Consequences of History-Cued and Means-End Strategies in Problem Solving

Author(s): John Sweller, Robert F. Mawer and Walter Howe

Source: *The American Journal of Psychology*, Autumn, 1982, Vol. 95, No. 3 (Autumn, 1982), pp. 455-483

Published by: University of Illinois Press

Stable URL: https://www.jstor.org/stable/1422136

AMERICAN JOURNAL OF PSYCHOLOGY
Fall 1982, Vol. 95, No. 3, pp. 455-483

Consequences of history-cued and means-end strategies in problem solving

JOHN SWELLER, ROBERT F. MAWER, AND WALTER HOWE
University of New South Wales, Australia

There are two broad processes that people can use when attempting to solve a problem. The first of these is a means-ends strategy in which attempts are made to reduce differences between a given problem state and a goal or subgoal. Moves are generated by the goal or subgoals. The second is a history-cued process in which people use previous moves to generate subsequent moves. It is suggested that a means-ends strategy tends to reduce transfer effects. A history-cued strategy may facilitate rule induction, which in turn may be an important contributing factor to transfer. A series of four experiments using hybrid problems that are soluble either by rule induction or by means-ends analysis supported the above suggestion. Two additional experiments indicated that with respect to the *insoluble problem effect,* the use of history-cued strategy was, of itself, insufficient to induce transfer effects. In order for transfer to occur, the structure of the problems and the manner in which they were presented had to be such as to ensure that problem solvers perceived a close relation between problems.

The strategies people use when solving a problem may determine not only the speed and efficiency with which the problem is solved but also what is learned during the problem-solving episodes. This learning in turn may determine the speed and efficiency of subsequent problem solving. A distinction can be made between history-cued strategies requiring an analysis of past responses and means-ends strategies (Newell & Simon, 1972) in which attempts are made to reduce differences between the goal state and any problem state. The latter requires the manipulation and consideration of future goals and subgoals.

As an example of this distinction, Egan and Greeno (1974) refer to a memorized pattern of moves that generate subsequent moves as

0002-9556/82/0300-0455 $2.90/0

"problem solving in the past" and refer to a goal structure approach in which moves are generated by a goal and subgoals as "problem solving in the future." (They also suggest "problem solving in the present" occurs when people recognize states of a problem and solve it by pairing these states with moves in paired-associate fashion.)

The manner in which moves are generated may affect the problem solver's knowledge of the problem structure. We suggest one of the effects of a means-end strategy is to reduce the probability of rule induction. Rule learning may be facilitated by a strategy that allows problem solvers to monitor their previous moves or responses. Any regularities from which a rule can be induced are thus attended to. A history-cued strategy automatically provides an emphasis on previous problem-solving episodes either within a problem or during solution of a previous problem. A means-ends strategy, on the other hand, emphasizes differences between a given problem state and the goal. While this does not eliminate the possibility of simultaneously monitoring moves in an attempt to extract a rule, this strategy may reduce it. It should in any case be noted that, unlike a situation involving rule learning, in theory a problem could be solved by means-ends analysis with nothing being learned whatsoever.

The relative effectiveness of these two strategies may depend on the type of problem. Problems can be classified into three categories according to the probability of rule induction occurring. First, a large class of problems can be solved *only* by a rule induction procedure. Conventional concept-discovery tasks fall into this category along with all problems whose structure does not contain a goal specifiable as a problem state that must be attained. Discovery of a clear-cut rule such as "always point to the red object" allows solution of these problems. They will be called *rule-induction* problems. A second class consists of problems that can not be solved by a simple rule, although some rules may assist in problem solution. These problems have a problem-state goal that must be attained, but this can only be done by a series of irregular, nonrule determined steps. These will be called *irregular-step* problems. A means-ends strategy appears to be frequently employed to solve these problems. The missionaries-cannibals problem is an example (Simon & Reed, 1976). In these problems, a number of missionaries and cannibals must be moved from one side of a river to the other with restrictions on the number and combinations of people that can be moved. No simple, readily memorized, recursive rule can generate the steps necessary to accomplish this since there is no clear relation between the moves. The problem tends to be solved by a series of irregular steps.

From the present theoretical point of view, the last category of problems is the most important. These are *hybrid* problems, which can be solved either by a rule-induction procedure or by means-ends analysis. These problems normally have a clear, problem-state goal, but, in addition, the series of steps that must be followed to attain the goal can be described by a rule. For example, a problem that can be solved by the alternation of two operators is a hybrid problem.

While, as stated previously, rule induction may be more probable under a history-cued strategy than under a means-ends strategy, it should be noted that the question of facilitating rule induction applies only in the case of hybrid problems. Rule-induction problems can only be solved by a history-cued strategy since no specific problem-state goal is provided. The only assistance subjects have in inducing the rule are previous problem-solving episodes of the current problem or previous problems. The question of facilitating this strategy is consequently probably irrelevant since it may be essential and automatic in this context. It is similarly irrelevant in the case of irregular-step problems since no simple rule is available to be extracted, although learning partial rules or sequences of moves may be possible. This leaves hybrid problems soluble either by the application of a rule or by a form of means-ends analysis. The probabilities of either solution method being used may be alterable by experimental manipulation.

The above analysis indicating a link between a history-cued strategy and rule induction may be the first link in a chain. Rule induction in turn may be a primary cause of transfer. When transfer effects occur, knowledge obtained in one task is used on subsequent tasks. Knowledge of a rule provides an obvious transfer medium and indeed *hypothesis* testing theory (Levine, 1975; Sweller & Gee, 1978; Sweller, 1980b) has explained a variety of transfer phenomena by assuming that hypotheses concerning rules are transferred to successive problems. While a means-ends strategy may result in knowledge concerning goal and subgoal structures (Anzai & Simon, 1979; Egan and Greeno, 1974), these normally do not provide a complete solution to a problem as a rule is capable of doing, and thus the means-ends strategy may reduce the scope for transfer. Some evidence comes from Sweller (1976, 1980a), who found that the sequence effect (see Hull, 1920), which is heavily dependent on transfer, could be obtained only on problems in which a rule is induced. In addition, Greeno, Magone, and Chaiklin (1979) found that in the case of some subjects, Einstellung was associated with a strategy that appeared to ignore the goal. This may provide further evidence that transfer is facilitated by a nongoal oriented approach.

It also should be pointed out that a means-ends strategy does not rule out either rule induction or transfer. Indeed, some theorists (e.g., Simon & Lea, 1974) suggest that both means-ends analysis and rule induction involve similar mechanisms. We suggest that they involve different problem-solving strategies that have different transfer consequences, i.e., means-ends analysis may reduce transfer effects. The question is an empirical one and is tested in the following experiments.

EXPERIMENT 1

It is conceivable that on hybrid problems the problem-solving strategy and the extent to which subjects induce rules can be strongly influenced by the manner in which the problems are presented and by the manner in which subjects are required to respond. We suggest that some hybrid problems can be transformed readily from irregular-step to rule-induction problems and vice versa without altering their isomorphism. The legal moves and the correct solutions may be identical but the problems are presented in a manner that increases the probability of either a history-cued or means-ends strategy being used. This, according to the present analysis, determines whether or not a rule will be induced.

Using hybrid problems, Experiment 1 investigated the possibility that transfer effects would differ depending on strategy. The particular hybrid problems used generate an instance space formally equivalent to the sample space of n Bernoulli trials. A particular sequence of binary choices determines a rule (e.g., alternation of each choice) that can be used to solve each problem; this would result in rule-induction problems. Alternatively, the same sequence of alternating steps can be carried out without referring to the relation between steps but rather referring only to the relation between each step and the goal—means-ends analysis. A rule is not used and consequently the same problem becomes an irregular-step problem; subjects would be unaware that a rule could be extracted.

The procedures used to induce this transformation were as follows: Subjects expected to induce a rule were encouraged to use a history-cued strategy by being (a) presented with their correct sequence of steps at the conclusion of each problem, (b) required to memorize those steps, and (c) required to reproduce the steps. This procedure is goal-independent, and it was hoped that it would result in subjects testing the rule on subsequent problems rather than adopting a goal-directed strategy. That is, it was expected that successive moves would be determined by the previous move and by comparison with, and extrapolation of, the previously memorized alternation pattern. This history-cued strategy is effectively autonomous with respect to the goal and any subgoals and is expected to maximize both positive and negative transfer effects. A history-cued strategy may be an example of the procedures suggested by Larkin, McDermott, Simon, and Simon (1980) when they suggest that people learn by hindsight. They suggest that learning may be most effective when, after solving a problem, the individual reviews the solution. A forced review of each problem solution may result in subsequent use of a history-cued strategy which, in turn, may alter transfer effects. This was tested in the present experiment.

Group H/2a/4a/4a/6a/10a/2c of Experiment 1 was expected to use a history-cued strategy and hence to induce an alternation rule. Subjects were asked to solve, in the following order, a 2-move, two 4-move, a 6-move, and a 10-move problem using an alternation rule (problems 2a, 4a, and 10a where "a" stands for alternation). This was followed by a 2-move problem that could not be solved by alternating the two choices. Solution could only be obtained by using the same choice on two successive moves (problem 2c where "c" stands for constant). Group M/2a/4a/4a/6a/10a/2c was given exactly the same problems but was not encouraged to use a history-cued strategy, and hence rule induction was not expected. It was assumed this group would solve the problems using a conventional means-end strategy.

Problems 10a and 2c are the critical problems. Predictions of group M/2a/4a/4a/6a/10a/2c performance are straightforward. Due to the presumed lack of a clear transfer medium such as a learned construct, there are no grounds for assuming large, specific transfer effects between irregular-step problems solved by means-ends analysis. (We assume transfer is due to some form of learning, and if learning is relatively small under means-ends analysis, transfer will also be small.) As a consequence, problem 10a should be solved slowly because it is a complex problem, but problem 2c should be solved rapidly because it is a simple problem. The following predictions concerning group H/2a/4a/4a/6a/10a/2c can be made on the basis of hypothesis theory. During the initial problems, subjects learn to test the alternation hypothesis. If they perceive the subsequent more complex problems as being related to the initial problems, they will continue to test this hypothesis and as a consequence solve problem 10a relatively rapidly. They should continue to test the alternation rule on problem 2c and as a consequence find this problem relatively difficult. The contrast between history-cued and means-ends strategies on transfer tasks should thus be demonstrated.

Four additional groups were also run. Groups H/2a/4a/4a/6a/2c and M/2a/4a/4a/6a/2c were identical to groups H/2a/4a/4a/6a/10a/2c and M/2a/4a/4a/6a/10a/2c, respectively, except that problem 10a was omitted. Group 10a was presented problem 10a alone, and group 2c was presented with problem 2c alone. The addition of these four groups allowed tests of effects using fully independent groups. Groups H/2a/4a/4a/6a/10a/2c and M/2a/4a/4a/6a/10a/2c can be used to test for the effects of the preceding problems on problem 10a with group 10a used as a control while groups H/2a/4a/4a/6a/2c and M/2a/4a/4a/6a/2c can be used similarly to test for the effects of the same preliminary problems on problem 2c with group 2c as a control. According to the present analysis, under conditions facilitating a history-cued strategy, problem 10a will be solved relatively rapidly, but problem 2c will be solved slowly. Where a goal-directed, means-ends strategy is used to solve the preliminary problems, problem 10a will be solved relatively slowly, but problem 2c will be solved rapidly. Groups 10a and 2c control for the effects of all preliminary problems.

It can be seen that we are assuming that on new problems, problem solvers will normally adopt a means-ends strategy unless provided with specific grounds for not doing so, i.e., means-ends analysis is a "natural" strategy. Our grounds for assuming this is that means-ends analysis can provide a solution to many transformation problems (see Greeno, 1978) without problem solvers having any previous familiarity with the problems. The technique is normally effective but probably requires no prior learned constructs. In contrast, with respect to a history-cued strategy, problem solvers either must operate a learned construct, such as a rule that they think is effective, or must have grounds for assuming that a history-cued strategy will allow them to learn something from previous moves that will help then on subsequent moves. A novel problem does not normally provide them with grounds for this assumption. A degree of experience may be necessary.

METHOD

Subjects

The subjects were 72 University of New South Wales undergraduates equally divided into the six conditions.

Apparatus and procedure

All information transmission to and from subjects following the initial instructions was conducted via a visual display screen under the control of a computer incorporating a real-time clock. Data generated was stored by the computer for later processing. All subjects were given the following initial instructions by the experimenter.

I am going to give you one or more problems to solve. They will be of the following type. You will be given an initial number and asked to transform it into a final number by multiplying 3 and/or subtracting 69 as many times as is required. As an example, assume the start number is 10 and the final number is 21. The correct solution is $10 \times 3 = 30, 30 \times 3 = 90, 90 - 69 = 21$. All calculations must be done on the terminal in front of you. In order to multiply by 3 you press the letter "X" key. To subtract 69 you press the "–" key. By pressing "B" you will go back (cancel) one move. By pressing "B" twice you will cancel your previous 2 moves, etc. You can thus go back all the way to the initial number if you wish. Alternatively, you can go back to the initial number in one step by pressing "I." A record will be kept of the time it takes you to solve each problem and the number of buttons you pressed. *N.B.* Each time you press a button you *MUST* then press the return key.

If asked, the experimenter informed subjects that both time and moves to solution were equally important. The five keys to be used were clearly marked in red on the keyboard. It should be noted that additional aids such as a pencil and paper were not provided. This was to ensure that calculations were carried out on the computer terminal, thus readily providing an accurate record of moves. Problem-solving decisions based on arithmetic errors were also eliminated as a consequence.

Table 1 gives initial numbers, final numbers, and solutions for each of the problems used in the experiment. It should be noted that each of the solutions listed is also the shortest solution available for that problem. The initial and final numbers remained on the screen for the duration of the problem along with the numerical outcome of the latest move. On all problems except problem 2c, no series of moves could extend beyond the minimum number of moves required to solve the problem. For example, after an incorrect series of four moves on problem 4a, a message would come on the screen informing subjects that the particular sequence of moves made would not allow them to solve the problem in the minimum number of moves possible and for that reason they would automatically be returned to the initial number. This prevented subjects from discovering longer alternative solutions to the problems and increased the probability of solution. With respect to problem 2c, the above message was presented after 10 moves. There are no alternative solutions available for this problem within 10 moves. After solving a problem or after failing to solve within 10 min., the next problem came on the screen.

Table 1. Problems used in Experiment 1

Problem	Initial number	Final number	Solution ($\times = \times 3$, $- = -69$)
2a	60	111	× –
4a (1)	31	3	× – × –
4a (2)	81	453	× – × –
6a	34	21	× – × – × –
10a	35	156	× – × – × – × – × –
2c	35	315	× ×

In addition to the above procedures, history-cued groups were presented with their solution to each problem immediately after solving it along with their previously successful solutions. For example, after the subject solved problem 6a, a message was screened stating:

The solution to problem 1 was × –
The solution to problem 2 was × – × –
The solution to problem 3 was × – × –
The solution to problem 4 was × – × – × –

The message also asked subjects to memorize the sequence required to solve the last problem. The screen was then cleared and a new message required subjects to type in the sequence for the problem just solved. The screen was then cleared and the next problem presented. The critical problems 10a and 2c were not presented with this message for any of the groups.

It was assumed that this procedure would, with time, result in subjects using the rule rather than the goal or subgoals to generate moves. Using this rule presumably requires a history-cued strategy because successive moves are determined by the previous move. Under these conditions, the goal should become virtually irrelevant. Means-ends strategy groups were neither presented with their successful solutions nor required to memorize and re-present them. It was assumed that these subjects would adopt a conventional means-ends strategy with moves being generated by the goal or subgoals rather than by previous moves.

RESULTS AND DISCUSSION

Relative speed of solution on problems 10a and 2c indicate the effects of the attempts to manipulate subjects' problem-solving strategies. The relevant means may be found in Table 2. Moves to solution refer to the total number of keys excluding the return key pressed while working on a particular problem. This measure is highly correlated with sec to solution, and, for this reason, analyses using sec to solution are not reported except where conclusions might differ from those based on moves to solution. Subjects unable to solve a problem within 10 min. were assigned a score of 600 sec and were presented with the next problem. All analyses were carried out on logarithmic (base 10) transformed data.

It was predicted that with a history-cued strategy resulting in rule induction, problem 10a would be solved relatively rapidly while problem 2c would be solved slowly. With a means-ends strategy the reverse should apply. Reduced transfer effects should result in problem 10a taking a long time to solve because it is a complex problem while problem 2c should be solved rapidly because it is a simple problem.

Separate analyses were carried out on the three groups ad-

Table 2. Mean moves and sec to solution on problems 10a and 2c of Experiment 1

Group	Problem 10a		Problem 2c	
	Moves	Sec	Moves	Sec
H/2a4a4a6a10a2c	17.3 (1.124)$_a$	98.6 (1.862)$_a$	18.1 (1.070)$_a$	105.9 (1.855)$_a$
M/2a4a4a6a10a2c	49.0 (1.572)$_b$	343.4 (2.442)$_b$	2.0 (.301)$_b$	16.4 (1.133)$_b$
H/2a4a4a6a2c	-	-	13.5 (.853)$_a$	83.7 (1.598)$_a$
M/2a4a4a6a2c	-	-	5.3 (.463)$_b$	30.3 (1.216)$_b$
10a	55.7 (1.714)$_b$	530.8 (2.709)$_c$	-	-
2c	-	-	2.0 (.301)$_b$	20.3 (1.275)$_b$

Note. Means based on logarithmic transformations are in parentheses. For any given column, a shared subscript indicates no significant differences between means.

ministered problem 10a (groups H/2a/4a/4a/6a/10a/2c, M/2a/-4a/4a/6a/10a/2c, and 10a) and the five groups administered problem 2c (groups H/2a/4a/4a/6a/10a/2c, M/2a/4a/4a/6a/10a/2c, H/2a/-4a/4a/6a/2c, M/2a/4a/4a/6a/2c, and 2c). Analysis of variance indicated a significant difference between groups on problem 2c, $F(4, 55) = 11.59$, $p < .05$. Duncan range tests at the .05 level of significance provide substantial support for our hypotheses (see Table 2). As predicted, subjects in group H/2a/4a/4a/6a/10a/2c tested the previously relevant hypothesis (alternation); this strategy, in comparison with the one used by group M/2a/4a/4a/6a/10a/2c, retarded solution of the problem. Additional evidence of this comes from further analysis of moves made by subjects in group H/2a/4a/4a/6a/10a/2c. Ten of the 12 subjects used multiplication followed by subtraction on their first two moves of problem 2c. In contrast, all group M/2a/4a/4a/6a/10a/2c subjects multiplied twice on their first two moves of this problem, thus solving the problem in the minimum number of moves. This contrasting pattern of moves may be used as a direct measure of subjects' strategies. After multiplying on the first move, the initial state (35) is transformed into 105. A means-ends strategy dictates that the second move should also be multiplication since this leads directly to the goal (315). A history-cued strategy dictates that it should be subtraction since, according to this strategy, moves are generated by previous moves rather than by differences between a given problem state and the goal, with a learned rule providing a template. The template for the first two moves in this case is "× − ." Using this criterion, group H/2a/4a/4a/6a/10a/2c is using means-ends analysis. The difference between groups using multiplication on their second move is significant using a Fisher exact probability test, $p < .05$. This contrast also clearly exemplifies the possible negative consquences of rule induction.

A similar contrast between groups H/2a/4a/4a/6a/2c and M/2a/4a/4a/6a/2c yields similar but, as would be expected, reduced effects. The difference between means is not as massive, although this is partly due to two subjects in group M/2a/4a/4a/6a/2c requiring more than two moves to solve problem 2c. Nevertheless, the fact that only 7 out of the 12 subjects in group H/2a/4a/4a/6a/2c began problem 2c by testing an alternation rule was a major factor in reducing this effect. The omission of problem 10a has reduced the extent of rule induction. The difference between means is, nevertheless, significant.

Using our criterion based on the second move being multiplication, all group 2c subjects used a means-ends approach. Einstellung (see Luchins, 1942) is not demonstrated by comparing means-ends groups to group 2c. On the other hand, a similar comparison using the history-cued groups clearly demonstrates the effect.

These findings are consistent with those obtained by Levine (1971) and Fingerman and Levine (1974). In their experiments, a powerful Einstellung effect was demonstrated. The vast majority of subjects were unable to solve a simple, critical problem within 100 trials. There is nevertheless a contrast in that all subjects in groups H/2a/4a/4a/6a/10a/2c and H/2a/4a/4a/6a/2c eventually solved problem 2c. The explanation is that after 10 moves subjects were informed, as they were for the previous problem, that the sequence of moves made so far would not allow them to solve the problem in the least number of moves and that they would be taken back to the initial number to try again. It might be noted, nevertheless, that a number of subjects tried the alternation sequence a number of times, despite being given this information and being taken back to the start point a number of times.

With respect to problem 10a, analysis of variance indicated a significant difference between the three groups administered this problem, $F(2, 33) = 14.826$, $p < .05$. The means-ends group is again closer to the control than to the history-cued group. In this case, the history-cued group demonstrates positive transfer rather than the negative transfer obtained using problem 2c. It needs to be noted that these differences are based on scores that include subjects who did not solve problem 10a within 600 sec. There were 0, 4, and 7 such subjects in groups H/2a/4a/4a/6a/10a/2c, M/2a/4a/4a/6a/10a/2c, and

10a respectively. The effect of these subjects is to substantially *reduce* differences between groups. If we make the assumption that all nonsolvers could eventually solve the problems given sufficient time, then the means of groups M/2a/4a/4a/6a/10a/2c and 10a would be increased while group H/2a/4a/4a/6a/10a/2c would remain constant since it had no nonsolvers. Specifically, the large difference between the history-cued and means-ends groups is underestimated by the inclusion of nonsolvers with artificially depressed scores. The difference between the means-ends and control group is, of course, also underestimated by this technique, since there were more nonsolvers in the control group.

The difference between groups H/2a/4a/4a/6a/10a/2c and M/2a/4a/4a/6a/10a/2c is predicted. Rule induction should result in group H/2a/4a/4a/6a/10a/2c testing the alternation hypothesis and thus solving problem 10a rapidly. Evidence of this occurrence is provided by inspection of the sequence of moves made by subjects in this group. Of the 12 subjects, 9 used alternation immediately and consequently solved the problem in the minimum of 10 moves. In contrast, only one group M/2a/4a/4a/6a/10a/2c subject solved problem 10c in 10 moves. This difference is significant using a Fisher exact probability test, $p < .05$.

This measure may also be used as an indicator of subjects' strategies, although the evidence may be somewhat ambiguous compared to that obtained using problem 2c. A history-cued approach based on the $\times$ $-$ rule should result in solution in the minimum number of moves. One would not expect a means-ends strategy to result in a perfect solution due to the large number of moves required. It is nevertheless possible. The nine group H/2a/4a/4a/6a/10a/2c subjects who solved problem 10a in the minimum number of moves could have been using a means-ends approach leading to alternation. Nevertheless, the fact that these subjects (and one additional subject) were unambiguously using a history-cued approach on the following problem (problem 2c) makes this improbable. Since we know a history-cued strategy should lead to alternation in the present context, while means-ends analysis is less likely to do so, the different strategies probably explain these results. It might also be noted that group 10a subjects, who could not have been using a history-cued strategy (this group had no history of prior problems), all required more than 10 moves to solve the problem.

The difference between groups H/2a/4a/4a/6a/10a/2c and 10a is also predicted due to rule induction by group H/2a/4a/4a/6a/10a/2c. This difference is an indicator of the sequence effect (see Sweller &

Gee, 1978). An analogous difference between groups M/2a/4a/4a/6a/10a/2c and 10a was not predicted nor obtained using moves to solution as a dependent variable, although, as pointed out previously, the inclusion of nonsolvers with artificially depressed scores probably reduced the size of this difference.

The results indicate the importance of problem-solving strategy in transfer. Alteration from a means-ends to a history-cued strategy resulted in large performance changes on transfer tasks. Previous results (see Sweller, 1980b; Sweller & Gee, 1978) have indicated simultaneous positive and negative transfer. The present results suggest that this may be only obtainable on tasks in which a history-cued strategy is used. Less transfer, probably due to reduced rule induction, was observed on problems in which a history-cued approach was not encouraged.

EXPERIMENTS 2 AND 3

The comparative lack of transfer due to failure to induce a rule by groups using a means-ends approach constitutes a primary finding of Experiment 1. The results of groups M/2a/4a/4a/6a/10a/2c and M/2a/4a/4a/6a/2c suggest that on this type of problem a history-cued approach resulting in rule induction will not be obtained simply by presenting subjects with a limited number of problems potentially soluble by a simple rule. The goal-oriented strategy automatically adopted by subjects apparently prevents rule induction. The possibility remains, nevertheless, that after a sufficient number of problems subjects will cease to use goal-generated moves and switch to rule-generated moves. This may occur even if the task has no other features designed to encourage a history-cued strategy. Practice alone may be sufficient to induce a switch from a means-ends to a history-cued strategy. We know that practice improves performance in most contexts. In the present context, it may do so by altering problem solvers' strategy from an initial means-ends to a subsequent history-cued approach. Where subsequent problems are correctly perceived as requiring the learned construct acquired through a history-cued approach, solution may be greatly facilitated. The same process would retard solution where subsequent problems are incorrectly perceived as requiring the learned construct. Evidence of a change in strategy due to expertise comes from Simon and Simon (1978). They found novice problem solvers used conventional means-ends analysis when solving physics problems while an expert used a "forward"-oriented approach — generating equations from the givens and virtually ignoring the goal. This closely resembles a history-cued approach. While the change in strategy from novice to expert may involve more than practice, it should nevertheless be useful to see if practice alone can alter strategies in the present context. Experiments 2 and 3 tested this possibility by vastly increasing the number of problems presented before the critical problems.

Subjects in Experiment 2 were presented with 14 preliminary problems soluble by an alternation rule. No information was presented to induce a history-cued strategy. Experiment 3 required the solution of five preliminary problems, with each problem repeated two or three times, giving a total of 14 preliminary problems. The preliminary problems were followed by the same two critical problems as used in Experiment 1. Evidence of a history-cued strategy resulting in rule induction can be obtained by analyzing the move sequences used by subjects.

METHOD

Subjects

The subjects were 28 University of New South Wales undergraduates; 14 subjects were used in each experiment.

Apparatus and procedure

The procedure was similar to that used in Experiment 1. Subjects were given the same information during the experiment as the means-ends strategy groups were given in Experiment 1; after successfully solving a problem, the screen was cleared and the next problem was presented.

Table 3 gives the initial numbers, final numbers and solutions for each of the 16 problems used in the two experiments. It might be noted that groups H/2a/4a/4a/6a/10a/2c and M/2a/4a/4a/6a/10a/2c of Experiment 1 required a total of 16 moves to solve their preliminary problems in the minimum number of moves possible (2 + 4 + 4 + 6). The equivalent figures for Experiments 2 and 3 are 50 and 64 respectively.

RESULTS AND DISCUSSION

Experiment 2

Four of the 14 subjects solved problem 10a in the minimum number of steps. Two subjects failed to solve the problem within 10 min.

On problem 2c, 10 of the 14 subjects solved it in the minimum of two moves. The remaining four subjects used the alternation pattern,

Table 3. Problems used in Experiments 2 and 3

Problem	Initial number	Final number	Solution (× = × 3, – = – 60)
2a (1)	39	48	× –
2a (2)	120	291	× –
2a (3)	24	3	× –
2a (4)	147	372	× –
2a (5)	70	141	× –
2a (6) *2	60	111	× –
4a (1)	72	372	× – × –
4a (2)	44	120	× – × –
4a (3)	37	57	× – × –
4a (4) *3	31	3	× – × –
4a (5) *3	81	453	× – × –
6a (1) *3	42	237	× – × – × –
6a (2)	47	372	× – × – × –
6a (3) *3	34	21	× – × – × –
10a *1	35	156	× – × – × –
			× – × –
2c *1	35	315	× ×

* The number following the asterisk indicates the number of times the problem was repeated in Experiment 3.

× –, on the first two moves and took from 9 to 22 moves to solve the problem, hence indicating rule induction. One of these subjects had previously solved problem 10a in the minimum of 10 moves.

While there is some evidence of moves being generated by a sequence of previous moves, most subjects appear to have retained a means-ends strategy. Strong evidence for use of the alternation rule was obtained for only one subject on both problems 10a and 2c.

Experiment 3

Experiment 3 increased the number of moves necessary to solve the preliminary problems in the hope that increased practice would increase the number of subjects adopting a history-cued rule-induction strategy. The increase in number of moves was accomplished by requiring subjects to solve each problem a number of times. It can also be argued that by repeating the same problem a number of times, subjects might attempt to memorize previous solutions, become aware of the alternation rule, and use it to solve subsequent problems, thus avoiding a means-ends, goal-directed strategy.

Of the 14 subjects, 4 solved problem 10a in the minimum of 10 steps (1 failed to solve it); 8 of 14 solved problem 2c in the minimum of 2 moves. The remaining 6 subjects took from 12 to 26 moves to solve the 2-move problem. Three of these six subjects had solved the previous problem, 10a, in the minimum number of moves. Despite a large amount of practice, the number of subjects providing unequivocal evidence of using the rule is still fairly low.

The results of Experiments 2 and 3 indicate that considerable practice and practice with repetition did lead to rule induction, but only by a minority of subjects. The presence of a goal has a powerful effect, inducing most subjects to persist with a means-ends strategy, and this in turn appears to prevent rule induction. Egan and Greeno (1974) observed in Tower-of-Hanoi problems that subjects tend to automatically adopt a goal-directed strategy, and thus attempts at emphasizing the sequential pattern in the problem were largely unsuccessful (p. 93). Of course, many more problems and/or repetitions might ensure greater success. In this respect, it should be noted that Experiments 2 and 3 do provide more evidence of a history-cued strategy being used by some subjects as a result of increased practice than that obtained in Experiment 1 on group M/2a/4a/4a/6a/10a/2c, and differences in number of subjects attempting to use alternation on problem 2c are significant, $\chi^2(2) = 6.48, p < .05$. Smaller differences in number of subjects using alternation were obtained using problem 10a, $\chi^2(2) = 1.97, p > .05$. (Yates correction was not used in either analysis. It might be noted that its use eliminates the significant effect found on problem 2c, $\chi^2(2) = 4.29, p > .05$.)

EXPERIMENT 4

The limited evidence of rule induction in Experiments 2 and 3 led to tests of alternative procedures that might cause subjects to abandon their goal directed strategies and adopt a history-cued strategy. There are several methods other than that used in Experiment 1 that could be expected to induce a history-cued strategy. Experiment 4 tested some of these.

Group 4afm/10afm(*2)/4a/10a/2c was directed towards a history-cued strategy by a variation of the methods used in Experiment 1—subjects were required to memorize previously correct moves. Four preliminary problems were presented before the critical problems, 10a and 2c. The group name provides the key to the characteristics of each problem. Terms are identical to those used in Experiment 1 with two additions. The term "f" refers to feedback and indicates that a correction procedure was used. An incorrect move (one that deviated from alternation) was immediately signaled to the subject and had to be replaced with the correct step. The term "m" indicates a memory requirement. After each move, subjects were asked to reproduce the sequence of previous correct moves. The term 10afm(*2) indicates that two problems with the characteristics 10afm were presented in succession.

It can thus be seen that group 4afm/10afm(*2)/4a/10a/2c was presented with a 4-move problem incorporating alternation for solution, feedback after each move, and memorization of previous steps. This was followed by two 10-move problems with the same requirements. A 4-move problem requiring alternation was then presented followed by two critical problems similar to those used to test for transfer in previous experiments. It should be noted that problem 4a was interpolated in order to reduce the perceptual disparity between the preliminary problems and the critical problems. Sweller and Gee (1978) found reduced transfer effects unless subjects perceived subsequent problems as being similar to previous ones. We predict that the requirement to memorize previous correct moves will induce subjects to use a history-cued strategy resulting in rule induction. Further moves will then be generated by the rule rather than by the goal, which in turn will facilitate transfer effects.

Group 10af(*5)/10a/2c was presented with five preliminary 10-move problems, with each incorporating the feedback-correction procedure. This type of problem partially resembles the conventional concept or rule-learning paradigm in which subjects are informed whether each response is correct or incorrect and the rule can only be induced by a history-cued strategy in which features are extracted from the feedback to previous responses. Hence it is possible that subjects in this group would be directed to a history-cued strategy by feedback as occurs in concept learning despite the possibility of using goal-directed strategy. This could be expected to lead to discovery of the alternation rule leading to the positive and negative transfer effects observed in Experiment 1.

Group 10as(*5)/10a/2c subjects were given subgoals (s = subgoals) by being informed of the number they had to attain after every three moves. It needs to be noted that the use of subgoals in this fashion bears some similarity to a correction procedure as used by group 10af(*5)/10a/2c. The primary difference is that subjects are informed, in effect, that an error has occurred somewhere in the preceding three moves rather than after every move. Hence it is possible that the use of subgoals in this manner will also enhance transfer, although one would not expect any effects to be as strong as those generated by a full correction procedure.

Group 10a/2c was a control group presented with problems 10a and 2c only. Unlike Experiment 1, a separate control group was not used for problem 2c on the assumption that problem 10a would have a minimal influence on solution of problem 2c.

METHOD

Subjects

The subjects were 40 University of New South Wales undergraduates, divided into four groups of 10 subjects each.

Apparatus and procedure

The basic procedure was similar to the previous experiments with the initial instructions as given previously. All groups received the same final two problems. See Table 4 for the preliminary and critical problems.

Group 4afm/10afm(*2)/4a/10a/2c subjects, in addition to this procedure, were given the following instruction to read: "You will be given the following instruction after each move on some of the problems: Using the × and − keys only, type in the correct sequence of moves carried out so far. If, for example, 3 moves have been made so far, all using the − key, you should type in − − −. Do not press the return key until the entire sequence is entered. You will be informed each time you make an incorrect move."

Table 4. Problems used in Experiment 4

Problem	Initial number	Final number	Solution (× = × 3, − = − 60)
* 4a	81	453	× − × −
10a (1)	41	1614	× − × − × − × − × −
10a (2)	40	1371	× − × − × − × − × −
10a (3)	39	1128	× − × − × − × − × −
* 10a (4)	38	885	× − × − × − × − × −
* 10a (5)	37	642	× − × − × − × − × −
* 4a	79	435	× − × −
10a	36	399	× − × − × − × − × −
2c	35	315	× ×

* An asterisk indicates the problems used in group 4afm/10afm (*2)4a/10a/2c. The five 10a problems followed by the two critical problems 10a and 2c were used in groups 10af(*5)10a/2c and 10as(*5)10a/2c.

For the first three problems, feedback was used after each step, in that after incorrect moves a message was screened informing subjects that the move was incorrect and that it was being cancelled. The correct step then had to be entered.

After each correct move on the first three problems (whether preceded by an incorrect move or not), subjects were required to type in the sequence of correct moves made to that point. The instruction screened was as above. If they deviated from the appropriate alternation sequence to that point during this memory test, they were returned to the initial number and had to begin the problem again.

Group 10af(*5)/10a/2c subjects were given the feedback correction procedure only on their first five problems. They were not required to memorize their previous moves.

Group 10as(*5)/10a/2c was given the three subgoal numbers that they had to reach on the third, sixth, and ninth moves, respectively. These subgoals for each preliminary problem were typed on sheets of paper and handed to each subject at the commencement of the experiment. Subjects were given instructions, by the experimenter, on how to use them.

Group 10a/2c, the control group, was given the critical problems only. These were identical for all four groups and did not involve feedback, memory, or subgoals. It might be noted with respect to problem 2c that whereas in the previous experiments subjects could not pursue an incorrect sequence of moves for more than 10 moves before being returned to the initial number, in the present experiment this was increased to 20 moves.

RESULTS AND DISCUSSION

As in Experiment 1, all analyses were performed on logarithmic transformed data, and analyses involving moves are reported only, except where conclusions based on sec to solution might differ from those based on moves. The relevant means may be found in Table 5.

Analysis of variance indicated a significant difference between groups on problem 10a, $F(3, 36) = 6.83$, $p < .05$. Duncan range tests at the .05 level of significance indicated positive transfer by all experimental groups compared to the control group.

With respect to problem 2c, analysis of variance indicated a significant difference between the four groups, $F(3, 36) = 6.28$, $p < .05$. Duncan range tests (.05 level) indicated the same differences as reported above, except that the relation between means was reversed, viz., negative transfer by all experimental groups compared to the control group. (Using sec to solution on problem 2c, the four groups failed to reach significance, $F(3, 36) = 2.35$, $p = .088$.

The pattern of moves followed by each subject on the critical problems is again instructive in providing some evidence of subject

Table 5. Mean moves and seconds to solution on problems 10a and 2c of Experiment 4

	Problem 10a		Problem 2c	
Group	Moves	Sec	Moves	Sec
4afm/10afm(*2)/4a/10a/2c	31.5 (1.24)$_a$	152 (1.87)$_a$	28.2 (1.31)$_a$	133 (1.98)$_a$
10af(*5)/10a/2c	23.0 (1.20)$_a$	123 (1.77)$_a$	24.4 (1.22)$_a$	140 (1.88)$_a$
10as(*5)/10a/2c	38.1 (1.40)$_a$	276 (2.13)$_a$	30.6 (1.15)$_a$	157 (1.89)$_a$
10a/2c	76.7 (1.86)$_b$	538 (2.72)$_b$	4.6 (.46)$_b$	46 (1.45)$_a$

Note. Means based on logarithmic transformations are in parentheses. For any given column, a shared subscript indicates no significant difference between means.

strategy and of rule induction. For groups 4afm/10afm(*2)/4a/10a/2c, 10af(*5)/10a/2c, and 10as(*5)½10a/2c, the number of subjects who used an alternation rule throughout problem 10a and hence solved it in the minimum of 10 moves was 7, 7, and 5, respectively. This contrasts with group 10a/2c, which had no subjects employing move alternation on the first 10 moves and had five subjects who failed to solve the problem within 600 sec. No group 10af(*5)/10a/2c subjects and only one subject in both of groups 4afm/10afm(*2)/4a/10a/2c and 10as(*5)/10a/2c failed to solve this problem. The reduction in the number of subjects failing to solve this problem further indicates the advantages of a history-cued strategy on some complex problems.

Further evidence of rule induction in the three experimental groups comes from the pattern of moves on problem 2c. On the first two moves of this problem (which only requires two moves for solution), nine group 4afm/10afm(*2)/4a/10a/2c subjects, eight group 10af(*5)/10a/2c subjects, and seven group 10as(*5)/10a/2c subjects used alternation. For these subjects, the second move was presumably generated by a process other than means-ends analysis. Only two group 10a/2c subjects used alternation on the first two moves of this problem. The remaining eight solved the problem in two moves. (The small increase in move-alternation behavior for all groups from problem 10a to problem 2c was caused by a few subjects inducing the rule during solution of problem 10a and attempting to employ it on problem 2c).

This experiment has indicated that three procedures specifically designed to induce subjects to employ a history-cued strategy resulted in rule induction and transfer. This contrasts with the results of Experiments 2 and 3, in which fewer subjects used the alternation rule to generate moves, preferring to use a means-ends strategy with moves generated by the perceived relation between the goal and any given problem state. It needs to be noted that the group bearing the greatest resemblance to those used in Experiment 2 and 3, group 10as(*5)/-10a/2c, also had the fewest subjects able to induce the rule.

EXPERIMENT 5

The previous experiments have indicated some prerequisites for transfer during problem solving. Transfer was minimal except under conditions strongly encouraging a history-cued strategy resulting in rule induction. It might thus be expected that if rule induction rather than hybrid problems were used, transfer would be inevitable. In fact, Sweller and Gee (1978) indicated that with respect to Einstellung, the occurrence of the phenomenon was strongly influenced by problem solvers' perception of the relation between problems. Despite using rule-induction problems, Einstellung could be abolished by minor alterations to conditions, which resulted in a reduction of subjects' perception that successive problems were related. The following experiments were intended to test whether the same effect influences another phenomenon—the insoluble problem effect. This occurs when people who have experienced insoluble problems have difficulty solving subsequent similar tasks. Since the previous experiments indicated the importance of a history-cued strategy to transfer, rule-induction problems that allow no other strategy were used.

There have been several demonstrations of the insoluble problem effect. Levine (1962) demonstrated the phenomenon using a two-dimensional discrimination problem. Subjects were given random feedback for a varying number of initial trials before continuing, without break, with correct or contingent feedback. Thus they initially experienced an insoluble problem before continuing with an identical, but soluble problem. Results demonstrated that after as few as four random feedback trials, subjects showed significant interference with subsequent learning when compared to controls. Similar results were obtained by Holstein and Premack (1965) and by Mandler, Cowan, and Gold (1964). More recently, experimenters have used a similar design with similar effects when studying learned helplessness (e.g., see Tiggemann & Winefield, 1978).

Levine (1975) has explained such effects in terms of hypothesis theory. Sweller and Gee (1978) made modifications to this theory to explain the relation between Einstellung (Luchins, 1942) and the sequence effect (Hull, 1920). Sweller (1980b) used this modified theory to provide a general explanation of both positive and negative transfer during problem solving involving rule-induction problems. This modified theory has three basic assumptions:

1. When subjects perceive a series of problems as being related, they tend to begin each problem by testing hypotheses as closely related to their previous (usually correct) hypothesis as possible. This tendency increases with increases in the number of previous, successful, similar problems.

2. A conspicuous or salient hypothesis will initially be tested by naive subjects. A simple problem is one that is solved by a salient hypothesis. A difficult problem is solved by an obscure hypothesis. The degree of salience of a hypothesis is determined by the number of hypotheses related to it—a salient hypothesis having few, similar related hypotheses; an obscure hypothesis, many.

3. Where assumption 1 and assumption 2 make conflicting predictions, assumption 1 will override assumption 2. A problem requiring a highly salient hypothesis will not be solved quickly if it is preceded by problems that are perceived as being closely related but that require hypotheses unrelated to the highly salient one.

With respect to the insoluble problem effect, subjects presented with an insoluble problem initially test salient hypotheses or rules and then move to more obscure ones when these are discounted. When another problem, perceived as being closely related to the initial insoluble one, is presented, subjects will continue to test the previous, obscure hypotheses and will have to test many related hypotheses before discovering the solution, thus demonstrating a retardation of learning; in comparison, subjects who have not had the prior experience of an insoluble problem will test fewer hypotheses.

A most important aspect of these three assumptions for the transfer of learning between problems is the perceived relationship between the problems. Sweller and Gee (1978) demonstrated that minor alterations to subjects' perception of similarity eliminated Einstellung. Transfer effects only operated when subjects perceive the problems as related.

In the previous experiments demonstrating the insoluble problem effect (Holstein & Premack, 1965; Levine, 1962; Mandler, Cowan, & Gold, 1964), subjects moved from an insoluble to a soluble problem without change of stimuli, instructions, type of feedback, or type of response required. Without the subjects' knowledge, feedback became contingent rather than given randomly. Consequently, subjects presumably perceived the problems as identical. However, it is possible that this extremely robust insoluble problem effect may be eliminated just as Einstellung was by changing subjects' perceptions of the relations between problems. The following experiments investigated this possibility. In Experiment 5 we attempted to alter problem solvers' perception of the relation between tasks by altering task instructions or altering the types of problems used.

METHOD

Subjects

Participants were 80 year-11 students (mean age 16.03 years) from four high schools in two New South Wales country towns (Goulburn and Bowral).

Apparatus and procedure

There were 116 file cards, 15.5 cm × 9.5 cm with the letters A and B typed on them in uppercase, 5 cm apart. Half the card had the letter A typed on the left-hand side and B on the right-hand side; the position of A and B was reversed on the other half (similar to Levine, 1971). These were randomly arranged in a stack with the exception that not more than two consecutive cards were identical. The arrangement of cards remained constant for all students on all problems.

There were also 15 similar file cards with two numbers typed on them 5 cms apart. The numbers varied from 0 to 9. These cards were randomly arranged in a stack. The arrangement of cards remained constant for all students in all problems.

There were two problems. A letter-discrimination problem involved subjects looking at the letter cards and saying which letter they thought correct. A number problem involved subjects looking at the number cards and saying another number they thought correct. Feedback was given as either "correct" or "wrong" in accordance with one dimension of the problem or in accordance with a prearranged random schedule. All subjects were instructed to get as many correct as possible.

There were 16 subjects in each of five groups.

For group "continuous," the letter cards were arranged in one stack. Subjects were given 15 trials of a letter-discrimination problem with noncontingent feedback (insoluble problem) given in accordance with a prearranged schedule consisting of seven correct and eight incorrect responses. They then continued without a break or an announcement from the experimenter to a problem in which feedback was given according to the simple rule "A is always correct" (or for half the subjects "B is always correct").

For group "another," the letter cards were arranged in two stacks. The first stack consisted of the first 15 cards presented to group continuous with the other stack consisting of the remaining cards. Using the first stack, subjects were given 15 trials of a letter-discrimination problem with noncontingent feedback. They were then told "here is another problem" and switched to the second stack. Feedback was given in accordance with the A-B rule.

Group "different" proceeded as for group another with the exception that after the first 15 trials, subjects were told "here is another, different, unrelated problem."

For group "numbers," the number cards were arranged in one stack and the letter cards, from 16 onwards, in another. Subjects were given 15 trials of the number problem with noncontingent feedback. They then proceeded with the letter-discrimination problem, as above, with contingent feedback.

We expect subjects' perception of similarity between the insoluble and soluble problem to fall in the order continuous, another, different, numbers, resulting in maximum negative transfer for group continuous.

For the control group, the letter cards, from 16 onwards, were arranged in one stack. Subjects only received the simple discrimination problem with contingent feedback.

RESULTS AND DISCUSSION

Mean trials to last error for each of the five groups is given in Table 6. A significant difference between groups was found, $F(4, 75) = 3.94$.

As indicated by a Duncan range test (Table 6), the insoluble problem effect has been demonstrated when the continuous and another groups are compared to controls. Experience of an insoluble problem followed by a problem perceived as identical or closely related has resulted in a performance decrement. The effect was reduced when subjects perceived the two tasks as dissimilar. It might be noted that groups continuous, another, and different were given identical problems. The only distinction between the groups concerned statements separating the two problems. This, nevertheless, was sufficient to

Table 6. Mean trial to last error on Experiment 5

Continuous	Another	Different	Numbers	Control
17.125_{a}	13.563_{ab}	12.063_{abc}	8.563_{bc}	6.625_{c}

Note. A shared subscript indicates no significant difference between means.

reduce the insoluble problem effect in the case of group another and eliminate a statistical effect in the case of group different. It might also be noted that we can predict the order in which the group means fall. The greater the presumed similarity between the tasks, the longer it should take to solve the final problem. The group means are, in fact, in the predicted order (continuous > another > different > numbers > controls). The probability of obtaining the above order by chance is 1/5! = .008.

EXPERIMENT 6

Experiment 6 replicated Experiment 5 and investigated the effects of the type of feedback on perceived similarity between tasks. Sweller and Gee (1978) found that on an A-B discrimination problem, feedback of the correct answer (A or B) to a problem, rather than "correct" or "wrong," eliminated Einstellung by introducing a perceptual disparity between problems. This occurred despite the fact that in a two-choice task either mode of feedback provides identical information. It was suggested that on a critical problem in which A was the correct response the change in the solution rule became more obvious when feedback consisted of a long string of As rather than a correct/wrong mixture. We can hypothesize that the insoluble problem effect is similarly affected. The use of A-B feedback rather than correct/wrong may reduce or eliminate the effect. A lower age group than that used in Experiment 1 was employed in order to test the generality of the previous results.

METHOD

Subjects

Participants were 100 year-3 students, mean age 8.05 years, from three elementary schools in a New South Wales country town (Goulburn).

Apparatus and procedure

The materials used were identical to those used in Experiment 1.

There was a total of 10 groups with 10 subjects in each. The procedures for five of the groups (CW groups, where CW stands for correct/wrong) were similar to those of the five groups of Experiment 1. The remaining five groups differed only in that rather than being told "correct" or "wrong" after each response, the experimenter said the correct response. These are labeled the AB groups, since their feedback consisted of A or B.

All subjects were given the following pretest experience in order to familiarize them with problem solving procedures.

The numbers from 1 to 12 were written across a page in front of the children and the numbers 2, 4, 6, and 8 circled. Subjects were asked to circle the next number in the sequence. Once done, subjects were asked how they obtained the correct answer. Subjects' attention was drawn to the pattern of "counting by 2s" and the rule "circle even numbers;" they were also told that during the experiment they would be required to notice a pattern and discover the rule that would allow them to solve the problems given in subsequent trials.

Subjects in the CW groups were required to write their answer followed by a tick or a cross, representing positive or negative feedback respectively. The AB groups followed a similar procedure except that following their answers, they were required to write A, B, or a number identical to the feedback given.

RESULTS AND DISCUSSION

Mean trials to last error for each of the ten groups are given in Table 7. A significant difference between groups was found $F(9, 90) = 2.676$, $p < .05$. As indicated by a Duncan range test, the insoluble problem effect has been demonstrated using group CW-continuous as the experimental group. An insoluble problem followed by an initially indistinguishable soluble one resulted in a substantial performance decrement on the latter problem. No other differences are significant, despite substantial differences in means. The reduction of effect due to the use of AB rather than correct/wrong was as predicted. Nevertheless, the means of the AB groups decrease from continuous to another to different to numbers to controls as we would predict assuming perceptual effects. This indicates that while a significant insoluble problem effect has not been obtained, differences due to perceptual effects have not been totally eliminated. This order is not obtained for the CW groups, where group CW-numbers does not fall within the predicted pattern. There is no obvious explanation for the high score of this group, and at present it

Table 7. Mean trial to last error on Experiment 6

	Continuous	Another	Different	Numbers	Control
CW (correct/wrong)	30.00_a	14.80_b	12.00_b	15.10_b	5.20_b
AB (correct response)	14.60_b	13.80_b	11.80_b	8.30_b	6.60_b
CW + AB	22.30	14.30	11.90	11.70	5.90

Note. A shared subscript indicates no significant difference between means.

can only be attributed to chance. It might be noted that the combined CW and AB means do fall in the predicted order.

Groups continuous, another, and different under both CW and AB conditions are again of particular interest since the same problems are used in all six groups. The reduction from group CW-continuous to the other groups is large and statistically significant and provides strong evidence of the effects that perception of the relation between problems can have on transfer. The use of statements interspersed between problems or alteration of feedback has reduced transfer effects. The reduction appears to be systematic in that the order of means is as predicted. The combined probability of obtaining the predicted order for both the three CW groups and three AB groups is $(1/3!)(1/3!) = .028$.

The results of Experiments 5 and 6 extend the findings of Sweller and Gee (1978) and Sweller (1980b) and indicate that even with the use of rule induction problems, transfer effects can be readily eliminated. The insoluble problem effect, like Einstellung, is mediated by subjects' perceptions of the similarity between tasks. When subjects perceive tasks as related, these transfer effects are more likely to operate; when subjects do not perceive a relationship, these effects are less likely to. A change to instructions (e.g., "Here is another problem"), stimuli (e.g., from a number problem to a letter problem), or information conveyed by feedback (the correct answer rather than "correct" or "wrong") all affect subjects' perceptions of task similarity. If the insoluble and soluble tasks are treated as unrelated problems, subjects are less likely to continue testing their previous, obscure hypotheses or rules, but rather, like naive subjects, test simple, salient hypotheses.

GENERAL DISCUSSION

We began this paper by pointing out that there are differences concerning the mechanisms by which people might benefit or gain knowledge from previous experience on problem-solving tasks. Our results indicate, first, that orientation to the problem is strongly determined by the problem structure and that in hybrid problems, soluble either by a history-cued or means-ends strategy, a history-cued strategy will result in greater positive transfer to problems soluble by a similar rule. In so far as this transfer indicates expertise or knowledge of the problem structure, use of a history-cued strategy will result in more rapid acquisition of knowledge. (This should not be taken as evidence that a means-ends strategy cannot result in useful knowledge concerning the problem structure.) It must, of course, be noted that in the case of a problem not soluble by the rule revealed by the history-cued strategy, a means-ends strategy proved superior.

A means-ends strategy appeared to be the "natural" strategy, in that it was automatically adopted unless specific structures were added to the problem-solving context. Given the likelihood that the strategy will be employed, it is of some interest that it appears to reduce both positive and negative transfer effects. Indeed, we know of no clear examples of negative transfer other than on rule-induction or hybrid problems that are solved by a history-cued strategy. Rule induction seems, at best, difficult using a means-ends strategy.

Our second set of findings concern factors affecting transfer under conditions where a conventional means-ends strategy is not possible and a history-cued, rule-induction strategy is necessary. We found that transfer as indicated by the occurrence of the insoluble problem effect will not occur even on rule-induction problems unless conditions are such as to clearly indicate to problem solvers that problems are closely related.

The simultaneous positive and negative transfer effects that can result from rule induction imply that, at least under some circumstances, rules can be characterized as having a narrowing and deepening effect. The narrowing effect is exemplified by the difficulty people have solving problems requiring hypotheses different from those previously used. These subjects demonstrate a lack of flexibility when attempting to solve problems bearing a superficial similarity to previously solved problems. Their choice of possible solutions is greatly narrowed compared to subjects who have not induced a rule on previous problems. The simultaneous deepening effect caused by rule induction is exemplified by the ease with which people who have induced a rule are able to solve immensely complex problems. People who have not induced the rule may find the same problem insoluble. While rule use may involve "mechanical" solution, this may be the only feasible method of solution by humans on some problems. Our results suggest that whether this narrowing and deepening effect occurs may depend on whether people have history-cued or means-ends problem-solving strategies.

Notes

This research was supported by grants to John Sweller by the Australian Research Grants Committee and by the Special Projects Grant of the University of New South Wales. The authors wish to thank Marvin Levine for extensive discussions and comments on an earlier draft of this paper. Thanks are also due to Eric Zeppenfeld for computer programming assistance.

Requests for offprints should be directed to John Sweller, School of Education, University of New South Wales, P.O. Box 1, Kensington, Australia, 2033. Received for publication July 6, 1981; revision received January 4, 1982.

References

Anzai, Y., & Simon, H. A. The theory of learning by doing. *Psychological Review,* 1979, *86,* 124–140.

Egan, D. E., & Greeno, J. G. Theory of rule induction: knowledge acquired in concept learning, serial pattern learning, and problem solving. In L. W. Gregg (Ed.), *Knowledge and cognition.* Baltimore, Md.: Erlbaum, 1974.

Fingerman, P., & Levine, M. Non-learning: The completeness of the blindness. *Journal of Experimental Psychology,* 1974, *102,* 720–721.

Greeno, J. G. Natures of problem solving abilities. In W. K. Estes (Ed.) *Handbook of learning and cognitive processes,* (Vol. 5). Hillsdale, N.J.: Erlbaum, 1978, 239–270.

Greeno, J. G., Magone, M. E., & Chaiklin, S. Theory of constructions and set in problem solving. *Memory and Cognition,* 1979, *7,* 445–461.

Holstein, S. B., & Premack, D. On the different effects of random reinforcement and presolution reversal on human concept identification. *Journal of Experimental Psychology,* 1965, *70,* 335–337.

Hull. C. L. Quantitive aspects of the evolution of concepts. *Psychological Monographs,* 1920, *28,* No. 123.

Larkin, J., McDermott, J., Simon, D. P., & Simon, H. A. Expert and novice performance in solving physics problems. *Science,* 1980, *208,* 1335–1342.

Levine, M. Cue neutralization: The effects of random reinforcement upon discrimination learning. *Journal of Experimental Psychology,* 1962, *63,* 438–443.

Levine, M. Hypothesis theory and nonlearning despite ideal S-R reinforcement contingencies. *Psychological Review,* 1971, *78,* 130–140.

Levine, M. *A cognitive theory of learning: Research on hypothesis testing.* Hillsdale, N.J.: Erlbaum, 1975.

Luchins, A. A. Mechanisation in problem solving: The effects of Einstellung. *Psychological Monographs,* 1942, *54,* No. 248.

Mandler, G., Cowan, P. A., & Gold, C. Concept learning and probability matching. *Journal of Experimental Psychology,* 1964, *67,* 514–522.

Newell, A., & Simon, H. A. *Human problem solving.* Englewood Cliffs, N.J.: Prentice-Hall, 1972.

Simon, H. A., & Lea, G. Problem solving and rule induction: A unified view. In L. W. Gregg (Ed.), *Knowledge and Cognition.* Baltimore, Md.: Erlbaum, 1974.

Simon, H. A., & Reed, S. K. Modeling strategy shifts in a problem-solving task. *Cognitive Psychology,* 1976, *8,* 86-97.

Simon, D. P., & Simon, H. A. *Individual Differences in Solving Physics Problems.* In R. S. Siegler (Ed.), *Children's thinking: What develops?* Hillsdale, N.J.: Erlbaum, 1978.

Sweller, J. The effect of task complexity and sequence on rule learning and problem solving. *British Journal of Psychology,* 1976, *67,* 553-558.

Sweller, J. Hypothesis salience, task difficulty, and sequential effects on problem-solving tasks. *American Journal of Psychology,* 1980, *93,* 135-145. (a)

Sweller, J. Transfer effects in a problem solving context. *Quarterly Journal of Experimental Psychology,* 1980, *32,* 233-239. (b)

Sweller, J. & Gee, W. Einstellung, the sequence effect, and Hypothesis Theory. *Journal of Experimental Psychology: Human Learning and Memory,* 1978, *4,* 513-526.

Tiggemann, M., & Winefield, A. H. Situational similarity and the generalizations of learned helplessness. *Quarterly Journal of Experimental Psychology,* 1978, *30,* 725-735.