Encoding and Retrieval Processes: Separate Issues in Problem Solving

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Abstract

Studies investigating the facilitation of spontaneous access during problem solving by manipulating encoding processes suggest that similar processing at acquisition and test (i.e., problem-oriented processing) enhances spontaneous access (Adams et al., 1988; Lockhart et al., 1988). Bowden (1985) argues that access difficulty is due to problem solving time (i.e., retrieval) constraints rather than acquisition processes. Ross et al. (1989) have challenged Bowden by suggesting that an increase in retrieval time allows subjects to "catch on" to the the experimental procedure. This study investigates this claim and also attempts to separate acquisition and retrieval factors by crossing problem solving time (40, 80, 120 sec) with acquisition processing factors (problem-oriented, fact-oriented, and mixed orientation). The mixed condition includes problem-oriented and fact-oriented as a within subjects variable. Results show an increase in performance from 40 sec to 80 sec, but no added benefit beyond 80 sec. Problem-oriented processing facilitates spontaneous access. The critical evaluation is that of the mixed condition. Performance in the mixed condition also shows a faciliation of spontaneous access for those acquisition materials that involve problem-oriented processing, but not fact-oriented processing, suggesting that one form of encoding facilitates later access.

Introduction

The ability of people to problem solve simply requires the access and application of previously acquired information to a new or unique situation. However, studies in human problem solving have consistently demonstrated a lack of spontaneous access abilities. Spontaneous access in problem solving means that people spontaneously, on their own, and with no external hints, access or retrieve the information necessary to solve a problem. In studies of access, psychologists have generally used the following procedure. First, information, necessary to solve problems that will later be attempted, is presented to subjects in an incidental learning task (acquisition information). Some of the subjects are informed as to the information's relevance to the later problems (informed subjects) and others are not (uninformed subjects). Then subjects are given a set of problems to solve. The number of problems solved is the measure of access. The results show that uninformed and baseline subjects perform equally, solving few, if any, of the problems while informed subjects solve a high percentage of the problems. In other words, humans do not make effective use of potentially relevant information during problem solving unless direction to do so is provided (Gick & Holyoak, 1980; Perfetto, Bransford, & Franks, 1983; and Weisberg, Dicamillo, & Phillips, 1978).

Perfetto et al. (1983) developed a very obvious set of solution sentences to 12 insight problems adapted by Gardner. An example of the insight problems used is "One night my uncle was reading an exciting book when his wife turned out the light. Even though the room was pitch dark, he continued to read. How could he do that?" The corresponding solution sentence was "A blind person can read braille in the dark." This study was intended to address the issue of access (i.e., do subjects access the acquisition materials during problem solving) versus application (i.e., do subjects access the acquisition materials but reject them as being relevant to the problem). It was believed that, because the solution sentences were so

obvious, if subjects accessed them at all application was insured. Using the past methodology, Perfetto et al. (1983) presented the acquisition information to informed and uninformed subjects and compared uninformed subjects' subsequent problem solving performance to the performance of informed and baseline subjects. Uninformed subjects performed no better than baseline subjects and informed subjects out performed all other groups. In other words, spontaneous access of the relevant information had still not been demonstrated in the laboratory.

A current research focus of spontanteous access during problem solving is in the area of facilitation during retrieval (Ross, 1984; 1987; Bowden, 1985). Bowden (1985) stated that the lack of laboratory demonstrated spontaneous access was due to the experimental methodology. He argued that humans usually are not under the time constraints to solve problems imposed by typical problem solving studies. These time constraints do not allow a full search in a problem space and, therefore, do not allow the demonstration of access that is naturally occuring in humans. He maintained that spontaneous access was not as critical an issue as most problem solving researchers believe. He demonstrated this by conducting a study using Perfetto et al.'s (1983) materials and general methodology. The critical difference involved the amount of time subjects were given to solve the problems (i.e, 120 seconds per problem as opposed to the usual 40 seconds per problem). With the increased time for problem solving, uninformed subjects performed as well as the informed subjects and both groups were superior to baseline performance.

More recently, Ross, Ryan, and Tenpenny (1989) attempted to replicate Bowden's (1985) study and found that the results did not replicate if a different order of problems was used. Ross et al. (1989) applied a simple mathematical model to the results that attributed the differences between the two studies to Bowden's uninformed subjects "catching on" to the relevance after solving some problems. Ross et al. (1989) maintained that subjects in Bowden's study were presented easier problems first and were able to generate a solution on their own. Once subjects generated a solution they realized they had recently heard similar information during the acquisition phase. This realization let subjects "catch on" to the procedure used in the study. Therefore, it was concluded, that extra problem solving time does not lead to spontaneous access unless subjects become "reminded" of the acquisition material and subsequently focus on it. Furthermore, this reminding is governed by the similarity between generated answers and the sentences presented during acquisition.

Other researchers have focused on encoding processes, as opposed to retrieval processes, as a way of facilitating spontaneous access. Adams, Kasserman, Yearwood, Perfetto, Bransford, and Franks (1988) developed a set of follow-up studies based on the Transfer Appropriate Processing model of memory retrieval. Simply put, Transfer Appropriate Processing suggests that memory access/retrieval is enhanced if the processing used at retrieval of information is similar to the processing used during encoding of that information. Adams et al. (1988) developed a series of materials based on the materials used in the Perfetto et al. (1983) studies. However, instead of using factually stated sentences for the acquisition information, as in the earlier studies, the acquisition information was cast into a problem oriented format. It was believed that if the acquisition sentences first presented an ambiguity, followed by a clarifier or solution, that processes necessary to comprehend the acquisition sentence would be similar to the processes used during problem solving. Therefore, the problem-oriented form of the fact-oriented sentence, "A blind person can read braille in the dark" became "It is possible to read in the dark; if you are reading braille." By using the problem-oriented form of acquisition materials, spontaneous access was demonstrated in the laboratory. That is, uninformed subjects performed at the same level as informed subjects. Other researchers, working in parallel and using a very similar approach, demonstrated spontaneous accesss as well (Lockhart, Lamon, & Gick, 1988).

Though researchers have focused on retrieval processes and encoding processes as facilitators of spontaneous access, little research exists that investigates the relationships between these processes. A recent study (Adams, 1992) attempted to identify the more critical process (i.e., encoding or retrieval) by crossing the two variables, acquisition sentence form and retrieval time. Four experimental

conditions were investigated: 1) fact-oriented acquisition sentences with a 40-sec solution time, 2) fact-oriented, 120-sec, 3) problem-oriented, 40-sec, and 4) problem-oriented, 120-sec. It was hypothesized that, because problem-oriented acquisition sentences already facilitated spontaneous access, increasing retrieval time would not notably improve problem solving performance because subjects in problem-oriented conditions are already reminded of the acquisition materials. Catching on should not be an issue for those in the problem oriented conditions. Therefore, when the four experimental groups are compared, an interaction between acquisition sentence form and retrieval time would be expected. Instead, main effects for retrieval time and acquisition sentence form were found. Results indicated that while an increase in problem solving time increases spontaneous access, problem-oriented acquisition processing enhanced access well beyond the benefits attributed to increasing problem solving time, suggesting that these are additive, independent effects. Those results did not support a simple "catching on" explanation of the spontaneous access during problem solving associated with an increase of problem solving time.

Instead, new questions were generated. If acquisition sentences are encoded as a list upon which, after catching on, one could focus a solution search, then no difference in performance would be expected between problem-oriented and fact-oriented conditions. If the list can be recognized, found, and searched in 2 minutes, why would one list, once found, be better searched than another? Is one list more easily found than another? If similarity between a subject generated response and the acquisition material triggers the finding of a memory list (as suggested by Ross et al, 1989), fact-oriented acquisition material would seem to be more similar in form to subjects' answers and, therefore, be more easily found. This is contrary to the study's results.

Another possible explanation to findings of the earlier research is that the acquisition sentences are not simply stored as lists, but are somehow integrated into exisiting conceptual frameworks or stored as miscellaneous information grouped according to other unique, identifying characteristics, such as meaning ambiguity or encoding processes. Indeed, this encoding strategy was proposed by Adams et al. (1988) as well as Lockhart et al. (1988). If the information is not encoded as a list, the catching on explanation of performance facilitation with an increase of problem solving time is also inappropriate.

The objective of the present study was to provide for a more rigorous replicaton of the above study (Adams, 1992) and to incorporate an extension that investigated the encoding issues raised by the that study's results. To that end, subjects were exposed to either fact-oriented or problem-oriented acquisition materials and were given either 40, 80, or 120 seconds to solve each problem in a susbsequent problem solving task. The addition of the 80 second condition allowed for the determination of a linear relationship, orthogonal and additive, between the acquisition sentence form and the retrieval time constraints. Additionally, baseline and informed conditions were included in the study for a more complete design and provide for more rigorous analyses of problem solving performance.

In order to investigate the encoding issues discussed earlier, a new condition was incorporated into the methodology. In this condition, subjects were presented a list of acquisition sentences that contained both fact-oriented and problem-oriented sentences (mixed orientation condition). The rationale for this condition is as follows. If the acquisition sentences are encoded as a single list and subjects simply find the list and search it, spontaneous access for all problems, regardless of the form of the associated acquisition sentence will be facilitated. On the other hand, if the sentences are encoded and stored differentially according to unique characteristics or qualities of the sentences, it is expected that the fact-oriented and the problem-oriented sentences would not be stored together due to the form differences. Because previous research demonstrates a facilitation of spontaneous access for problem-oriented acquisition sentences (Adams, et al., 1988, Lockhart, Lamon, & Gick, 1988), better performance for those problems that had problem-oriented acquisition sentences would be expected.

Methods

Subjects

Subjects were 420 undergraduate psychology students from the Illinois State University subject pool.

Procedure

Subjects were randomly assigned to one of 3 experimental conditions: the fact-oriented condition, the problem-oriented condition, and the mixed-orientation condition. Within these conditions, subjects were either allowed 40, 80, or 120 seconds per problem during the problem solving task. Baseline groups were also run, where subjects attempted to solve the problems, without exposure to the acquisition sentences, with 40, 80, or 120 seconds per problem. Additionally, informed groups (subjects are told of the relationship between the acquisition sentences and the problems prior to problem solving) mirroring the experimental conditions were run. Subjects were tested in groups of 8 to 12 subjects at a time.

Prior to participation, subjects were told that they would be asked to do a series of unrelated tasks to help finish several in-progress experiments. This cover story was presented so the subjects would not automatically assume that the acquisition sentences were related to the subsequent problem solving task.

During the acquisition phase, subjects, excluding those in the baseline conditions, listened to a taped presentation of the acquisition sentences. The first and last sentence in the presentation were filler sentences, taking fact-oriented form in the fact-oriented and mixed-orientation conditions and a problem-oriented form in the problem-oriented conditions. After each sentence, during a 20-sec pause, the subjects rated the sentence on general truthfullness using a 1 to 5 scale (1 = true only in a specific instance to 5 = always true).

There was a 4 minute interval between the acquisition phase and the problem solving task. The subjects were then given a booklet containing three filler problems followed by 10 insight problems. The 10 insight problems were presented in one of seven random orders.

The subjects were told not to open their booklets until instructed to do so. They were then told that they had 40/80/120 seconds to solve each problem and that the experimenter would tell them when to go on to the next problem. They were also told not to work ahead or go back to an earlier problem. Subjects were instructed to write an answer for every problem, even if they did not believe it was correct. At this point, subjects in the informed conditions were also told of the relationship between the acquisition sentences and the problems. Upon completion of the problem solving task, subjects were asked to fill out a questionnaire that asked if subjects noticed the relationship between the acquisition sentences and the problems and if they were familiar with any of the problems prior to participating in the study. Data from subjects familiar with 2 or more insight problems was discarded.

Results and Discussion

An overall 4(Acquisition Sentence Type) X 3(Problem Solving Time) X 2(Informed Status) ANOVA was performed on the number of correcly solved target problems. Significant main effects for Acquisition Sentence Type, Problem Solving Time, and Informed Status were found, $F(3,419) = 29.6$, $p = .0001$, $F(2,419) = 13.7$, $p = .0001$, and $F(1,419) = 45.4$, $p = .0001$. No significant interactions were found. Though several different types of analyses were performed, the analyses that directly address issues of spontaneous access are those related to the performance of uninformed subjects. The overall problem solving performance of uninformed subjects is presented in Table 1.

A 4(Acquisition Sentence Type) X 3(Problem Solving Time) ANOVA performed on the number of correctly solved problems for those subject in the Uninformed conditions maintained significant main effects for both factors, $F(3,236) = 18.1$, $p = .0001$, $F(2,236) = 7.0$, $p = .001$, respectively. No significant interactions were found. Using Dunn's multiple comparison procedure, the fact-oriented and problem-oriented conditions performed significantly better than baseline for all problem solving times,

Table 1
Number of Problems Solved in Relation to Acquisition Sentence Form, Problem Solving Time for Uninformed Subjects

Acquisition Sentence	Problem solving time (in sec) 40	80	120
Baseline	1.5	2.5	2.5
Fact-oriented	3.8	4.2	3.8
Problem-oriented	4.2	5.1	5.5
Mixed-condition	3.2	5.5	4.8

$\underline{d}(3,236) = 0.53$, $\underline{p} < .01$, $\underline{d}(3,236) = 0.55$, $\underline{p} < .01$, and $\underline{d}(3,236) = 0.65$, $\underline{p} < .01$, for the 40, 80, and 120 sec conditions, respectively. Subjects in the problem-oriented conditions solved significantly more problems than those in the fact-oriented conditions if allotted 80 or 120 sec for problem solving. There was no significant difference in performance between the fact-oriented and problem-oriented groups in the 40 sec condition.

Similar comparisons between the different problem solving times for the baseline, fact-oriented, and problem-oriented groups suggest that subjects solve fewer problem in the 40 sec condition than the 80 or 120 sec conditions. No significant difference in performance was found between the 80 and 120 sec conditions except for the fact-oriented groups. Subjects in the fact-oriented groups actually performed better in the 80 sec condition than in the 120 sec condition. These results replicate previous research in that an increase (up to 80 sec) in problem solving time and problem-oriented acquisition sentences both seem to facilitate spontaneous access.

An investigation of performance in the mixed-orientation condition showed no facilitation of spontaneous access for acquisition sentences that were presented in a fact-oriented form even though they were presented with problem-oriented acquisition sentences. When the proportion of problems solved by subjects in the problem-oriented condition (0.42, 0.51, 0.54 for the 40, 80, and 120 sec conditions, respectively) is compared with the proportion of problems solved that were associated with problem-oriented acquisition sentences in the mixed condition (0.36, 0.58, and 0.50.), no difference in performance is found. Furthermore, when making the same comparison between performance in the fact-oriented conditions (0.37, 0.41. 0.38, for the 40, 80, and 120 sec conditions, respectively) and the fact-oriented materials in the mixed-orientation conditions (0.28, 0.51, and 0.45), no differences are found. If the acquisition material was simply stored as a list during presentation, once subjects solved a few problems and "caught on" to the experimental manipulation, facilitation for fact-oriented and problem-oriented problems would be expected. However, this was not the case. This suggests that the acquisition sentences are encoded and stored differentially and that one form of encoding facilitates later access of that information. Furthermore, a catching on explanation associated with an increase of problem-solving time would be inappropriate if the information is indeed encoded separatedly.

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