Hints Do Not Evoke Solutions Via Passive Spreading Activation

Steven M. Smith (SMS@Psyc.TAMU.Edu)
Department of Psychology; Texas A&M University
College Station, TX 77843-4235 USA

Cynthia M. Sifonis (CMS1210@Acs.TAMU.Edu)
Department of Psychology; Texas A&M University
College Station, TX 77843-4235 USA

Deborah R. Tindell (DRT4239@Acs.TAMU.Edu)
Department of Psychology; Texas A&M University
College Station, TX 77843-4235 USA

Abstract

A passive spreading activation theory of incubation effects states that hints, encountered by chance after an unsolved problem has been put aside, direct spreading activation to solutions in memory. Results from three experiments reject this explanation. Pretested hints that were seen seconds before unsolved problems were retested did not aid resolution unless hints were intentionally used to help problem solving.

Introduction

The term *incubation* has been used to refer to a stage of creative problem solving in which work on an initially unsolved problem is temporarily put aside (Wallas, 1926). After a time away from the problem, the solution may come suddenly to mind, a phenomenon referred to as *illumination* or *insight*. A provocative and popular account of this phenomenon, sometimes referred to as the *unconscious work* (e.g., Smith & Dodds, in press) or *cognitive unconscious* (Weisberg, 1993) hypothesis, states that incubation is the result of problem solving processes that occur without and beyond one's conscious control or direction.

One contemporary version of a theory of incubation that could be characterized as a type of unconscious work explanation is based on the notion of semantic activation of information in memory (e.g., Yaniv & Meyer, 1987). The theory, dubbed the *memory sensitization* hypothesis, states that concepts representing solutions to unsolved problems (or key information needed for reaching solutions) can be activated by problems, but that this activation might at times be insufficient for bringing the activated material into consciousness. The activation imparted to these critical concepts occurs by the passive and automatic process of spreading activation, the same process used to explain semantic priming effects found with a lexical decision task (e.g., Meyer & Schvaneveldt, 1971). This memory sensitization hypothesis further states that the critical concepts remain activated below the conscious threshold level until further activated by (perhaps chance) encounters with other stimuli that are related to the key concepts. Such encounters should add enough activation to the already sensitized concepts to "raise the critical traces above threshold (Yaniv & Meyer, 1987, p 200)." Presumably, exceeding such a threshold should either push the critical concepts into conscious awareness, or make them more accessible when the subject returns to the unsolved problem.

A set of experiments on intuitive guiding by Bowers, Regehr, Balthazard, & Parker (1990) used Remote Associates Test (RAT) problems, which consist of triads of words (e.g., *APPLE-HOUSE-FAMILY*), each of which is associated with a single solution word (e.g., *tree*). According to Bowers et al.'s theory, activation spreads from each word of a RAT triad to the word's associates. The solution to the triad therefore gets activation from each of the three problem words, because the activation from each stimulus word adds incrementally to the activation of the solution, even if that level of activation does not exceed a threshold for conscious awareness. Bowers et al.'s theory, therefore, predicts that activation spreads without awareness from encountered stimuli to solutions, as in a passive spreading activation theory.

The spreading activation theory (e.g., Yaniv & Meyer, 1987) would predict that encounters with a fourth word, a hint semantically related to a RAT solution word, should increase the likelihood of accessing that solution. A RAT solution word, for example, receives activation not only from the three problem words, but additional activation from a fourth word. This fourth word is an example of the way in which a hint to the solution of a problem, encountered by chance during an incubation period, might impart extra activation to the solution, making it more accessible.

Pasteur's notion that "chance favors the prepared mind" implies that when chance hints come along, one must be ready to use such clues to solve problems, a theory sometimes known as *opportunistic assimilation* (e.g., Seifert, Meyer, Davidson, Patalano & Yaniv, 1995). Whether chance hints automatically aid the resolution of unsolved problems is the issue under consideration in the present study. Do hints in the environment, such as a fourth word associated with the solution to a RAT triad, unconsciously prime solutions to problems?

There is reason to believe that hints in the environment might contribute unconsciously to the discovery of insightful solutions to problems. For example, Maier found that when a seemingly accidental hint was given, subjects often used the hint to quickly solve the problem, even though they seemed unaware of having used the hint to reach a solution.

Other research, however, suggests that hints may not automatically yield solutions, but rather that hints must be deliberately considered within the context of the problem. Studies of analogical transfer in problem solving show that hints to the solutions of problems in the form of story analogues rarely stimulate spontaneous transfer, although subjects are able to use the analogues when instructed to do so (e.g., Gick & Holyoak, 1980, 1983). It may be that opportunistic assimilation only works if hints are intentionally applied to the problem.

This line of reasoning leads to the hypothesis that the way that hints facilitate problem solving is not by providing passive spreading activation that increases the accessibility of solutions. In the present experiments we tested the efficacy of a passive spreading activation mechanism for explaining incubation effects in problem solving. In Experiment 1 a set of associates to RAT solution words was tested to determine whether the associates primed the solution words in a lexical decision task. This experiment was necessary to determine whether semantic activation spread from the associates to the solution words. In Experiments 2 and 3 RAT problems were presented twice, the problems intermixed with trials of a lexical decision task. Immediately prior to the second presentation of a RAT problem, there was a word on the lexical decision task (to be referred to as a *cue word*) that was either unrelated to the solution, or the semantic associate of the solution word. The passive spreading activation theory predicts that more initially unsolved problems should be resolved at retest when the cue word is semantically related to the solution. One condition of Experiment 3 also involved instructing participants to intentionally use the cue words as hints for subsequent RAT problems. Related cue words were predicted, both by the passive spreading activation theory and the intentional version of the opportunistic assimilation theory to facilitate resolution of initially unsolved problems when the cues were intentionally used to aid problem solving.

Experiment 1

Experiment 1 tested whether passive spreading activation from associates would spread to solution words, as measured by a lexical decision task.

Method

Participants. The participants in all three reported experiments were student volunteers from introductory psychology classes who enrolled for experimental sessions by signing up on posted sheets in the Department of Psychology. Participants fulfilled part of a course requirement by participating in experiments. There were 46 participants who participated in the lexical decision task.

Materials. Twelve RAT problems were selected that were judged to have unambiguous solution words, each of which forms a compound word or common two-word phrase with the three corresponding RAT problem words.

There were 72 stimuli presented in a session, 36 of which were words, and 36 of which were nonwords that resembled English words (e.g., " pormoil"). The 36 words shown in each of the two counterbalancings were drawn from a set of 42 words, 12 of which were the RAT solution words, 12 of which were associates related to the solution words, and 18 of which were words unrelated to solutions and associates. Each counterbalancing included all 36 nonwords, all 12 solution words, all 18 filler words, and six of the 12 associates of solution words. The six associates used in counterbalancing A were different from the six used in counterbalancing B.

Procedure. Participants sat facing a computer screen with the left index finger resting on the "1" key and the right index finger on the "0" key. Instructions to participants, which were shown on the computer screen, indicated that the "0" key was to be pressed when a nonword was shown, and the "1" key was to be pressed when a word appeared. Participants were urged to press the correct key for each item as quickly as they could give an accurate response. There were 3-sec given between each response and the onset of the next verbal stimulus.

Design. Half of the 12 solution words in each of the two counterbalancings were immediately preceded by related associates (the primed items), and half were preceded by unrelated words (the nonprimed items). The six items that were primed in counterbalancing A were nonprimed items in counterbalancing B, and vice versa. Thus, priming (primed vs. nonprimed) was manipulated within-subjects, and counterbalancing (A vs. B) was manipulated between-subjects.

Results and Discussion

A significance level of $p < .05$ was used in all tests in all three of the experiments reported in the present study, unless otherwise indicated.

A one-way ANOVA compared the reaction times for primed vs. nonprimed responses to solution words, a within-subjects comparison. Responses exceeding 1000 msec were omitted from the analysis. A total of 40 of the original 552 responses, 21 in the related prime condition and 19 in the unrelated prime condition, were thereby omitted. The 40 omitted responses came from 31 different participants.

Priming was significant [$F(1,45) = 32.37$, MSe = 1325.30]; responses to solution words were faster when the words had been preceded by related words (mean = 583 msec) rather than unrelated words (mean = 626 msec). The priming effects for all but two of the items exceeded 30-msec.

The selected associates primed the semantically related RAT solution words. This result clearly satisfies the standard criterion, showing that activation reliably spreads from the associates to the RAT solutions (e.g., Meyer & Schvaneveldt, 1971). It is also noteworthy that priming did not depend on any intentional relation of primes to RAT solution words; participants were not instructed or encouraged to relate test stimuli in any way. Therefore, it can be concluded that activation appears to have passively spread from associates to RAT solution words in Experiment 1.

Experiment 2

Given that associates primed processing of RAT solution words, is it the case that such associates also facilitate the resolution of initially unsolved RAT problems? In Experiment 2 participants were given two opportunities to solve each of 12 RAT problems. Participants saw, immediately prior to the second presentation of each RAT problem, a prime word that was either unrelated or related to the solution to the subsequent RAT problem. For example, prior to the second presentation of the RAT problem *APPLE - HOUSE - FAMILY* (solution: *tree*) appeared either the related prime (*leaves*) or an unrelated prime (*ironic*). The passive spreading activation hypothesis predicted that the probability that an initially unsolved problem would be resolved on a second attempt would be greater if the retest of a problem were preceded by a word that was semantically related to the solution word.

Method

Participants. There were 55 participants in Experiment 2. Experimental sessions were held in groups ranging in size from 5 to 12 participants at a time.

Materials. Twelve RAT problems with corresponding cue words were used. There were also 90 filler items, half of which were English words that were not obviously related to any of the RAT problem solutions (e.g., *ironic*), and half of which were nonwords that resembled words (e.g., *pormoil*). The stimulus sequence presented 24 blocks of items, with each block consisting of four lexical decision items, followed by a single RAT problem. Thus, the procedure consisted of 120 trials, including 96 lexical decision trials, and 24 RAT problems (each of the 12 problems was repeated). The 12 RAT problems presented in the first 12 blocks were repeated in the same order in the next 12 blocks of trials. A nonword (in the lexical decision task) immediately preceded the first presentation of each RAT problem. A single word (in the lexical decision task), to be referred to as a *cue word*, appeared in the stimulus sequence immediately before the second presentation of each RAT problem. For six of the retested RAT problems, the immediately preceding cue word was the semantically related word used as a prime in Experiment 1, whereas the other six retested problems were preceded by unrelated words, also drawn from the lexical decision materials in Experiment 1. Six of the 12 related cue words were used to cue second presentations of corresponding RAT problems in counterbalancing A, and the other six were used in counterbalancing B.

Procedure. The instructions informed participants that they would alternate between two different tasks: a lexical decision task, and a Remote Associates Test. For each trial of the lexical decision task a letter string appeared on a television screen for 2-sec. Participants then had 3-sec to circle either *yes* (if the letter string formed an English word) or *no* (to indicate the string was not a word) in the appropriate spaces on their response forms. For each RAT problem participants were given 10-sec to write the solution.

Design. Cuing (related vs. unrelated cue) was a within-subjects factor, and counterbalancing (A vs. B) was manipulated between-subjects. Each participant's resolution score was calculated as the number of initially unsolved problems that were solved at retest divided by the number of initially unsolved problems. Resolution scores were computed separately for retested problems corresponding to related cues vs. retested problems corresponding to unrelated cues.

Results and Discussion

The RAT problems were solved on their first presentation 33% of the time, leaving approximately two-thirds of the problems initially unsolved. The resolution rate was the proportion of initially unsolved problems that were successfully solved at retest. A one-way within-subjects ANOVA was computed to analyze the effect of cuing, using the proportion of resolved RAT problems as a dependent measure. Cuing, a repeated factor, was either related or unrelated. There was no main effect of cuing [$\underline{F}(1,53) = .27$, MSe = .010]. The mean resolution rates for related vs. unrelated cuing conditions are shown in Table 1.

Table 1: Resolution Rates and Cuing in Expt.s 2 and 3.

	Related Cue	Unrelated Cue
Experiment 1	.13	.12
Experiment 2		
Not Instructed	.10	.13
Instructed to Use Hints	.16	.12

The results show that cuing retested RAT problems with semantically related words did not facilitate resolution of the initially unsolved RAT problems. The same cue words, processed the same way (i.e., judging whether the letter string was a word or not), successfully primed solution words in a lexical decision task in Experiment 1, indicating that the related cues provided passive spreading activation to solution words. The failure of the same words to cue RAT solutions in Experiment 2 is evidence that passive spreading activation from semantically related words does not facilitate resolution of initially unsolved problems, and cannot explain incubation effects in problem solving.

Experiment 3

There were two purposes for conducting Experiment 3. One purpose was to replicate the non-effect of cuing on the resolution of initially unsolved RAT problems, using a larger number of participants in order to enhance the power for detecting effects. The second purpose was to determine whether the cue words could be *intentionally* used as hints to facilitate resolution. Even if the results do not support a passive spreading activation theory of incubation effects, it may nonetheless be possible that hints encountered in the environment can be intentionally used to facilitate resolution of initially unsolved problems. Furthermore, an instruction to intentionally use related cue words might facilitate resolution because participants might be more likely to consider the hints and cues as part of the same task. In contrast, uninstructed participants should be more likely to see the two tasks as unrelated, thereby failing to use the cues as hints to facilitate resolution.

Method

Participants. There were 152 participants in Experiment 3; 79 participants were in the nonintentional instruction condition, and 73 were in the intentional instruction condition.

Materials. The same materials described for Experiment 2 were used in Experiment 3.

Procedure. The procedure in Experiment 3 was the same as that used in Experiment 2, with one exception. In the intentional instruction condition participants were told that sometimes the words immediately preceding RAT problems could provide hints to the subsequent problem solutions. The intentional instructions stated, "Some of the Remote Associates Test problems will be preceded by hints. That is, for some, but not all problems, the word that appears just before the problem on the word decision task will be closely related to the solution to the problem. Pay attention to those words, and try to use the hints to help you solve the problems." This instruction was omitted in the nonintentional instruction condition. As in Experiment 2, half of the retested problems were immediately preceded by cue words, and half were preceded by unrelated words.

Design. Cuing, a within-subjects variable, was related or unrelated cues. Counterbalancing (A vs. B) and instruction (intentional vs. nonintentional) were between-subjects variables.

Results and Discussion

The solution rate for initial attempts at RAT problems was 36%. A 2 (cuing) X 2 (instruction) ANOVA was computed, using resolution rate as the dependent measure. Cuing, a within-subjects factor, was either related or unrelated cues. Instruction, a between-subjects factor, was either intentional or nonintentional instructions. There were no significant main effects of instruction [F (1,150) = 1.02, MSe = .036] or of cuing [F(1,150) = .04, MSe = .010]. There was a significant cuing X instruction interaction [F(1,150) = 7.51, MSe = .010]; related cues, relative to unrelated cues, improved resolution in the intentional instruction condition, but impeded resolution in the nonintentional condition (Table 1). Simple main effects analyses indicate that cuing with related items marginally reduced resolution rates in the nonintentional instruction condition [F(1,79) = 3.72, p = .057, MSe = .010], but improved resolution in the intentional instruction condition [F-(1,73) = 3.76, MSe = .010].

The results of Experiment 3 show that when participants were not instructed to intentionally use the cue words as hints, the presence of semantically related cues before the retest did not aid resolution of initially unsolved RAT problems. In contrast to these results, the intentional use of semantically related cue words facilitated resolution of initially unsolved RAT problems. Cue words were not detrimental to retrieval of solution words. Unless cues were intentionally applied to the problems, however, they did not facilitate resolution through some passive process, such as spreading activation.

General Discussion

Experiment 1 showed that cue words primed solution words on a lexical decision task, indicating that cue words impart spreading semantic activation to solution words.

Cue words that were incidentally encountered a few seconds before retested RAT problems did not facilitate resolution of initially unsolved RAT problems, contrary to the prediction made by a passive spreading activation theory of incubation effects. This failure of cue words to facilitate resolution occurred in both Experiments 2 and 3. The lack of a cuing effect in Experiments 2 and 3, and the trend towards a reversed effect in Experiment 3, shows that passive spreading activation arising from incidentally encountered stimuli does not account for incubation effects in problem solving.

Cue words helped participants retrieve RAT solutions only when participants were explicitly instructed to use cue words as hints for the RAT problems (Experiment 3). The facilitative effect of intentionally using cue words as hints for the RAT problems shows that the cue words, in and of themselves, did not impede retrieval of correct solutions. This result is consistent with findings that analogues do not spontaneously transfer to newly encountered problems, but rather that attention must be directed to relate the base analogue to the target (e.g., Gick & Holyoak, 1980; 1983). The general pattern that emerges from these studies is that an active use of incidentally encountered information is necessary if one is to take advantage of hints that might facilitate resolution of unsolved problems.

Although the results of the present experiments are inconsistent with a passive spreading activation theory of incubation, they do not necessarily contradict the assertion of Yaniv & Meyer's (1987) memory sensitization hypothesis that activation from an initial attempt at a problem accrues and persists at nodes representing information that may be critical for solving problems. Such activation and persistence of activation was not tested in the present experiments. The results do indicate, however, that if memory sensitization is important for incubation, then it is not because chance encounters with relevant stimuli passively bestow the extra activation needed to bring solutions or key information above the threshold of conscious awareness. What is rejected is the notion that semantic activation that passively spreads from incidental encounters with stimuli can explain incubation effects.

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