study will be used for teaching or research publication purposes. In either case, your anonymity is guaranteed. However, consent to participate, or for the use of the information you provided, may be withdrawn at any time by indicating this to the researcher.

**CONSENT FORM**

This study has been reviewed and approved for ethics through the Office of Human Research & Animal Care at the University of Waterloo. However, if you have any questions or concerns resulting from your participation in this study, please contact Dr. Susan Sykes, Office of Human Research, University of Waterloo, 888-4567, ext. 6005.

I grant permission to Julie Torrance Perks to collect data from my participation in this research being conducted by Dr. Ken Bowers.

I understand that the study will involve working on five different problems.

I understand that all information gathered in this study will be used for research purposes only and that my anonymity will be protected. I understand that I may withdraw this permission at any time and that recordings of my participation will be destroyed at my request.

**Name (Please print):**

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**Signature:**

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**Date:**

---



**Appendix AB**

**Written Feedback for Experiment III**

### **The Role of Implicit Clues in the Incubation Effect**

This study investigates factors that may be involved in the "incubation effect" in problem solving. The incubation effect occurs when taking one's mind off a difficult problem that one had been previously trying to solve is followed by the successful solution to the problem.

One explanation of the incubation effect proposes that when a person takes their mind off a problem, this allows them to come in contact with information in their surroundings that may actually be helpful or related to solving the problem. That is, they may, by chance, "bump into" an implicit clue to the problem in their environment. One specific hypothesis related to this idea is the 'Memory Sensitization' hypothesis developed by Yaniv & Meyer (1987). They propose that initial work on a problem begins to activate ideas or knowledge structures, called memory traces, related to the problem in the problem solver's mind. During the time off task in the incubation period, this partial activation sensitizes the person to information or inputs in their surroundings that might be related to the problem they had previously been working on. In other words, after having spent some time working on a problem, but not achieving a solution, people may be likely to notice external information which might help them solve it. At present, there has been very little research that has investigated the implicit clue hypothesis of incubation.

There has, however, been a substantial amount of research investigating whether people can spontaneously transfer their previous experiences, or information they have previously learned to help them solve a problem. This research almost always takes the form of presenting a helpful clue or analogy to a problem to subjects before they attempt to solve the problem. The general conclusion from this research is that people do not spontaneously make use of helpful information or "clues" to help them solve a problem, that is, people perform no better on a problem when given an implicit clue to the problem immediately before trying to solve it than if they had not been given the clue at all. The results of this research would seem to cast doubt on the implicit clue hypothesis of incubation.

Recall, however, Yaniv & Meyer's emphasis on the preliminary partial activation relating to the problem in the problem solver's mind. It is this partial activation which leads a person to notice the clue or helpful information in his/her surroundings. Thus, according to this perspective, information presented during an incubation period, after some partial work on the problem, may be more likely to be 'picked up' by the problem solver and have greater benefits on performance than when the same information is presented before attempting the problem.

The present study investigated this very hypothesis. Participants received information that provided a clue to a problem either before or after attempting the problem. As well, on a third control problem, participants received no clue to the problem. We predict that receiving the hint after some initial work on the problem will result in more problems solved than when receiving the same hint before attempting the problem.

Thank you very much for participating in this study. If you have any further questions about the study, feel free to contact Julie Torrance Perks, 885-1211, x 2813. If you have any concerns resulting from your participation in this study, please contact Dr. Susan Sykes, Office of Human Research, University of Waterloo, 888-4567, x 6005.

**Appendix AC**

**Word Definitions used in Experiment IV**

**List 1**

1. A navigational instrument used in measuring angular distances, especially the altitude of the sun, moon and stars at sea. (sextant)
2. A small boat used in the river and harbour traffic of China and Japan, propelled with an oar. (sampan)
3. An infectious and usually fatal bacterial disease of animals, especially cattle and sheep. (anthrax)
4. A person who believes that nothing can be known about God; expressing ignorance of God; not an atheist. (agnostic)
5. In old Greek stories, the food of the Gods; supposed to give immortality to any human who ate it; anything that has a delightful taste. (ambrosia)
6. An animal able to live both on land and in water; aircraft designed to take off from and land on either land or water; flat bottomed vehicle able to move in water and on land. (amphibian)
7. A small planet; one of the thousands of small planets between Mars and Jupiter with diameters from a fraction of a mile to nearly 500 miles. (asteroid)
8. A style of artistic expression prevalent in the 17th century that is marked generally by extravagant form and elaborate ornamentation, esp. in music and architecture. (baroque)
9. The Capital of Syria. (damascus)
10. Building in which Muslims worship Allah. (mosque)
11. A Soviet traveller beyond the earth's atmosphere. (cosmonaut)
12. Illegal trade; smuggling goods into or out of a country, contrary to the law. (contraband)
13. A state of being unable to feel pain, heat, etc; branch in chemistry concerned with substances producing this state. (anesthesia)
14. A word made by changing the order of the letters in another word; e.g. plum-lump. (anagram)
15. The first name of the character "Scrooge" in Dickens "A Christmas Carol". (ebenezer)
16. Goblet, consecrated cup, wine cup, esp. one used in church for communion. (chalice)
17. A new convert, esp. a newly baptized Christian; generally, a beginner or novice.

(neophyte)

18. A mixture of metals, esp. a metal of low quality with a metal of higher value. (alloy)
19. A grotesque carved or sculpted figure projecting at the upper part of a building, usually from a roof gutter. (gargoyle)
20. A fanatical partisan; one who is carried away in his pursuit of a cause or object. (zealot)
21. An object believed by primitive people to have magical power to protect or aid its owner; an object of special devotion. (fetish)
22. Authorized period of delay in performance of a legal obligation or the payment of a debt; a waiting period set by an Authority; a suspension of activity. (moratorium)
23. Officer who acts as a go-between for two armies. (liaison)
24. Picture writing used by Ancient Egyptian priesthood. (hieroglyphic)
25. Any of the numerous extinct Pleistocene elephants distinguished from recent elephants by large size, very long tusks that curve upwards, and well-developed body hair. (mammoth)
26. The technical terminology or characteristic idiom of a special activity or group; an obscure and often pretentious language marked by circumlocutions and long words. (jargon)
27. Puzzle; an obscure speech or writing; something hard to understand or explain; an inscrutable or mysterious person. (enigma)
28. A style of cooking; manner of preparing food. (cuisine)
29. Trunk of a statue with head and limbs missing. (torso)
30. Strength, staying power, endurance. (stamina)
31. Fiftieth anniversary of an event; its commemoration, or celebration. (jubilee)
32. Combat between mounted knights with weapons such as lances, swords, or battle-axes, esp. as part of a tournament. (joust)
33. Branch of zoology dealing with birds. (ornithology)
34. A person who appeals to people's prejudices, making false claims and promises in order to gain power; false leader of people. (demagogue)
35. A track contest consisting of ten different track-and-field events. (decathlon)

36. To place side by side; put close together. (juxtapose)
37. The first artificial satellite put in orbit by Russia in 1957. (sputnik)
38. The author of the book "1984". (orwell)
39. The Apollo lunar module that landed the first man on the moon. (eagle)
40. One of the two times in the year when the sun crosses the equator and day and night are equal everywhere: March 21 and September 23. (equinox)
41. The country of which Bagdad is the Capital. (iraq)
42. Last name of Batman's secret identity in the Batman comics. (wayne)
43. Sediment deposited by running water. (silt)
44. The chapel whose ceiling was painted by Michelangelo. (sistine)
45. Opposition to war or violence as a means of settling disputes; refusal to bear arms on moral or religious grounds. (pacifism)
46. A government ban on shipping through a port; a government act forbidding commerce with another nation. (embargo)
47. An expert in children's diseases. (pediatrician)
48. Pertaining to or used in common speech. (colloquial)
49. The capital of Australia. (canberra)
50. Listlessness; state of apathy or indifference. (lethargy)
51. Formation of words in imitation of natural sounds. (onomatopoeia)
52. An institution for the care or relief of the insane; a refuge, protection. (asylum)
53. To bestow by will; to hand down to descendants. (bequeath)
54. A regional form of language, differing from the standard. (dialect)
55. A going forth from a place or country; departure of the Israelites from Egypt; second book of the Old Testament. (exodus)
56. An apparatus for beheading condemned persons by means of a heavy knife sliding between uprights. (guillotine)

**List 2**

1. Dizziness or swimming of the head; giddiness; nausea; not drunkenness. (vertigo)
2. Horizontal sounding box, and played with picks and fingers; not a harp. (zither)
3. The capital of Burma. (rangoon)
4. The well being and happiness of others first; unselfishness. (altruism)
5. The capital of Finland. (helsinki)
6. With identity concealed; disguised. (incognito)
7. Large bright coloured handkerchief. Brightly coloured square of material with red or yellow spots usually worn round the neck. (bandanna)
8. The act of an authority by which pardon is granted to a large group of individuals; general pardon, esp. for offenses against the state. (amnesty)
9. Fissure, narrow opening in a rock, wall, etc., resulting from a split or crack. (crevice)
10. The French author of "The Plague". (camus)
11. Incapable of being expressed in words; indescribable; unspeakable or unutterable; inexplicable; inexpressible. (ineffable)
12. To expose milk, cheese, or fermented liquids to a high temperature but below the boiling point for a given period of time, killing bacteria and arresting fermentation. (pasteurize)
13. Made or done on or as if on the spur of the moment; improvised; composed or uttered without previous preparation; extemporaneous. (impromptu)
14. Hardened, unfeeling, or indifferent to insults and the suffering of others. (callous)
15. A monster, half bull, that was confined in a labyrinth where it consumed its tribute of Athenian youths and maidens, until slain by Theseus. (minotaur)
16. A rigid airship of a large dirigible type. (zeppelin)
17. Bestowal or invocation of divine favour. (blessing)
18. A hiding place used by explorers for concealing or preserving provisions or implements. (cache)
19. Belief that events are determined by force beyond human control; a doctrine that events

are fixed in advance for all time in such a manner that human beings are powerless to change them. (fatalism)

20. The dense, fibrous, opaque, white, outer coat of the eyeball. (sclera)

21. The capital of Thailand. (bangkok)

22. Manual skill, neatness, deftness, adroitness. (dexterity)

23. A ceremonial embrace; A ceremony or salute to mark the conferring of knighthood, or marking the recognition of special merit; award. An expression of praise. (accolade)

24. The science of coins. (numismatics)

25. A connoisseur of food and drink. (gourmet)

26. Sorcerer; one skilled in magic; magician. (wizard)

27. Shallow body of water, near or connected to a larger body of water. (lagoon)

28. Homesickness; an excessively sentimental condition yearning for return to or of some past period or irrecoverable condition. (nostalgia)

29. Small group, often of military officers, that rules a country after a coup d'état and before a legitimate government is formed; used esp. in Central and South America. (junta)

30. A mythical figure, half man, half horse. (centaur)

31. A statement that is seemingly contradictory or opposed to common sense and yet is perhaps true. (paradox)

32. Dwarf; an ageless and often deformed man of folklore who lives in the earth and guards precious ores or treasures. (gnome)

33. Right to exercise legal authority or the territory over which authority is exercised. (jurisdiction)

34. Collector and disposer of refuse; animal that devours refuse and carrion. (scavenger)

35. Cleansing agent; any of numerous synthetic-water soluble or liquid organic preparations that are able to emulsify oils, and hold dirt in suspension. (detergent)

36. The act of talking to oneself; a dramatic monologue that gives the illusion of being a series of unspoken reflections. (soliloquy)



37. False testimony while under oath. (perjury)
38. Yearly calendar with detailed information on year's tides, events, etc. (almanac)
39. Socrates' most famous student. (plato)
40. The author who wrote under the pseudonym of Mark Twain. (clemens)
41. Chief and lowest timber or steel plate of a vessel extending from stem to stern along the bottom and supporting the whole frame. (keel)
42. The rubber roller on a typewriter. (platen)
43. Heathen; idolater or worshipper of many gods. (pagan)
44. Animal or plant living on another; toady; sycophant. (parasite)
45. The three-leaf clover that is the emblem of Ireland. (shamrock)
46. The country of which Budapest is the capital. (hungary)
47. The proper name for a badminton bird. (shuttlecock)
48. The mountain range in which Mount Everest is located. (himalayas)
49. The kind of poison Socrates took at his execution. (hemlock)
50. Large tent, esp. one supported on posts or a temporary open building for shelter, entertainment etc. (pavilion)
51. The process by which plants make their food. (photosynthesis)
52. An institution for the care or relief of the insane; a refuge; protection. (asylum)
53. To bestow by will; to hand down to descendants. (bequeath)
54. A regional form of language, differing from the standard. (dialect)
55. A going forth from a place or country; departure of the Israelites from Egypt; second book of the Old Testament. (exodus)
56. An apparatus for beheading condemned persons by means of a heavy knife sliding between uprights. (guillotine)

**Appendix AD**

**Lexical Decision Task Stimuli used in Experiment IV**

**Lexical Decision Task Stimuli**

1. borrow revolve hidden cottle lystem
2. mountain proclaim innocent peverend lovernor
3. garbage number ostrich inhobit invide
4. anthrax rangoon analyze dericit gomplex
5. window valley ashore manter ringle
6. sampan zither entity nostral infome
7. amphibian incognito professor intenesly rifficult
8. sextant vertigo whistle feapure aderage
9. ambrosia helsinki carnival cohereng dostance
10. damascus crevice acrobat risgust morling
11. agnostic altruism triangle approach caffeine
12. baroque amnesty amplify koward fiscuit
13. contraband pasteurize collective cohistent lomething
14. asteroid bandanna adorable herecent tegither
15. cosmonaut ineffable lightning fepresent sipuation
16. ebenezer minotaur epidemic congider specfrum
17. mosque camus figure buchet motine
18. anagram callous imitate hebause proplem
19. alloy cache seize podel rouch
20. anesthesia impromptu direction compocent fonscious
21. neophyte blessing mahogany somution fruitrul
22. fetish bangkok temper jolder lottir

23. chalice zeppelin blanket scenfle selated
24. zealot sclera gallop symgol garrel
25. hieroglyphic numismatics delinquency refrimenator sentitental
26. gargoyle fatalism juvenile kequence matogony
27. liaison accolade neglect durakle harlest
28. enigma lagoon velvet lecond regort
29. moratorium dexterity difficulty pargicular secremary
30. jargon wizard island napure sambol
31. stamina centaur plaster amitate inxiety
32. mammoth gourmet opinion aroumal endorge
33. torso junta cease speef plean
34. ornithology jurisdiction organization pergormance restansible
35. cuisine nostalgia shortcut auditoxy acaderic
36. joust gnome cable frime dresk
37. juxtapose soliloquy adventure ignoyance tanderine
38. jubilee paradox package dashier exomple
39. decathlon detergent magnitude defermine spructure
40. eagle plato flask nasis slobe
41. demagogue scavenger universal hormation knowledge
42. orwell almanac larynx larrow ramily
43. wayne platen globe slong chelf
44. sputnik perjury message gederal brimary
45. iraq keel drab pata gour

46. pacifism shamrock bacteria finosaur peantime
47. equinox clemens tactful sactioin morship
48. sistine parasite salivate faisure sucround
49. colloquial himalayas embarrass adandoned parchsent
50. silt pagan ulcer kreak mact
51. pediatrixian shuttlecock mathematics prolability tedimentary
52. onomatopoeia photosynthesis repercussion recommentation sultiplication
53. embargo hungary oatmeal pushion econofy
54. lethargy pavilion pendulum benerage splendit
55. derogatory franchise obedience pronision somethere
56. canberra hemlock antenna capsute fredict

**Appendix AE**

**Recognition Task Stimuli used in Experiment IV**

**Recall Recognition Task Stimuli**

anthrax ragoon teacher  
sampan zither needle  
amphibian incognito disembark  
sextant vertigo pepper  
ambrosia helsinki ancestor  
damascus crevice bungalow  
agnostic altruism marriage  
baroque amnesty tobacco  
contraband pasteurize helicopter  
asteroid bandanna remember  
cosmonaut ineffable geriatric  
ebenezer minotaur sickness  
mosque camus lawyer  
anagram callous thunder  
alloy cache major  
anesthesia impromptu poinsettia  
neophyte blessing innocent  
fetish bangkok cliché  
chalice zeppelin student  
zealot sclera sorrow  
hieroglyphic numismatics disreputable  
gargoyle fatalism hyacinth  
liaison accolade plaster  
enigma lagoon secret  
moratorium dexterity restaurant  
jargon wizard church  
stamina centaur forehead  
mammoth gourmet citadel  
torso junta decay  
ornithology jurisdiction intelligent  
cuisine nostalgia extinct  
joust gnome robin  
juxtapose soliloquy afternoon  
jubilee paradox ancient  
decathlon detergent fluctuate  
eagle plato lemon  
demagogue scavenger supervise  
orwell almanac fridge  
wayne platen heavy  
sputnik perjury diamond  
iraq keel silk  
pacifism shamrock elephant  
equinox clemens rubbish

sistine parasite seafood  
colloquial himalayas hemisphere  
silt pagan loud  
pediatrician shuttlecock frustration  
onomatopoeia photosynthesis incompatible  
embargo hungary soldier  
lethargy pavilion marriage  
canberra hemlock subtract



**Appendix AF**

**Information Letter and Consent Form for Experiment IV**

**INFORMATION CONSENT LETTER**

The following study investigates factors involved in problem-solving. The study is being conducted by Ms. Julie Torrance Perks under the supervision of Dr. Jennifer Stolz and Dr. Ken Bowers of the Department of Psychology at the University of Waterloo.

You will be asked to respond to two different types of problems: one having a high level of difficulty and requiring sustained thought, and a second, more reactionary speed performance task. More specifically, you will be asked to complete (1) a word definition task which will involve reading the definitions of words and attempting to come up with the words the definitions indicate, and (2) a number of word/nonword discrimination tasks, which will require you to decide whether something presented on the screen is a word or nonword and respond as accurately and quickly as you can. The completion of these tasks will require approximately one hour, for which you will receive partial credit towards your Introductory Psychology course.

There is little or no risk associated with participation in this study. All information collected as a result of your participation in the study will be used for teaching or research publication purposes. In either case, your anonymity is guaranteed. However, consent to participate, or for the use of the information you provided, may be withdrawn at any time by indicating this to the researcher.

**CONSENT FORM**

This study has been reviewed and approved for ethics through the Office of Human Research & Animal Care at the University of Waterloo. However, if you have any questions or concerns resulting from your participation in this study, please contact Dr. Susan Sykes, Office of Human Research, University of Waterloo, 888-4567, ext. 6005.

I grant permission to Julie Torrance Perks to collect data from my participation in this research being conducted by Dr. Jennifer Stolz and Dr. Ken Bowers.

I understand that the study will involve completing word definitions and word/nonword discriminations tasks.

I understand that all information gathered in this study will be used for research purposes only and that my anonymity will be protected. I understand that I may withdraw this permission at any time and that recordings of my participation will be destroyed at my request.

Name (Please print):

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Signature:

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Date:

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**Appendix AG**

**Written Feedback for Experiment IV**

### Factors Involved in the Incubation Effect

This study investigates factors that may be involved in the "incubation effect" in problem solving. The incubation effect occurs when taking one's mind off a difficult problem that one had been previously trying to solve is followed by the successful solution to the problem.

One explanation of the incubation effect proposes that movement towards a solution can occur, without a person's awareness and without the person thinking explicitly of the problem. This idea has been discussed in the literature in terms of "spreading activation", a process whereby being presented with a problem activates ideas or knowledge structures, called memory traces, relevant to the problem in the problem solver's mind. This activation then spreads to other knowledge in memory related to the problem. One way of investigating whether movement towards a solution has been made, in the absence of a solution itself, is to determine whether a person, after working on a problem, can respond more quickly to the presentation of the answer to the problem than to other similar words that are not solutions to the problem. Such a method was employed in the present study using the word/nonword discrimination tasks. Some of the words in this task were the answers to previous word definitions, while some were unrelated words. Participants responded to the answers to the previous word definitions in the word/nonword discrimination task after varying amounts of time delays. One-third of the time the answer to the previous word definition was one of the words in the word/nonword discrimination task on the very next trial. One-third of the time the answer to the previous word definition was one of the words in the word/nonword task 3 trials later. Finally, the answer word to a previous word definition came as one of the words in the word/nonword task 7 trials later one-third of the time.

If movement towards a solution, through a process of activation spreading to relevant information in memory, is indeed a factor involved in the incubation effect, one would expect that such activation would be more apparent for yet unsolved items than for items already solved. Thus, it was predicted that when the word definition task was not solved, people would respond equally as fast to the answer words in the word/nonword task in the 1, 4 and 7 trial delay conditions (indicating continued activation of related problem elements over this time period). However, for the solved word fragments, activation should "die off" more quickly. Thus, in cases where the word definition was initially solved, response time to the answer words should become longer as more time passes, that is, people should respond increasingly slower to the answer word over the 1, 4 and 7 trial delays.

Thank you very much for participating in this study. If you have any further questions about the study, feel free to contact Julie Torrance Perks, 885-1211, x 2813. If you have any concerns resulting from your participation in this study, please contact Dr. Susan Sykes, Office of Human Research, University of Waterloo, 888-4567, x 6005.