Memory & Cognition
1988, 16 (1), 36-44

Conceptual transfer in simple insight problems

ROBERT S. LOCKHART and MARY LAMON
University of Toronto, Toronto, Ontario, Canada

and

MARY L. GICK
Carleton University, Ottawa, Ontario, Canada

Three experiments explored the conditions under which information presented in the first part of an experiment facilitates the subsequent solving of simple insight problems. We argue that previous unsuccessful attempts to obtain such facilitation are attributable to the experimenters' failure to present this information in a form that induces the conceptual operations needed to solve the problem. Substantial facilitation is obtained if the information is presented in a form that induces a few seconds of puzzlement and then a clue is presented that leads to an appropriate reconception; if identical information is presented without such a period of puzzlement and reconception, no facilitation is observed. The results demonstrate that conceptual processing operations, not merely informational content, must be relevant if conceptual transfer is to occur. One possible mechanism involved in such transfer is the indexing of concepts such that they contain pointers to conceptually anomalous episodes.

Inability to solve a problem is frequently a matter of failure to access available information. Solving simple insight problems, such as those used by Perfetto, Bransford, and Franks (1983), typically entails nothing more than the application of a well-known concept that yields an appropriate meaning. But this meaning is made inaccessible by a context that invites the application of a different concept, the result of which is a puzzling riddle. For example, a problem such as "A man who lived in a small town married twenty different women of the same town. All are still living and he never divorced a single one of them. Yet, he broke no law. Can you explain?" is resolved by application of the concept "clergyman" instead of the concept "man" that is usually triggered by the riddle.

Attempts to facilitate the solving of these problems have met with some notable failures. Perfetto et al. (1983) found that preceding the problem solving phase of the experiment with sentences that essentially contained the solution did not raise the experimental group's solution level above that of a control group who heard no such sentences. Only if subjects were explicitly informed of the relation between the sentences and the subsequent problems did they access the previously presented sentences. It would seem that the problems themselves do not remind subjects of the previously presented sentences, despite their relevance and the fact that the sentences and the problems share the same content.

This research was supported by Grant A0355 to the first author from the Natural Sciences and Engineering Research Council of Canada. The assistance of Beth Merikle, Anna Palamedes, and Ian McBain is gratefully acknowledged. Requests for reprints should be sent to Robert S. Lockhart, Department of Psychology, University of Toronto, Toronto, ON M5S 1A1, Canada.

The literature contains other examples of the failure of information to transfer from one part of an experiment to a later problem solving phase. Weisberg, Dicamillo, and Phillips (1978), for example, found that learning the paired associate *candle-box* did not facilitate subjects' subsequent performance on Duncker's (1945) box and candle problem. There is also a substantial body of data showing that subjects, when confronted with a novel problem, have extreme difficulty in accessing isomorphic (analogous) problems that they have seen previously (e.g., Gentner & Landers, 1985; Gick & Holyoak, 1983).

These failures of conceptual transfer pose a very fundamental question: why are concepts bound to the particular episodes or the specific content of their instantiations? In addressing this question, it is helpful to make use of a theoretical distinction made by James (1890). In his analysis of reasoning, James distinguished two aspects of elementary problem solving. One aspect concerns appropriate conception, a skill James referred to as *sagacity*. The second aspect is *learning*, the possession of relevant knowledge. To understand what James meant by sagacity it is necessary to understand his theory of concepts. According to James, concepts are not entities, but functions—mental operations—through which we selectively represent objects and events. Conception is the selection of "a partial aspect of a thing which *for our purpose* we regard as its essential aspect, as the representative of the entire thing" (James, 1890, p. 335n). Sagacity, then, is the skill of constructing or selecting appropriate representations. The second aspect, learning, is the ability to recall the "consequences, concomitants, or implications" of that conception (James, 1890, p. 331). Take as an example the multiple-marriages problem given above. Solving the problem entails both knowledge (that a common duty of a clergyman is to conduct marriages) and also the sagacity to conceptualize "man" as a clergyman.

Assuming that all subjects possess this relevant knowledge about clergymen, failure to solve the multiple-marriages problem is a failure of sagacity. That is, the source of the problem's difficulty is almost entirely a matter of initially applying an inappropriate conception. Indeed, once the appropriate concept is found, the consequences or concomitants of that conception are brought to mind so rapidly and the immediacy of the solution is so subjectively compelling that such puzzles have been referred to as "aha!" problems (Auble, Franks, & Soraci, 1979; Gardner, 1978).

In general, however, problems vary in the extent to which the source of their difficulty is a matter of appropriate conception or a matter of knowing the concomitants of that conception. For a person knowledgeable about simple arithmetic, a problem such as multiplying two seven-digit numbers poses no difficulty in conception; the difficulty lies entirely in executing the procedures implied by that conception. Other problems are more balanced in their relative demands of sagacity and knowledge. In such problems achieving the appropriate conception is nontrivial but so, too, is the task of extracting the relevant consequences of that conception, so that a problem may remain unsolved even if the conceptual difficulty has been overcome. The nine-dot problem studied by Weisberg and Alba (1981a) would seem to be such a case: The conceptual difficulty stems from the need for the subject to realize that the lines connecting the dots can lie outside the square defined by the dots; but that conception, once achieved, does not lead to an immediate solution. Much of the debate about the role of insight in the nine-dot problem (e.g., Dominowski, 1981; Ellen, 1982; Weisberg & Alba, 1981b, 1982) is clarified if the Gestalt term *insight* is replaced with the Jamesian notion of sagacity, or appropriate conception. According to this analysis insight does not in itself constitute a solution; it is merely one necessary condition for a solution to occur (cf. the discussion by Ohlsson, 1984a, 1984b).

This distinction between sagacity and learning is helpful in attempting to understand possible reasons for the failures of transfer, such as those of Perfetto et al. (1983). Consider again the multiple-marriages problem given above. This scenario poses a problem to the subject because the habitual or dominant conception of "man" does not have as one of its acceptable consequences the multiple marriages described. For the problem to be solved, this dominant conception needs to be replaced by an acceptable one. It is this need to reconceptualize that is the source of the problem's difficulty; once the appropriate reconception is achieved, its relevant implications are straightforward (assuming the subject knows about the duties of clergymen). This analysis of the *conceptual* operations (as opposed to *knowledge*) needed to solve the problem suggests that, in fact, there are no strong grounds for expecting transfer from the kind of declarative sentences used by Perfetto et al. (1983); such sentences entail the use only of the knowledge component—that clergymen perform many marriages—and not the process of reconception, the achievement of which is the problem's focal difficulty. Similarly, there is nothing in the paired-associate training task of Weisberg et al. (1978) that corresponds to the act of altering a dominant conception (box as container) to the less dominant one of conceiving the box as a supporting platform.

This analysis suggests that facilitation in solving insight problems of the type used by Perfetto et al. (1983) might be obtained by a very simple change in the form of their clue sentences. What is needed is a form of presentation that not merely presents relevant information but also entails appropriate reconception. We investigated this possibility in Experiment 1 using Gardner's (1978) "aha!" problems. A word should be said in defense of these problems since they may seem trivial and more suitable as jokes than as experimental materials. In fact, they are excellent examples of problems that require considerable sagacity but place only minimal demands on knowledge. That is, it can be safely assumed that no failures to solve the problems occur through a lack of knowledge.

EXPERIMENT 1

The basic manipulation used in this experiment was to present the initial information in the "aha!" form used by Auble et al. (1979). Consider the difference between the statement "It made the clergyman happy to marry several people each week" and the sentence "The man married several people each week because it made him happy" followed a few seconds later by the word *clergyman*. We refer to these forms of presentation as *declarative* and *puzzle* forms, respectively. In the end, the state of affairs described is the same in both cases. However, unlike the declarative form that induces the appropriate interpretation from the outset, the puzzle form initially induces an inappropriate conception followed by a clue that initiates a process of reconception.

It is known from Auble et al. (1979) that presenting information in this puzzle form facilitates the recall of that information compared with a control condition in which the same information is presented in declarative form. It would, of course, be of little theoretical interest if improvement in problem solving were attributable to a general facilitation of memory as measured by subjects' ability to free recall the information. Such a facilitation could then be obtained with any manipulation known to improve free recall, and no special significance could be assigned to the process of reconception assumed to underlie the comprehension of information presented in puzzle form. To control for this possibility, we included a condition in which we intentionally enhanced the recallability of information given in the declarative form by presenting it twice.

Method

Subjects. The subjects were 80 volunteers who either were paid $5 or were given course credit in an introductory psychology course at the University of Toronto.

Design. A between-subjects design was employed in this experiment. The independent variable was type of acquisition with four condition types: a puzzle condition, a control condition, a single-presentation declarative condition, and a repeated-presentation declarative condition in which acquisition sentences were presented twice. The control group was given no acquisition task. Problem solving accuracy, free recall, and cued recall were measured. The subjects were assigned randomly to one of the four conditions, with 20 subjects in each group.

Materials. Materials for this experiment included 15 insight-type problems adapted from Gardner (1978). Some of these problems had been used previously (Perfetto et al., 1983); the remainder were selected by the authors. Three problems were used as practice problems; the rest were target problems. A test booklet was constructed for each subject consisting of the 3 practice problems and the 12 target problems. Ordering of the problems was random across subjects, except that practice problems always preceded targets.

Two types of acquisition sentences were constructed for each of the 12 target problems. Both types contained information relevant for solving a particular target problem, but the information was expressed in either of two distinct forms. For the declarative sentences the solution information was given within a single sentence. For example, given the multiple-marriages problem, the declarative sentence was "It made the clergyman happy to marry several women each week." In the puzzle form the information was conveyed as a puzzle followed by a clue that resolved the conundrum. The sentence-clue pair for the multiple-marriages problem was "The man married several women each week because it made him happy" and "clergyman." Each acquisition sentence was printed separately on a 3×5 in. index card. For puzzle sentences the clue word was printed on the reverse side, ensuring that it could not be seen until the sentence was read. Across subjects, order of the acquisition sentences was random within the constraint that for the repeated declarative-acquisition condition there were at least two intervening items between presentations of the same sentence.

Procedure. Each subject was tested individually during a single 1-h session. The subjects were told that they would participate in a number of cognitive tasks. The initial task was acquisition of the solution sentences through an incidental orienting task. The stated purpose of the first task was to gather normative data for a future experiment. The subjects were provided with a set of sentence cards and a numbered rating sheet with a 5-point scale printed at the top. The scale ranged from 1 (*not at all comprehensible*) to 5 (*entirely comprehensible*). Instructions for the two declarative conditions were to read each sentence and then rate it for comprehensibility. The subjects in the repeated-declarative group were told that sentences would be repeated so that the consistency of their comprehension ratings could be checked. For the subjects in the puzzle-acquisition group, the instructions were to read the sentence, turn the card over to read the clue, and then rate how helpful the clue was for comprehending the sentence. The subjects in the two declarative-acquisition groups were allowed 10 sec per sentence. The subjects in the puzzle-acquisition group were allotted 5 sec to read the sentence. There was a 3-sec delay during which the card was removed, then returned to them, at which point they were allowed to turn the card over to read the clue for 2 sec. Thus total presentation time for each item was equivalent across experimental conditions. The subjects in the puzzle-acquisition condition read and rated 12 sentence-clue pairs, the subjects in the single declarative-acquisition condition read and rated 12 sentences, and the subjects in the repeated-declarative-acquisition condition read and rated each of the 12 sentences twice.

Following the acquisition task, there was a delay of 3 min during which attendance forms were completed. After the delay, problems booklets were presented. The subjects were told to try to solve each problem in the order presented and were instructed not to return to previous problems. The subjects were permitted to work on each problem until an answer had been written or until 60 sec had elapsed.

Following the problem solving task, all subjects except those in the control condition were given an unexpected free recall task for the acquisition sentences. The subjects were instructed to try to remember and write down the sentences that they had rated for comprehensibility at the beginning of the experiment. This task was self-paced. Finally, the subjects were presented with a cued recall task. A key word from each of the sentences (excluding clue words for the puzzle sentences) was printed in a column. For example, the word *marriage* was used as the cue for the clergyman sentence. The subjects were instructed to try to remember and to write the appropriate sentence next to the cue. There was no time limit for the cued recall task.

Results and Discussion

The data of central interest are the responses to target problems. Responses were scored as correct if they were congruent with the solution information provided in the acquisition phase of the experiment. Although subjects generated alternate answers, none were adequate solutions to the problems. For example, for the multiple-marriages problem, the modal incorrect solution was that the man was a polygamist, but, since the problem explicitly stated that "the man broke no laws," this answer was clearly inadequate as a solution and certainly reflects a failure to access the previously presented information.

The mean proportions of correct solution are given in Table 1. A one-way analysis of variance revealed a significant effect of type of acquisition [$F(3,76) = 5.82$, $MSe = .05$, $p < .01$]. Orthogonal comparisons revealed no difference between the baseline condition and the repeated-declarative-acquisition condition [$t(76) = 1.14$, $p > .10$]. That is, presentation of relevant solution information per se did not facilitate problem solving performance even when the material was presented twice. Results comparing the puzzle-acquisition condition to the other three conditions revealed a significant difference [$t(76) = 3.83$, $p < .001$]. Thus, differences between groups were localized to a facilitation of problem solving for the puzzle-acquisition condition only.

One possible reason for the facilitation observed for the puzzle-acquisition group relative to other groups was that

Table 1
Problem Solving and Final Free Recall Scores for Experiment 1

	Acquisition Condition			
Measure	Control	Single Declarative	Repeated Declarative	Puzzle
Problems Solved	.33	.36	.41	.60
Free Recall		.28	.53	.50
Cued Recall		.64	.78	.70

this type of encoding operation increased memorability of the solution information. This interpretation is supported by neither the final free recall nor the final cued recall. The mean proportions of items recalled on the final free recall test are given in Table 1. A one-way analysis of variance revealed a main effect of acquisition condition [$F(2,57) = 13.0$, $MSe = .03$, $p < .01$]. However, orthogonal comparisons revealed no difference between puzzle-acquisition and repeated-declarative-acquisition conditions [$t(57) = .67$, $p > .25$]. Rather, differences were found only between these two groups and the single-declarative-acquisition group [$t(57) = 5.11$, $p < .001$]. Thus, although information presented either in repeated-declarative sentences or in puzzle form facilitates free recall equally, only the puzzle form facilitates subsequent problem solving. This seemingly straightforward result was explored in two further experiments.

EXPERIMENT 2

An obvious criticism of Experiment 1 is that final free recall, being measured at the end of the experiment, is influenced by the preceding problem solving phase. It is possible, but unlikely, that immediately before the problem solving phase the free recall of information presented in puzzle form is superior to that presented twice in declarative form and that this difference is obscured by subsequent problem solving. Experiment 2 therefore obtained a measure of the recallability of the initial information prior to problem solving.

A second purpose of Experiment 2 was to discover whether the superiority associated with the puzzle form would be obtained in a within-subjects design. It is possible that this superiority has nothing to do with the differences in the specific processing underlying particular sentences, but rather is a consequence of a very general problem solving set induced by the puzzle form of the acquisition task. That is, the puzzle form of the sentences could serve as a cue ("this is a problem solving experiment") that is functionally equivalent to informing subjects of the relationship between the two phases of the experiment. If this is true, then giving subjects some sentences in puzzle form should be sufficient to induce such a set, and all problems should benefit, regardless of the type of acquisition sentence.

Finally, the publication of Bowden's (1985) results suggested the need to consider the time made available to subjects to solve the problems. Bowden found that, given additional time, subjects presented with information in declarative form solved as many problems as a group explicitly informed of the relevance of this information.

Method

Subjects. The subjects were 40 students who volunteered in order to receive credit in an introductory psychology course at the University of Toronto.

Design. The experiment employed a between-within design. Interpolated free recall was a between-subjects factor, with half the subjects receiving a free recall test prior to being presented with the problems. Type of prior acquisition sentence was a within-subjects factor. All sentences given in declarative form were presented twice, because no useful purpose was served by the once-presented form of this factor. Problem solving accuracy and response times were measured for all subjects as was final recall for the acquisition sentences.

Materials. Acquisition sentences, practice problems, and target problems were the same as in Experiment 1 except that 2 additional problems were selected from Gardner (1978) for a total of 14 target problems. The target problems were divided into two equally difficult subsets by matching pairs of problems for difficulty using data from Experiment 1. One member of each pair was assigned to each subset. One of the 2 new problems was assigned to each subset. The subsets were labeled A and B. As in Experiment 1, two types of acquisition sentences, a puzzle and a declarative form, were used for each problem. The acquisition sentences for each subject consisted of 7 puzzle and 7 declarative sentences. Sets of items were balanced so that half of the subjects received Set A puzzle sentences and Set B declarative sentences; the remaining subjects received Set A declarative sentences and Set B puzzle sentences. Each sentence was printed separately on a 3×5 in. index card. On the reverse side of the card, a clue word was printed for puzzle sentences, and all cards contained the instruction "Now rate the sentence for comprehensibility." Order of sentence presentation was random within the constraint that the same declarative sentence was not presented twice in succession.

Each subject was tested individually during a single 1-h session. The subjects were informed that they would participate in a number of cognitive tasks. They were instructed that the purpose of the first task was to assess sentence comprehensibility. The first task, in fact, was to acquire the solution information through an incidental orienting task. As in Experiment 1, the subjects were given a set of sentence cards and told to read each sentence carefully, then turn over the card, read the clue if one was provided, and follow the instructions printed on the reverse. The same 5-point rating scale used in Experiment 1 was again employed. Subjects were allowed 10 sec to read each sentence and whatever was printed on the reverse side of the card. All subjects read and rated 21 sentences: 7 puzzle sentences presented once and 7 declarative sentences each presented twice.

Subsequent to the acquisition task, the subjects in the interpolated-recall condition were given a recall sheet that instructed them to try to remember and write down all of the sentences that had just been rated for comprehensibility. There was no time limit for this task. The subjects in the no-interpolated-recall condition were given some simple mathematical problems to solve in order to equate for retention interval between the acquisition and problem solving tasks.

Recall protocols or mathematical problems were then collected, and subjects were given the problem booklets. The subjects were instructed to work through the set of problems one at a time in the order given. They were told to signal the experimenter as soon as they began to read a problem and again as soon as they had written an answer so that response time for each problem could be measured. To avoid the possible time-limit effects reported by Bowden (1985), we allowed subjects a maximum of 4 min for each problem. If no answer had been written after 4 min, subjects were asked to proceed to the next problem. Response times were measured in seconds with a stopwatch.

After all problems had been attempted, the booklets were collected and the subjects were given an unexpected free recall test for the initial acquisition sentences. There was no time limit for this task. Finally, the subjects were asked to complete a questionnaire designed to assess whether or not they had noticed a relation between acquisition and problem solving tasks, and, if so, at what point they had noticed a relation: after the first few problems, by the end of the problems, or during the final recall task.

Results and Discussion

The mean proportions of problems correctly solved are presented in Table 2. A between-within analysis of variance revealed no effect of recall condition [$F(1,38) = 1.67$, $MSe = .062$, $p > .10$], no effect of acquisition type [$F(1,38) < 1$, $MSe = .023$], and no interaction between recall condition and acquisition type [$F(1,38) = 1.0$, $p > .25$]. Evidently, there was no problem-specific facilitation for puzzle acquisition when both types of sentences were included in the same list.

Response times show that the 4-min time allowed for solving the problems was more than sufficient. In fact, 84% and 97% of all correct solutions were produced after the first and second minute, respectively.

The results show no evidence for the claim that, prior to the solution phase, puzzle sentences are more recallable than are declarative. In fact, the difference is in the opposite direction.

Although explicit recall of solution information did not facilitate problem solving performance, there was evidence that this task was of some benefit for final recall. A between-within analysis of variance revealed a significant interaction between recall condition and acquisition type [$F(1,38) = 6.50$, $MSe = .041$, $p < .05$] as well as a main effect for interpolated recall condition [$F(1,38) = 9.0$, $MSe = .057$, $p < .01$]. Clearly, the interpolated recall task was of benefit for final recall of both types of sentences, but particularly for puzzle-type sentences.

Responses to the questionnaire regarding how aware subjects were of the relation between acquisition and problem solving tasks suggested that most subjects did realize during the problem solving task that the sentences provided information relevant to solving the problems. Forty percent of subjects in the interpolated-recall group and 35% of subjects in the no-interpolated-recall group realized the relation between tasks after working on the first few problems. A further 50% and 35% of subjects in the interpolated-recall and no-interpolated-recall groups, respectively, realized the relation by the end of the problem solving task. A chi-square test did not reveal any difference between groups [$\chi^2(3) = 2.73$, $p > .40$]. A post hoc analysis of the order of problems and acquisition type suggested that working on a problem for which a puzzle sentence had been given may have been helpful for solving subsequent problems for which repeated declarative sentences had been given.

Although the results of Experiment 2 show that the results of Experiment 1 cannot be attributable to simple memory factors, failure to find a difference between declarative- and puzzle-acquisition conditions obviously requires clarification. Two general explanations are possible. The first is that the superiority of the puzzle-acquisition condition found in Experiment 1 is attributable to a general problem solving set induced by the puzzle form of acquisition sentences. The second is that solving problems in the puzzle-acquisition condition triggers an awareness of the relevance of the initial information, and, once such an awareness has been created, subjects are essentially an "informed" group, a condition which we know yields improved problem solving performance (Perfetto et al., 1983). Since the problems were presented in a random order, most subjects would have received at least one puzzle-acquisition problem within the first two or three presentations. The data from the awareness questionnaire supports this "awareness" interpretation. Experiment 3 served to distinguish between these two possibilities, at the same time replicating the results of Experiment 1 under more relaxed timing conditions.

Table 2
Problem Solving, Interpolated Free Recall, and Final Free Recall Scores for Experiment 2

	Acquisition Condition			
	Interpolated Recall		No Interpolated Recall	
Measure	Declarative	Puzzle	Declarative	Puzzle
Problems Solved	.59	.57	.49	.53
Interpolated Free Recall	.67	.46		
Final Free Recall	.60	.51	.47	.34

EXPERIMENT 3

This experiment contains a replication of the conditions of Experiment 1 together with two variants of the mixed-acquisition conditions of Experiment 2. The latter two conditions were designed to provide a means of comparing solution rates for declarative-acquisition problems given to subjects before and after they attempted a set of puzzle-acquisition problems. If the awareness interpretation of the results from Experiment 2 is correct, then solution rates for the after condition should be higher than for the before condition. If the correct interpretation is to be found in terms of a general, non-item specific, problem solving set being induced by the puzzle sentences in the acquisition phase, then there should be no difference since both conditions have identical acquisition phases.

Method

Subjects. Subjects were 80 volunteers who either were paid $5 or were given course credit in an introductory psychology course at the University of Toronto.

Design. The experiment employed a simple between-subjects design. Problem solving accuracy and response times were measured as was final recall for the acquisition sentences. The subjects were assigned randomly to one of five conditions with 20 subjects in each group. These included a baseline group given no acquisition, a pure puzzle-acquisition group, a pure declarative-acquisition group, and two mixed-acquisition groups given an equal number of puzzle and declarative sentences. These two mixed groups differed in that one group received all puzzle-acquisition problems first followed by the declarative-acquisition problems, whereas the other group had this order reversed.

Materials. Materials for this experiment consisted of the same 15 insight-type problems (adapted from Gardner, 1978) that were used in Experiments 1 and 2. The 2 most difficult problems from Experiment 2 were dropped. The same 3 problems were again used as practice problems; the remaining 12 were target problems. As in Experiment 2, problems were divided into two equally difficult subsets using item analyses from the previous experiments. For the two mixed-acquisition lists, one-half of the subjects in each group received one subset in the puzzle form and the remainder in the declarative form. In the two mixed conditions, subsets were balanced so that each problem was associated with a particular acquisition form an equal number of times. A test booklet, consisting of the 3 practice problems and the 12 target problems, was constructed for each subject. Ordering of the problems was random across subjects in the pure acquisition and control groups, except that the practice problems always preceded the targets. For the two mixed groups that were given blocks of six puzzle-acquisition problems either preceding or following six declarative-acquisition problems, order within the block was randomized across subjects.

The same two types of acquisition sentences were used again for each of the 12 target problems. Each acquisition sentence was printed separately on a 3×5 in. index card. For puzzle-type sentences the clue word was printed on the reverse, ensuring that it could not be seen until the sentence was read. Across subjects, order of the acquisition sentences was random within the constraint that there were at least two intervening items between presentations of the same declarative sentence.

Procedure. Each subject was tested individually during a single 1-h session. The subjects were told that they would participate in a number of cognitive tasks. Again, the initial task was acquisition of the solution sentences through an incidental orienting task. The subjects were told that the first task was to assess sentence comprehensibility. All were provided with the same numbered rating sheet and 5-point scale that had been used in the previous experiments. They were instructed to read each sentence carefully. The experimenter presented the cards individually for 10 sec and then instructed the subjects to turn the card over, read what was printed on the reverse, and rate the sentence for comprehensibility. The subjects in the puzzle-acquisition condition read and rated 12 sentence-clue pairs, and subjects in the twice-presented declarative-acquisition condition read and rated each of the 12 sentences twice for a total of 24 sentences. The subjects in the mixed-acquisition conditions read and rated 18 sentences: 6 puzzle sentences presented once and 6 declarative sentences each presented twice.

Following the acquisition task, there was a delay of 3 min during which attendance forms were completed. Then problem booklets were presented. The subjects were told to try to solve each problem in the order presented and were instructed not to return to previous problems. The subjects worked on each problem until a solution had been written or until 3 min had elapsed. This time is shorter than that allowed in Experiment 2, but is justified by the fact that in that experiment fewer than 2% of correct solutions were given after 2 min. The subjects were instructed to signal the experimenter as soon as they began to read a problem and as soon as an answer had been written. The experimenter measured the response time in seconds with a stopwatch.

Following the problem solving task, the subjects were given an unexpected free recall task for the acquisition sentences. The subjects were instructed to try to remember and write down the sentences that they had rated for comprehensibility at the beginning of the experiment. This task was self-paced. Finally, the same awareness questionnaire as had been used in Experiment 2 was administered to all subjects except those in the control condition.

Results and Discussion

Mean proportions of problems solved correctly are given in Table 3. The overall level of performance is somewhat higher than in the previous two experiments, a result directly attributable to having dropped the two most difficult items. A one-way analysis of variance reveals a difference between acquisition conditions [$F(4,75) = 6.81$, $MSe = 0.057$, $p < .01$]. Puzzle-acquisition, declarative-acquisition, and control conditions constitute a replication of Experiment 1 and yield the same results in this experiment. Planned orthogonal comparisons reveal no difference between control and declarative-acquisition groups ($t < 1$), and a comparison of the average of these two groups and the puzzle-acquisition group again reveals a significant difference [$t(75) = 3.78$, $p < .01$]. The comparison between the two mixed-acquisition conditions shows that the group receiving the puzzle-acquisition problems first solved more problems in total than the group receiving the declarative-acquisition problems first [$t(75) = 2.12$, $p < .05$].

Table 3
Problem Solving and Final Free Recall Scores for Experiment 3

Measure	Acquisition Condition				
	Control	Declarative	Puzzle	Mixed (P→D)	Mixed (D→P)
Problems Solved	.42	.44	.77	.71	.55
Solution Times	45.50	49.86	33.06	32.62	37.81
Final Free Recall		.44	.45	.49	.46

Note—D = declarative; P = puzzle.

This difference between the two mixed-acquisition groups can be analyzed further in terms of the two types of items. When this is done, it is clear that the major effect is precisely the one predicted on the basis of Experiment 2: There is a substantial increase in the solution rate for declarative-acquisition problems when these problems *follow* a set of puzzle-acquisition problems than when they *precede* them. The solution rates are .78 and .51, respectively. A separate analysis shows this difference to be significant [$t(30) = 2.60$, $p < .05$]. The former solution level is comparable to that of the pure puzzle-acquisition condition (.77), whereas the latter is comparable to the declarative-acquisition condition (.44). It seems clear then that the failure to obtain differences between declarative-acquisition and puzzle-acquisition problems in Experiment 2 is a consequence of the random order in which the problems were presented, an order that resulted in most subjects receiving at least one puzzle-acquisition problem among the first few problems to be presented.

Surprisingly, solution rates for puzzle-acquisition items in the mixed conditions are lower than those for the pure puzzle-acquisition group, the solution rates being .64 and .59 for conditions preceding and following declarative-acquisition problems, respectively. Evidently, declarative-acquisition sentences interfered with problem solving for puzzle-acquisition items.

The mean response times for correct solutions to the problems are given in Table 3. These data do little more than confirm the picture apparent in the accuracy data: higher solution rates are associated with faster solution times. More important, the response time data establish clearly that differences in solution rates between the acquisition conditions are not an artifact of the time subjects were given to find a solution. Virtually all correct solutions were achieved in the first 2 min for all condi-

Table 4
Number of Subjects Aware of Relevance of Acquisition Sentences as a Function of Acquisition Condition in Experiment 3

	Acquisition Condition			
Time of Awareness	Declarative	Puzzle	Mixed (P→D)	Mixed (D→P)
After First Few Problems	5	11	11	7
After End of Problems	1	4	2	3
Not at All	10	1	3	6

Note—D = declarative; P = puzzle.

tions. Of the total 552 correct solutions, only 11 were given after 120 sec.

Analysis of the subjects' reports of their awareness of the relation between acquisition and problem solving tasks confirms the general picture that puzzle-acquisition problems make subjects aware that the sentences provide useful information for solving the problems. The data are shown in Table 4. A chi-square test comparing the four acquisition groups was significant [$\chi^2(6) = 14.38$, $p < .05$].

GENERAL DISCUSSION

Sagacity is the skill of appropriate conception, of being able to construct a representation or assign a meaning that generates consequences needed to solve the problem. Experiments 1 and 3 both provided clear demonstrations of enhanced sagacity through conceptual transfer: Problem solving is facilitated by previously presented information when this information is presented in a form that requires for its comprehension the same conceptual processing as that demanded by the subsequent problem. This common processing involves replacing a dominant but inappropriate conception with one that resolves the anomaly that constitutes the problem. When the number of previously unsuccessful attempts to obtain positive conceptual transfer is considered, the manipulation producing the effect seems quite a subtle one. The manipulation is essentially nothing more than a rearrangement of the order in which words are presented, a reordering that induces a difference in the sequence of activated concepts but which, in the end and within a matter of seconds, presents the same information. With this very tight control over the *content* of the information presented, it is possible to conclude that the source of the transfer lies not only in the content of the information but in the processing operations that underlie the acquisition of that information. Relevance of content is a necessary but not sufficient condition to bring about positive conceptual transfer.

The present results allow us to reject several plausible explanations of this transfer effect. First, the effect cannot be explained adequately in terms of differences in the subsequent recallability of the initially presented information. In all three experiments, the free or cued recall of information presented twice in its declarative form was as good as, or better than, that same information presented in the puzzle form. Second, the effect cannot be explained in terms of insufficient time being allowed for solving the problems in the declarative-acquisition condition, an explanation made plausible by the results reported by Bowden (1985). It is quite clear that the functions depicting the cumulative number of correct solutions over time have reached different asymptotes. A third explanation is that the puzzle form of information induces a general problem solving orientation that alerts the subject to the relationship between the two phases of the experiment. This explanation is quite inadequate since it cannot account for the observed difference between the two mixed conditions in Experiment 3, and, in particular, it cannot account for the large difference between the two declarative-acquisition problem blocks in those conditions.

There is another possible explanation that deserves careful consideration. Perhaps the capacity of the problems to cue the puzzle form of the acquisition sentences is simply a consequence of these sentences being more similar to the problems than were the sentences in the declarative form. Before addressing this question, we need to specify exactly what we mean by similarity, since similarity is always relative to a conceptual framework or point of view. Indeed, we have argued that one plausible explanation of the results from the present experiments is in terms of the greater similarity of processing operations between puzzle sentences and their corresponding problems. However, the important question is whether these results can be accounted for on the basis of some other similarity relationship that is theoretically less interesting. It is possible to distinguish two broad forms of similarity of this type. One is at the level of task strategy; the other is at the level of shared content.

The former possibility can be disposed of quickly since its elimination was the major purpose of Experiment 3. The argument is essentially the same as the interpretation in terms of "problem solving orientation" discussed above. The claim is that the superior performance of the puzzle-acquisition condition is a consequence of this condition being more similar to the problem phase in the sense that the form of the task and the task demands are more "problem-solving-like" than are declarative acquisition sentences. Again, the results of Experiment 3 enable us to reject this version of the similarity account.

The possible role of similarity at the level of shared content requires more detailed attention. It would be uninteresting if the results could be attributed to the fact that puzzle sentences and problems were more similar in the sense of having more words in common, since the effectiveness of such commonality has been well established (e.g., Gentner & Landers, 1985). Although our tight control over the wording of the acquisition sentences makes this explanation unlikely, we examined the possibility by making an explicit count of the number of content words shared by each of the acquisition forms and the problems. The results are clear-cut. The overlap between problems and acquisition sentences of either form is very small, but, more important, it is identical for puzzle and declarative forms, averaging 1.25 (range 0–3) words in common over the 16 problems used in the three experiments. Indeed, only 2 of the 16 acquisition forms differed in their similarity to the problem. For one problem the puzzle form shared 2 words with the problem, whereas the declarative form shared only one; for a second problem, the puzzle form shared no words but the declarative form shared 1. On the other hand, the overlap between the two acquisition forms themselves was very high. The average number of content words was 8 for both the puzzle and declarative forms. Of these, an average of 7.1 were shared. None of this is surprising since the acquisition sentences were designed to differ only in the order in which information was presented and at the level of word content to be equally similar (or dissimilar) to the problems.

We are, therefore, led to an explanation in terms of item-specific interactions between puzzle sentences and their corresponding problems. Such an explanation can be offered in terms of the correspondence of conceptual operations existing between a puzzle sentence and the subsequent problem. That is to say, the results simply confirm the earlier analysis used to generate the prediction that was tested and confirmed in Experiment 1. Such an explanation in terms of the repetition of operations is very much in the spirit of the theoretical outlook advocated by Kolers and Roediger (1984). As far as it goes, it is probably a sound interpretation, but a more detailed analysis is needed to do justice to the present results. It seems unlikely that an interpretation in terms of repetition of operations is the whole story since we must account for the apparent role of awareness as reflected in subjects' reports and in performance in the mixed-acquisition conditions. Solving puzzle-acquisition problems leads subjects to an awareness—a spontaneous recognition—of the relevance of the entire set of Phase 1 material. This awareness is functionally equivalent to instructing subjects explicitly that the previously heard sentences will help them solve the problems, an instruction that, not surprisingly, facilitates problem solving (Perfetto et al., 1983). In the mixed-acquisition conditions of Experiments 2 and 3, it facilitates the solving of declarative-acquisition problems, provided they are presented after some puzzle-acquisition problems have been solved. Presumably this awareness also facilitates the solving of subsequent puzzle-acquisition problems as well, over and above the facilitating effect attributable to the repetition of operations.

The question that remains is why awareness of the relevance of Phase 1 material occurs so much more readily with puzzle-acquisition problems. Again, one can appeal to the closer identity of operations as the basis for such enhanced spontaneous recognition and, again, this identity may well be an essential part of the effect, but such an analysis needs greater depth and precision. To begin with, even in the case of declarative-acquisition problems, there is considerable overlap of content between sentences and problems. Why do the common operations underlying this content not yield reminding? One possible explanation lies in Schank's (1982) concept of event indexing. Schank's basic claim was that events are structured in terms of expectations and when the structure (e.g., a script) generates expectations that fail, that failure is marked, and the structure is indexed with a pointer to the episode that contained the failed expectation. If the same deviation is encountered a second time, the index leads directly to the recovery of the prior episode. That is, the second expectation failure reminds us of the episode containing the first one. Thus, to use Schank's own example, if there is a deviation from expectation for an episode structured in terms of your restaurant script (e.g., you order food and the restaurant demands payment *before* you eat), then this failure is marked, the script now containing a pointer to this particular episode. If this same deviation is encountered in another restaurant, an experience that is also being structured in terms of your restaurant script, you will be reminded of the first episode.

The application of these ideas to the present data is straightforward. Puzzle sentences are puzzles precisely because they lead to failures of expectation. In this case, the processing structures that generate these contradicted expectations are simple concepts. Multiple marriages contradict the expectations generated by the concept of "legally behaving man" as normally applied. However, if the meaning of the sentence is structured in terms of the concept "clergyman," there is no deviation from expectation. Thus, in the case of puzzle sentences, the critical concept (e.g., "man") contains an index pointing to the episode that contained the deviation, an episode that also contains the solution. Since declarative sentences do not generate failures of expectation, they are not indexed. In this way, puzzle-acquisition problems remind the subject of the acquisition phase of the experiment, whereas sentence-acquistion problems do not. Once this awareness is achieved, acquisition sentences are accessible through free or cued recall.

The significance of this indexing is that it links episodes through their common underlying processing structures (concepts, scripts, schema, etc.) rather than by the features of individual words or elementary events considered apart from these structures. It is the processing structure itself that contains the index pointing to the episode containing the anomaly.

In this way, episodic memory and conceptual transfer are closely linked, a point of view that finds support in recent work such as that of Brooks (1987). That is, problem solving occurs not through direct application of abstract structures but via the recovery of particular episodes that were interpreted in terms of those structures.

This is not to claim that all reminding is mediated through common underlying structures; evidence such as that of Gentner and Landers (1985), Holyoak and Koh (1987), and Ross (1984) clearly indicates that it is not. Indeed, the challenge seems to be to find conditions under which episodes will be linked by virtue of their common underlying structure rather than by their connection being exclusively in terms of their common surface conperiments establish conditions of successful conceptual transfer when the degree of common surface content is not sufficient to achieve such a linkage. In so doing, they illustrate a possible relationship in problem solving betwen abstract conceptual knowledge and specific episodes.

In making this point, it is helpful to return to James's notion of sagacity with which this paper began. To claim that the major obstacle to successful problem solving is a lack of sagacity—a failure of appropriate conception—is to claim first that previous examples of solved problems are relevant to a current problem only by virture of sharing a common conceptual structure, and second that unsuccessful problem solving is often the result of a failure to access conceptual skills that are nevertheless available. That is, on the one hand, past examples are useful only insofar as they serve as a means of accessing relevant abstract knowledge and thereby eliciting appropriate conceptions; however, on the other hand, possession of abstract knowledge is useful only if it is accessed. The theoretical significance of a mechanism such as event indexing is that it avoids assigning to examples the unduly strong role of providing a solution directly, while at the same time recognizing that possessing the conceptual knowledge necessary to solve a problem does not ensure that it will be solved. The role of examples, then, is to enhance sagacity: Although a problem may not access an appropriate concept directly, it may remind the problem solver of a past solved example that serves to elicit that concept.

REFERENCES

AUBLE, P. M., FRANKS, J. J., & SORACI, S. A., JR. (1979). Effort toward comprehension: Elaboration or "aha!"? *Memory & Cognition*, **7**, 426-434.

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

BROOKS, L. R. (1987). Decentralized control of categorization: The role of prior processing episodes. In U. Neisser (Ed.), *Categories reconsidered: The ecological and intellectual bases of categories*. Cambridge: Cambridge University Press.

DOMINOWSKI, R. L. (1981). Comments on "An examination of the alleged role of 'fixation' in the solution of several 'insight' problems" by Weisberg and Alba. *Journal of Experimental Psychology: General*, **110**, 193-198.

DUNCKER, K. (1945). On problem-solving. *Psychological Monographs*, **58** (Whole No. 270).

ELLEN, P. (1982). Direction, past experience, and hints in creative problem solving: Reply to Weisberg and Alba. *Journal of Experimental Psychology: General*, **111**, 316-325.

GARDNER, M. (1978). *Aha! Insight*. New York: Freeman.

GENTNER, D., & LANDERS, R. (1985). Analogical reminding: A good match is hard to find. In *Proceedings of the International Conference on Systems, Man and Cybernetics*. Tucson, AZ.

GICK, M. L., & HOLYOAK, K. J. (1983). Schema induction and analogical reasoning. *Cognitive Psychology*, **15**, 1-38.

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

JAMES, W. (1890). *The principles of psychology* (Vol. 2). New York: Dover.

KOLERS, P. A., & ROEDIGER, H. L. (1984). Procedures of mind. *Journal of Verbal Learning & Verbal Behavior*, **23**, 425-449.

OHLSSON, S. (1984a). Restructuring revisited: I. Summary and critique of the Gestalt theory of problem solving. *Scandinavian Journal of Psychology*, **25**, 65-78.

OHLSSON, S. (1984b). Restructuring revisited: II. An information processing theory of restructuring and insight. *Scandinavian Journal of Psychology*, **25**, 117-129.

PERFETTO, G. A., BRANSFORD, J. D., & FRANKS, J. J. (1983). Constraints on access in a problem solving context. *Memory & Cognition*, **11**, 24-31.

ROSS, B. H. (1984). Remindings and their effects in learning a cognitive skill. *Cognitive Psychology*, **16**, 371-416.

SCHANK, R. C. (1982). *Dynamic memory*. Cambridge, England: Cambridge University Press.

WEISBERG, R. W., & ALBA, J. W. (1981a). An examination of the alleged role of "fixation" in the solution of several "insight" problems. *Journal of Experimental Psychology: General*, **110**, 169-192.

WEISBERG, R. W., & ALBA, J. W. (1981b). Gestalt theory, insight, and past experience: A reply to Dominowski. *Journal of Experimental Psychology: General*, **110**, 199-203.

WEISBERG, R. W., & ALBA, J. W. (1982). Problem solving is not like perception: More on Gestalt theory. *Journal of Experimental Psychology: General*, **111**, 326-330.

WEISBERG, R., DICAMILLO, M., & PHILLIPS, D. (1978). Transferring old associations to new problems: A nonautomatic process. *Journal of Verbal Learning & Verbal Behavior*, **17**, 219-228.

(Manuscript received January 12, 1987;
revision accepted for publication July 21, 1987.)