THE EFFECTS OF SOLUTION FEEDBACK, STRATEGY EFFICIENCY, AND INTERRUPTION OF PROBLEM SOLVING ACTIVITY ON EINSTELLUNG

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by

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A Thesis submitted in partial fulfillment
of the requirements for a degree of
Master of Science

Department of Psychology
Memorial University of Newfoundland
December 1983

St. John's Newfoundland

Abstract

The present study was designed to investigate the effects of solution feedback and interrupting problem solving activity on breaking set. Individual differences analyses indicated that subjects who used an efficient problem solving strategy were likey to break set. Twelve concept attainment problems were given to an equal number of male and female university students. The solution to Problems 1 to 5 (the preliminary problems) was specified by a conjunctive rule, while the solution to the last seven problems (the critical problems) was specified by a single attribute rule. Each problem consisted of five blank trial sequences that began with the presentation of a positive example followed by five response probes. Subjects were informed at the end of a blank trial sequence whether their responses to the five probes were correct or that one or more were incorrect. Half of the subjects were told the solution at the end of each problem (complete feedback), while the rest of the subjects were told the solution following the first three problems only (partial feedback). Subjects worked continuously through all problems, or at the end of Problem 6 received a 15 minute interruption filled with a task either related or unrelated to the concept attainment problems. From exposure to solution feedback, all subjects developed a set to sample conjunctive hypotheses by Problem 3. Partial feedback subjects continued to sample conjunctive hypotheses up to the end of Problem 12, while complete feedback subjects broke the conjunctive set by Problem 8. The interruptions had marginal and inconsistent effects on set breaking which were apparently superseded by problem solving efficiency. Subjects were classified as efficient or inefficient problem solvers based on their ability to solve the preliminary problems. Efficient problem solvers broke set faster than inefficient problem solvers, whether or not solution feedback was provided. Einstellung was suggested to be related to strategy efficiency which determines the rate of exhaustion of the conjunctive hypothesis domain.

Acknowledgements

I would like to thank my advisor, Dr. R. E. Anderson, for the unceasing assistance she provided throughout all stages of this thesis, also the other members of the committee, Dr. F. M. Rabinowitz for supplying the advise and computing education that helped to make this thesis possible, and to Dr. C. Penney for her helpful suggestions.

I would also like to thank the Natural Sciences and Engineering Research Council (NSERC) for the Graduate Scholarship that provided me with the financial capability for existing throughout all stages of my Master of Science education and this thesis.

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Introduction

The effects of interrupting problem solving activity, of feedback, and of individual differences in problem solving efficiency on breaking set in concept attainment problems were investigated. Set is defined as the tendency of subjects to responsed consistently with a rule that specified the solution to five set-inducing problems (preliminary problems). This operational definition of set is comparable to other definitions of set (cf. Luchins 1942; 1970; Lane, McDaniel, Bleichfeld, and Rabinowitz, 1976; Levine, 1975; Lewis, 1979; Sweller and Gee, 1978). Seven set-breaking problems (critical problems) followed the preliminary problems. The critical problems were identical to the preliminary ones, except that the solutions to the critical problems were derived from a simpler rule. Einstellung is defined here as a tendency of subjects to responsed during the critical problems in a way consistent with the rule specifying the solution to the preliminary problems.

Einstellung

In 1942 Luchins experimentally demonstrated Einstellung in problem solving behavior. Subjects were given a series of 11 water-jar problems. In order to solve the first six problems, subjects were required to use a complex formula that combined the contents of three water-jars (i.e., B-A-2C). Problems 7, 8, 10, and 11 were solvable using either the complex formula, or a simpler one which combined the contents of just two of the water-jars (i.e., A-C or A+C). Problem 9 could only be solved by applying the simple formula. Luchins found that the majority of subjects would continue to use the complex formula on Problems 7 and 8, fail to solve Problem

9, and then continue to use the complex formula on Problems 10 and 11.

Luchins and Luchins (1970) concluded from the findings of numerous studies that Einstellung was not caused solely by stress, repetition, task complexity, or generalization of a response. Rather, they found that if a subject solved the preliminary problems so that responses were not blindly repeated and alternative solutions were looked for, Einstellung could be avoided or substantially reduced. As such, Luchins and Luchins suggested that the problem solving procedures included in the particular method are the crucial factors which promote or prevent Einstellung.

Two hypotheses have been introduced since the Luchins' research to explain the theoretical mechanisms responsible for the formation and breaking of a problem solving set. These include the composition hypothesis suggested by Lewis (1979), and the transfer hypothesis suggested by Levine (1975).

Composition hypothesis. Based on experimental and simulated data, Lewis (1979) demonstrated that Einstellung could be described by the composition process. Once a subject has developed a composed list of procedures for solving a series of preliminary problems, if a change in solution criteria is introduced, the composed procedures developed for solving the preliminary problems are automatically executed, and hence cause Einstellung. The duration of Einstellung is directly related to the number of composed procedures in a problem solving method. Since more procedures are required to determine a complex solution than a simple solution, Lewis suggested that the composition hypothesis could account for the finding that Einstellung only occurred when the solution criteria changed from complex to simple (cf., findings of Fingerman and Levine, 1974; Ress and Levine, 1966; Lewis, 1979;

and Sweller and Gee, 1978). If the solution criterion change in a direction of increasing complexity, the new method just requires an addition of one or more new procedures to the old approach. Consequently, the preliminary method does not have to be decomposed, rather, the new procedures can just be added. In contrast, if the solution criterion change in a direction of decreasing complexity, a number of the procedures in the preliminary method have to be removed. In order to achieve this result, the procedures in the preliminary method are decomposed, and then the inappropriate procedures are discarded. At this point, a new method can be developed. Therefore, based on the composition process, it will take a problem solver longer to break the preliminary set if the solution criterion change in a simpler as compared to a more complex direction.

Ress and Levine (1966) and Fingerman and Levine (1974) found that after subjects had solved a series of complex position sequence problems, most subjects could not solve a simple two choice discrimination problem where the solution was defined as one of the alternatives. Using a sequence extrapolation task, Sweller and Gee (1978) demonstrated similar Einstellung effects. Subjects had no difficulty in learning to solve a series of problems that had increasingly more complex position sequence solutions. However, if a problem with a simpler position sequence solution was introduced, subjects were unable to determine the solution. These findings were found to be equivalent to sequence effects investigated by Sweller (1976).

Transfer hypothesis. Using a blank trial procedure, Levine, Leitenberg, and Richter (1964) and Philips and Levine (1974) demonstrated that subjects search for the solution to concept attainment and discrimination problems by generating and testing hypotheses. A blank trial procedure involves the presentation of an example stimulus followed by a series of response probes. Each example stimulus is a positive instance in that the attribute(s) that specify the solution are present. A negative instance is alternatively defined as a stimulus in which the attribute(s) that specify the solution are not present. Each probe stimulus is a variation of the preceding example stimulus, and is either a negative or positive instance of the solution. A subject is to respond "yes" to each probe that is a positive instance, "no" otherwise. After all the probes in a blank trial sequence have been presented, the subject is informed whether all the probe responses were correct, or that one or more of the responses were incorrect. The basic assumption is that a subject will respond to each probe according to a generated hypothesis until feedback is encountered. If all the responses are correct, the subject will continue to use that hypothesis to guide future responses. If one or more of the responses are incorrect, the subject will generate a new hypothesis. Using this method, Levine et al. (1964) and Philips and Levine (1974) found that subjects produced response patterns consistent with a rule that corresponds with the subject's generated hypothesis.

Consider the sample concept attainment problem in Table 1. This problem is a variation of the problem used by Lane et al. (1976). The problem consists of the presentation of five blank trial sequences. Within each blank trial sequence, an example stimulus is followed by five probe stimuli. The example and probes consist of a string of five attributes (i.e., X1 K2 D2 M1 Y2). These attributes are derived from a 5 X 2 array of dimensions and values, respectively (the stimulus universe). The five dimensions are represented by letters randomly selected from the alphabet. The two values are represented by the numbers 1 and 2. Each attribute consists of one dimension with one value (i.e., X1). The total array consists of ten single attributes, of which only five are present in an example or a probe string. The solution to this sample problem is the single attribute D2. Therefore, each example stimulus contains the attribute D2. In order to solve the problem, a subject must respond "yes" to each blank trial probe that contains D2, and "no" to each probe that contains D1. A blank trial response pattern would be scored as consistent with a single attribute rule if a subject responded "yes" to all the probes within a particular blank trial sequence that contained one of the attributes present in the immediately preceding example stimulus, and "no" otherwise. A response pattern would be scored as consistent with a conjunctive rule if a subject responded "yes" to all probes within a blank trial sequence that contained two of the attributes that were present in the immediately preceding example stimulus, and "no" otherwise.

An hypothesis domain (H-domain) consists of the total number of hypotheses that can be derived from the the stimulus universe by using a particular rule (e.g., single attribute rule). Thus, in the sample problem the single attribute H-domain consists of 10 hypotheses, and the conjunctive H-domain consists of 40 hypotheses. According to Levine (1975), once a subject begins to sample hypotheses that are consistent with a particular rule, the hypotheses in that H-domain will be sampled until the solution is discovered or until all the hypotheses have been tested and disconfirmed. If the subject exhausts that H-domain and determines that the solution is not specified by one of the tested hypotheses, future hypotheses tested by the subject will be consistent with a new rule (transfer hypothesis). If the H-domain contains an infinite number of hypotheses, where infinite refers to any number which exceeds a subject's memory limitations, exhaustion of the H-domain is impossible. This is known as the infinite set assumption. Alternately, the exhaustion of the H-domain is impossible if all the hypotheses cannot be tested as a result of problem constraints (i.e., fewer blank trial sequences than the number of hypotheses in the H-domain).

The transfer hypothesis assumption was used by Levine (1975) to account for Einstellung findings. Once a subject becomes set to produce response patterns consistent with a rule that specifies a particular H-domain, a change in solution criteria will not be detected until all hypotheses in that H-domain have been tested and disconfirmed. If memory limitations or problem constraints prevent a subject from exhausting the H-domain, the change in solution criteria will not be detected.

Lane et al. (1976) tested Levine's (1975) hypothesis that Einstellung was related to the exhaustion of the H-domain. Subjects were asked to solve six preliminary and two critical concept attainment problems. For half of the subjects, the solution was specified by a single attribute rule for the preliminary problems and a conjunctive rule for the critical problems. For the remaining subjects, the solution was specified by a conjunctive rule for the preliminary problems, and a single attribute rule for the critical problems. The problems were presented with the same blank trial procedure and stimuli as outlined in the sample problem (see Table 1), with the exception that eight blank trial sequences were presented during each problem. Subjects became set by the third preliminary problem to produce response patterns that were consistent with the solution rule. A blank trial sequence was scored as being consistent with a single attribute hypothesis if a subject responded "yes" to each blank trial string that contained one particular attribute in the immediately preceding example string, and "no" otherwise. A blank trial sequence was scored as being consistent with a conjunctive rule if a subject responded "yes" to each blank trial string that contained two particular attributes present in the immediately preceding example string, and "no" otherwise.

Subjects who became set to produce response patterns consistent with a single attribute rule had no difficulty in breaking set by Problem 8. In contrast, subjects who became set to produce response patterns consistent with a conjunctive rule did not break set. The results of this study provided support for Levine's (1975) transfer hypothesis and infinite set assumption in that Einstellung was found to be directly related to the size of the H-domain. Eight responses appeared to be a sufficient number to enable subjects to exhaust the single attribute H-domain, but not to exhaust the conjunctive attribute H-domain.

Predictions derived from Levine's (1975) transfer hypothesis can be expanded to encompass the effect of the efficiency of concept attainment sampling strategies. Gholson (1980) and Tumblin and Gholson (1981) have discussed three sampling strategies found to be used by subjects when solving single attribute concept attainment problems. These strategies involve systematic sequences of prediction hypotheses that always lead to the solution, if the hypotheses are from the solution H-domain (Gholson, 1980). In order of increasing efficiency, these include hypothesis checking, dimension checking and focusing. Efficiency refers to the number of samples necessary to exhaust an H-domain.

Discussion of these strategies is based on the sample concept attainment problem presented in Table 1. Each problem consists of five blank trial sequences. The five example stimuli change in the following way. The dimensions that do not specify the solution have their values change across the five example stimuli such that the order of change is random, and one dimension changes its value on each subsequent example. Once the value of a dimension changes, it remains in the changed form for the duration of the problem (see Table 1). Feedback is provided after responses have been made to the five probes in a blank trial sequence. Here, a subject is informed if all responses were correct or if one or more of the responses were incorrect. At the end of each problem the subject is told the attribute(s) that specify the solution.

Suppose that a subject has developed a set to produce response patterns consistent with a conjunctive rule. A change in solution criteria is introduced. The solution to the sample problem is now specified by a single attribute. Based on the transfer hypothesis, the 40 hypotheses that can be derived from the stimulus universe (i.e., a 5 by 2 stimulus array) by using a conjunctive rule must be disconfirmed before the change in solution criteria can be detected.

Hypothesis checking is the least efficient strategy. Four pairs of attributes (conjunctive hypotheses) are specified by each pair of dimensions and the corresponding values (e.g., attribute pairs X1 K1, X1 K2, X2 K1, X2 K2). A subject is assumed to test each conjunctive hypothesis systematically by working through the 10 pairs of dimensions. Hypotheses are disconfirmed through feedback. A subject using this strategy would not be able to exhaust the conjunctive attribute H-domain in less than 40 blank trial sequences, because all of the 40 hypotheses must be individually disconfirmed.

Dimension checking is considerably more efficient than hypothesis checking. A subject is assumed to disconfirm conjunctive hypotheses by eliminating dimensions systematically. This is accomplished by testing one pair of attributes that are locally consistent (present in the immediately preceding example stimulus) at the time of selection. Four conjunctive hypotheses can be specified by each dimension pair and the two values (i.e., for dimensions X and K, conjunctive hypotheses X1 K1, X1 K2, X2 K1, X2 K2). If the conjunctive hypothesis X1 K2 is present in the example stimulus, which must be a positive instance, hypotheses X1 K1, X2 K1, and X2 K2 can logically be eliminated. Therefore, for each conjunctive hypothesis tested, a total of four hypotheses can be eliminated. As such, the number of hypotheses that must be tested in order to exhaust the conjunctive H-domain are reduced by a factor of four from 40 to 10.

The focusing strategy is the most efficient. A subject remembers which attributes are present in each of the examples. Dimensions that change their value across the example stimuli are irrelevant. Hypotheses derived from attributes based on the irrelevant dimensions can logically be eliminated. If a different dimension changes in value on succeeding examples and if a subject disconfirms through feedback a further hypothesis per blank trial sequence, less than five responses are needed to exhaust the conjunctive H-domain. Therefore, a subject who uses a focusing strategy can exhaust the conjunctive H-domain in the sample problem. Furthermore, since the one relevant dimension is unchanged in Example 5, a subject using this strategy should be able to reject the conjunctive rule and detect that the solution is specified by a single attribute.

Consistent with Levine's (1975) transfer hypothesis, only those subjects using a focusing strategy should be able to break the set to generate conjunctive hypotheses. The composition process, suggested by Lewis (1979) would lead to a different prediction. If a subject uses a dimension checking strategy, s/he has to keep track of either the dimensions that have been disconfirmed or the dimensions that can still specify the solution on the basis of feedback to the sampled hypotheses. In contrast, a subject who uses a focusing strategy must keep track of all the above information in addition to remembering the detail of each subsequent example stimulus in order to determine the relevant dimensions by searching for differences between the presented example stimuli. Since a focusing strategy involves more procedures than a dimension checking strategy, according to Lewis' (1979) notion of complexity, focusing is a more complex strategy than dimension checking. Therefore, a composed problem solving routine that involves sampling conjunctive hypotheses through the application of a focusing strategy should take longer to decompose compared to a composed problem solving routine that uses a dimension checking strategy. According to the composition hypothesis, subjects who develop this most efficient strategy should be affected by Einstellung for the longest duration.

Interruption of problem solving activity. Three hypotheses have been proposed to explain how the interruption of problem solving activity may facilitate the breaking of a set. Silveira (1972) suggested that an interruption may facilitate the recovery of ideas relevant to solving the problem. The recovery of relevant solution information may be brought about by a continuation of either conscious or unconscious problem solving activity during the interruption. Alternatively, both Luchins and Luchins (1970), and Sweller and Gee (1978) have suggested that a prolonged time out between problems may facilitate the breaking of a set by implicitly suggesting that the pre-interruption problems are different from the post-interruption problems because they are separated in time.

Using an unfilled interruption Murray and Denny (1969) and Silveira (1972) found that an interruption facilitated solution discovery. However, attempted replications of the two studies by Dominowski and Jenrick (1972) and Olton (1979) failed to produce the predicted results. Dreistadt (1969) was the only one who demonstrated that solution related cues, presented during the interruption, facilitated problem solving attempts. His results were not consistent and attempts at replication by Olton and Johnson (1976) were unsuccessful.

Evidence supporting the different type of problem hypothesis proposed by Luchins and Luchins (1970) and Sweller and Gee (1978) is contradictory. Here, the general procedure involved presenting a series of problems that could all be solved by the application of the same or increasingly complex rules, then providing an interruption. After the interruption, the subjects were presented with the same type of problem that could only be solved by applying a simpler rule. An interruption sometimes facilitated the breaking of a set, while in other cases an interruption strengthened a set. Tresselt and Leads (1953a; 1953b) reported Einstellung to be significantly increased after a 24-hour interruption. Luchins and Luchins (1970) reported that Einstellung remained stable for at least a month. However, they also reported that a time out between the set-inducing problems and the critical problems promoted a marginal weakening of Einstellung.

The present study. The present study was designed to test a number of hypotheses regarding the breaking of set that were derived from the previous discussion of Einstellung and the interruption of problem solving activity. The methodology, rationale for its selection, and the predicted outcomes based on experimental manipulations are as follows.

The results from Lane et al.'s (1976) study were replicated in a pilot experiment. Therefore, the concept attainment procedure used by Lane et al. is an appropriate framework to test a number of hypotheses regarding factors that effect Einstellung. The use of this type of procedure provided subjects with more than one opportunity to solve each problem, and thus supplied a means for determining the degree of problem solving efficiency.

In order to discriminate efficient from inefficient problem solvers, the number of response trials within each problem was reduced from eight (the number used by Lane et al., 1976) to five. This alteration was necessary in order to ensure that problem solvers could break the conjunctive set on the first critical problem only if they were using some form of a focusing strategy. If breaking set is prevented by learning a larger list of procedures (i.e., the focusing strategy versus dimension or hypothesis checking) then efficient problem solvers should not break set on the first critical problem. In contrast, if the use of the most efficient strategy permits the exhaustion of the conjunctive H-domain by the fifth response trial, then the most efficient problem solvers should break set on the first critical problem.

A series of 12 concept attainment problem was presented to each subject. The first five problems were the preliminary or set inducing ones, and the last seven were the critical or set breaking problems. These changes from Lane et al.'s (1976) design (six preliminary and two critical problems) were undertaken for two reasons. First, in both Lane et al.'s study and the pilot study, all subjects had developed a set to sample conjunctive attribute hypotheses by Problem 3. Therefore, five preliminary problems were sufficient to ensure that set developed. Secondly, in the pilot study, some subjects were still sampling conjunctive attribute hypotheses on the fourth critical problem. In order to provide an examination of Einstellung across a greater number of problems, seven critical problems were used.

Two interruption manipulations and a no interruption control were included in the experiment. A third of the subjects received no interruption. The remaining subjects received a 15 minute interruption. The interruption was introduced after the first critical problem in order to be consistent with the interruption studies. One manipulation was a related interruption. Subjects in this condition were instructed to think about how they had been solving the problems, and how they could get better at it. The other manipulation was an unrelated interruption. Subjects in this condition were given a spatial relations test to do during the interruption. This activity was provided to ensure that subjects did not think about the concept attainment problems during the interruption. Neither group was told that they would have to solve more concept attainment problems after the interruption terminated.

The interruption manipulations provided a framework to test the recovery hypothesis (Silveira, 1972), and the different type of problem hypothesis (Luchins and Luchins, 1970; Sweller and Gee, 1978). If an interruption provided an opportunity for solution information to be discovered (recovery hypothesis) through conscious processing, subjects in the related interruption condition should break set faster than subjects in the unrelated interruption and the interruption control conditions. In contrast, if the interruption provides the opportunity for solution information to be discovered through unconscious processing, subjects in the unrelated interruption should break set faster than subjects in the related interruption and the interruption control conditions. Alternatively, if the interruption suggests to the subjects that the pre and post-interruption problems are different (different type of problem hypothesis), subjects in both interruption conditions should break set faster than subjects in the interruption control condition.

Subjects in the present study were assigned to either complete or partial feedback conditions. Complete feedback provided two sources of information.

First, subjects were informed whether all of their responses to the probes within a blank trial sequence were correct, or that one or more of their responses were incorrect. Second, subjects were told at the end of each problem, what attribute(s) specified the solution. Partial feedback was identical to complete feedback with the exception that the second source of information (i.e., the attribute(s) that specified the solution) was removed after Problem 3. This second source of information was not provided to the subjects in the partial feedback condition after Problem 3 for two reasons. The first was to ensure that the removal of the complete feedback occurred after the subjects became set. The third was to ensure that subjects in the partial feedback condition would not learn of the change in solution criteria from the change in feedback parameters, but only if they exhausted the conjunctive set or benefited from either of the interruption manipulations.

The proportion of response patterns for Problems 1 to 5 that was consistent with a conjunctive rule was used to determine the presence of the conjunctive set and to determine when that set was broken. The proportion of response patterns for Problems 6 to 12 that was consistent with a single attribute rule was used to determine when subjects had detected the change in solution criteria. Strategy efficiency was determined according to a subject's ability to solve the preliminary problems.

The time between the onset of the stimulus and each response in the blank trial probe sequences was recorded. These data were collected for the exploratory purpose of determining whether any relationships existed between response time patterns and hypotheses testing behavior.

Method

Subjects. Seventy-four Memorial University students were paid for their participation in the experiment. Subjects were quasi-randomly assigned to the six experimental groups so that there were an equal number of males and females in each group. Half of the subjects in each group were male and half female. Data collected from one female and one male subject were not included in the analyses because both failed to reach the established set criterion.

Apparatus. An Exidy Sorcerer Z80 micro computer with a model MV 12 Exidy Video Terminal was used to collect the data and present all concept attainment problems. Responses were transmitted to the computer via a button box containing start, yes, and no buttons. Response times in milliseconds were collected by having the computer count the pulses from a 100 Hz crystal.

Problems. The problem stimuli, presentation, and response procedures were similar to those used by Lane, et. al., (1976). Variations on their method were incorporated into the experiment for the computerized presentation.

Twelve concept attainment problems were presented to each subject. The solutions to the five preliminary problems were consistent with a conjunctive rule. The solutions of the seven critical problems were consistent with a single attribute rule. Each problem consisted of five blank trial sequences where a sequence included a positive example stimulus followed by five probe stimuli. An example stimulus remained on the video screen for 10 seconds and was then replaced by the first probe stimulus of the sequence. Each probe remained on the video screen until a subject responded, then it was replaced by the next probe stimulus. Probes were either positive or negative instances. Subjects were to press the "yes" button if they thought the attribute(s) that defined the solution was (were) present in a preliminary problems. The fourth irrelevant dimension had one value present on the first, second, third, and fourth example, and the other value on the remaining example. Therefore, each example differed from the preceding one in terms of only one attribute.

The five probe stimuli following an example had the following configuration. Each probe was identical to the immediately preceding example stimulus with the exception of one attribute. Therefore, four attributes remained the same as those in the example, while the fifth changed on a particular blank trial (see Table 1). The order of change across the five blank trial sequences was randomly determined such that no sequences within a problem were the same.

Design and Procedure. Feedback (complete and partial) and interruption (none, related, and unrelated) were between-subject factors, while problem (12), examples (5 or fewer), and blank trial sequences (5) were within subject factors. Both feedback groups received feedback following the last response of each blank trial sequence regarding the correctness of all responses to the probes within a blank trial sequence. Subjects in the complete feedback condition were told what the solution of each problem was following the final blank trial sequence of that problem. They were then told whether or not they solved the problem. Subjects in the partial feedback condition were told the solution following the final blank trial sequence of only the first three problems. At the end of each of Problems 4 to 12, the partial feedback subjects were just told whether or not they solved the problem.

Subjects in the no interruption condition did not receive a break. Subjects in both interruption conditions received a 15 minute break at the end of Problem 6. Subjects in the related interruption groups were given instructions to think about probe, otherwise the "no" button. Feedback was provided after each blank trial sequence was completed. The feedback informed subjects whether they responded correctly to all five probes in the blank trial sequence, or whether they responded incorrectly to one or more. A problem was considered solved if a subject responded correctly to each probe in two consecutive blank trial sequences within a problem. A subject was told the solution to a problem either after s/he solved it or at the end of the problem.

Stimuli. The stimuli were displayed on the centre of the video screen. The stimuli consisted of five letters that represented five dimensions. Each letter was followed by the number 1 or 2. This created a string of five attributes, (e.g., X1 K1 D2 M2 Y1). Five different letters were randomly selected from the alphabet for each subject on each of the twelve problems. The letters remained in the same position within a problem.

The position of the attribute(s) which defined the solution was randomly selected for each problem. The position of the solution attribute(s) was never the same for two consecutive problems. Within each problem, the example strings differed only with respect to the dimensions representing the nonsolution attributes. For the five preliminary conjunctive problems, one irrelevant dimension had one value present on the first and fifth example, and the other value present on the remaining examples. A second irrelevant dimension had one value present on the first and second example, and the other value present on the remaining examples. The final irrelevant dimension had one value present on the first, second, and third example, and the other value present on the remaining examples. For the seven critical single attribute problems, three of the irrelevant dimensions differed in the same way as the irrelevant dimensions in the how they were solving the problems and how they could improve. Subjects in the unrelated interruption groups worked on a Spatial Relations test (Bennett, Seashore, and Wesman, 1963) for 15 minutes.

Subjects were tested individually in a small room which contained a chair, table, and testing apparatus. Instructions for concept attainment problems were presented on the video screen one page at a time. Subjects read these instructions at their own rate. After being told the general format of the presentation of example stimuli and blank trial sequences, subjects received two practice problems (see Appendix A). Each involved the presentation of one example stimulus followed by five blank trial probes. The example stimulus for the first problem was an addition equation (e.g., 6+3=9), and a subtraction equation for the second problem (e.g., 7-3=4). The five blank trial probes for the first problem consisted of three addition equations and two multiplication equations (e.g., 3X2=6). For the second problem, the five blank trial probes consisted of three subtraction equations and two multiplication equations. To solve the practice problems, subjects had to respond "yes" to all blank trial probes that were the same type of equation as the preceding example stimulus, and "no" to all probes that were multiplication equations. The practice problems were given for three reasons: (1) to demonstrate the presence of a solution in an example stimulus, (2) to familiarize subjects with the blank trial probes, and (3) to show the subjects how to predict the solution based on the example stimulus and how to respond in a way that was consistent with the prediction. Subjects were told that the practice problems and stimuli were not the same as the experimental problems. Upon completion of the practice problems the subjects were given details about the experimental problems in terms of the nature of the stimuli, and how these would change during the presentation of subsequent example strings and blank trial probes.

The experimenter remained in the testing room while the subjects read the instructions and solved the practice problems. Questions about the instructions were answered prior to the start of the experimental problems. Information about specific rules (e.g., conjunctive) or specific sampling strategies (e.g., focusing) was not supplied. The subjects were not told how many problems they would be required to solve. They were told to continue solving problems until the computer indicated otherwise, and then at this time they were to follow the instructions displayed on the video screen. When the subjects were satisfied that they knew what to do, the experimenter told them to begin the problems and left the room.

Subjects in the partial feedback condition were informed at the end of the third problem that they would no longer be given the solution to the remaining problems, but would be informed whether or not they solved the problem. At the end of Problem 6 subjects in the two interruption groups were told to go to the experimenter's office. At this time subjects were taken into a different room and given their respective tasks. At the end of 15 minutes, the experimenter told the subjects that they had several more problems to solve and accompanied them back to the testing room. Questions pertaining to the concept attainment problems were not answered during the interruption.

Upon completion of the Problem 12, subjects were told that the experiment was over and to go to the experimenter's office to receive payment. Subjects were paid, debriefed, and asked not to discuss this experiment with other students.

Results

Hypothesis testing. The blank trial sequences following each example yielded $2^5=32$ possible yes-no response patterns. Response patterns were classified as either conjunctive attribute hypotheses, single attribute hypotheses, or neither. Ten of the possible response patterns corresponded to conjunctive hypotheses, five to single attribute hypotheses, and the remaining 17 were classified as random. A response sequence was consistent with a single attribute rule if "yes" was the response to each probe that was a positive instance of a particular attribute, "no" otherwise. A response pattern was consistent with a conjunctive rule if "yes" was the response to each probe that was a positive instance of a particular pair of attributes, "no" otherwise.

A criterion of sampling 70% conjunctive hypotheses across Problems 4 and 5 was used to ensure that all subjects included in the analyses were set immediately prior to the first critical problem. The data from the 72 subjects who reached the set criteria (only 2 subjects failed to reach criteria) were used in the following hypothesis sampling analyses.

Conjunctive attribute hypotheses. The number of conjunctive response patterns on Problems 1 to 12 were submitted to a 2 X 3 X 2 X 12 (Feedback X Interruption X Sex X Problem) analysis of variance. If a subject reached criterion prior to the fifth blank trial sequence within any of Problems 1 to 5, then the remaining blank trial sequences within the problem were classified as consistent with a conjunctive rule and added to that subject's score for the analysis. The effects of Feedback, $F(1,60)= 21.33$, $p<.001$, Problem, $F(11,660)=41.01$, $p<.001$, and Feedback X Problem, $F(11,660)=9.64$, $p<.001$, were significant. The Feedback X Problem interaction is presented in Figure 1. The difference in the number of conjunctive response patterns between the complete and partial feedback conditions was not significant for Problems 1 to 6, maximum $F(1,543.28)=0.829$, $p>.05$. The majority of the blank trial response patterns of the two feedback conditions was consistent with a conjunctive rule for Problems 3 to 6. The groups diverged across Problems 7 to 12. Less than 40% of the blank trial response patterns were consistent with a conjunctive rule for subjects in the complete feedback condition on Problem 7 compared to 60% for subjects in the partial feedback condition. This proportion decreased to 10% on Problem 12 for subjects in the complete feedback condition and 45% for subjects in the partial feedback condition. The differences in the number of conjunctive response patterns between the two feedback conditions was significant for Problems 7 to 12; minimum $F(1,543.28)=20.002$, $p<.05$.

Single attribute hypotheses. The number of single attribute response patterns on Problems 6 to 12 were submitted to a 2 X 3 X 2 X 7 (Feedback X Interruption X Sex X Problem) analysis of variance. If a subject reached criterion prior to the fifth blank trial sequence, the remaining blank trial sequences within the problem were classified as consistent with a single attribute rule and added to the score used in the analysis. The effects of Feedback $F(1,60)=48.55$, $p<.001$, Problem, $F(11,660)=35.83$, $p<.001$, and Feedback X Problem, $F(11,660)=10.18$, $p<.001$, were significant. The Feedback X Problem interaction is presented in Figure 2. The difference in the number of single attribute response patterns between the complete and partial feedback conditions was not significant on Problem 6; $F(1,234.61)=0.035$, $p>.05$. On Problem 6, 21% of the response patterns of both feedback conditions corresponded to single attribute hypotheses. The two groups diverged across Problems 7 to 12. The proportion of single attribute response patterns of the complete feedback condition increased to 87% on Problem 12 compared to 40% for subjects in the partial feedback condition. The difference in single attribute response patterns between the two feedback conditions was significant for Problems 7 to 12; minimum $F(1,234.61)=17.238$, $p<.05$.

Problem solving efficiency. An examination of the data revealed the presence of two fairly distinct populations of problem solvers. One group of subjects seemed quite adept at problem solving, while the other group of subjects was not. In an attempt to operationalize this observation, subjects were classified as efficient (N=26) or inefficient (N=46) problem solvers on the basis of whether or not they solved Problem 5, the last preliminary problem. Since this criterion clearly demarcated the two groups, further analyses with the total sample of subjects based on other criteria were not pursued. A 2 X 2 X 3 X 2 (Efficiency X Feedback X Interruption X Solution) factorial Chi Square analysis (Winer, 1971) was performed for each of Problems 6 to 12. The Solution variable used in this analysis was whether or not a subject solved the problem being analyzed.

The interaction of Efficiency X Solution was significant across all single attribute problems with the minimum $\chi^2(1)=14.22$, $p<.001$, on Problem 11 (see Table 2 for representative data). These significant interactions indicate that a greater proportion of efficient problem solvers solved single attribute problems than inefficient problem solvers. The interaction of Feedback X Solution was significant on Problems 7, 10, 11, and 12. The minimum significant $\chi^2(1)=6.722$, $p<.01$, occurred on Problem 7 and increased across Problems 10 to 12 (see Table 3 for representative data). These interactions indicate that proportionally more subjects in the complete feedback condition solved Problems 7, 10, 11, 12 than subjects in the partial feedback groups. The interaction of Efficiency X Feedback X Solution was significant only on Problem 12, $\chi^2(1)=5.56$, $p<.02$ (see Table 4).

Inspection of the data reveals that over 95% of the efficient problem solvers solved Problem 12 regardless of which feedback condition they were in. In contrast, only 70% of the inefficient problem solvers in the complete feedback condition solved Problem 12 versus 11% of the inefficient problem solvers in the partial feedback condition.

The interaction of Interruption X Solution was significant for Problem 8 only, $\chi^2(2)=8.278$, $p<.02$. More subjects in the related interruption group solved Problem 8 than subjects in the unrelated and control interruption groups (see Table 5).

Twenty-nine subjects were found to be missing one or more response times from their data files. The clock (crystal) used for computing response times was apparently malfunctioning during the testing of these subjects. The original intention had been to analyze the response time data of all subjects. Since this was impossible, a decision was made to select a sample of 24 subjects with complete data sets based on a more rigid criterion of efficiency. The 43 subjects with complete response time data were rank ordered according to the number of preliminary conjunctive problems solved. From this rank ordering it was possible to select 12 efficient and 12 inefficient problem solvers, balanced for feedback condition. However, it was not possible to achieve equal representation of the three interruption groups in this sample. Each of the 12 efficient problem solvers solved a minimum of two conjunctive attribute problems, while the 12 inefficient problem solvers did not solve any of the conjunctive attribute problems. Comparison between this subsample and the total sample indicated an almost perfect overlap between subjects classified by the two efficiency criteria. Only one efficient subject in the subsample was classified as inefficient in the total sample. Even though Problem 5 was not solved by this subject, Problems 3 and 4 were. Prior to presentation of the response time analyses, the results of the hypotheses sampling data analysis of this subsample is provided.

A 2 X 2 X 12 (Efficiency X Feedback X Problems) analysis of variance was performed on the number of conjunctive response patterns for each problem. The effects of Feedback, $F(1,5)=13.66$, $p<.001$, Efficiency X Feedback, $F(1,5)=24.95$, $p<.001$, Problem, $F(11,55)=16.84$, $p<.001$, Feedback X Problem, $F(11,55)=2.52$, $p=.005$, and Efficiency X Problem, $F(11,55)=5.70$, $p<.001$, were significant. The interaction of Feedback X Problem confirms that subjects in the select group were comparable to the total sample of subjects (see Table 6 and Figure 1). Subjects in both feedback conditions sampled greater than 60% of their hypotheses from the conjunctive H-domain on Problems 3 through 6. The proportion of conjunctive hypotheses sampled by subjects in the two feedback conditions increasingly diverged across Problem 7 through 12. The proportion of conjunctive hypotheses sampled by subjects in the complete feedback condition decreased to 11.7% compared to 43.3% for partial feedback subjects. The Efficiency X Feedback interaction indicates that inefficient subjects in the partial feedback condition sampled more conjunctive hypotheses than the other three groups. The interaction of Efficiency X Problem reveals that the efficient subjects sampled more conjunctive hypotheses across Problems 1 to 5 and fewer conjunctive hypotheses across Problems 6 to 12 than the inefficient subjects (see Table 7).

A 2 X 2 X 12 (Efficiency X Feedback X Problem) analysis of variance was performed. Subjects were assigned a score of "1" if they solved a problem, "0" otherwise. The effects of Efficiency, $F(1,20)=137.96$, $p<.001$, Problem, $F(11,220)=6.07$, $p<.001$, Efficiency X Problem, $F(11,220)=1.85$, $p=.048$, and Efficiency X Feedback X Problem, $F(11,220)=3.26$, $p<.001$, were significant.

Results of this analysis confirm that the efficient and inefficient problem solvers in both the total and subsample behaved equivalently. Data representing the Efficiency X Feedback X Problem interaction are presented in Table 8. Inspection of these data reveals that nine out of 12 efficient subjects solved the first critical problem, where as only 1 out of 12 inefficient subjects solved Problem 6. Furthermore, the efficient problem solvers did not need complete feedback in order to detect the change from a conjunctive to a single attribute rule, and to solve the critical problems. On the other hand, inefficient problem solvers who were not given complete feedback, did not solve any of the critical problems. Inefficient problem solvers in the complete feedback condition had to be informed of the rule change a number of times before some began to solve the critical problems.

Problem solving efficiency and response times. As a result of an error in the algorithm for data collection and storage, only the first four response times from each blank trial sequence were collected. The absence of the fifth response trial is not critical as pilot data indicated that no differences existed between the fourth and fifth response time in a blank trial sequence. If a subject reached the criterion for solving a problem prior to the fifth blank trial sequence, the problem was terminated. As a consequence, response time data were missing for subjects who solved any of the problems in two or three blank trial sequences. Cell means were not used to fill these missing data points. Rather, the subject's response times for the last blank trial sequence completed within the problem that was solved were used. This procedure was conservative since latencies decreased across blank trial sequences. Therefore, the degrees of freedom in relevant error terms were not corrected in the analysis.

The response time data were submitted to a natural logarithm transformation to minimize the skew due to long response times. The dependent variable y was set equal to ln(x+1), where x was the response time in seconds. The transformed data of the subsample were submitted to three analyses of variance, one on the five preliminary problems, the second on the last preliminary and first critical problem, and the third on Problems 8 to 12, the last five critical problems. Since the interruption conditions were not equally represented in the subsample, Problem 7 was not included in any analysis. This omission should have minimized short term interruption effects that might have affected response times for Problem 7.

Response time data for Problems 1 to 5 were submitted to a 2 X 2 X 5 X 5 X 4 (Efficiency X Feedback X Problem X Example X Trial) analysis of variance. Example refers to the five blank trial sequences within a problem, and Trial to the five responses within each blank trial sequence. The effects of Efficiency, $F(1,20)=5.26$, $p=.031$, Problems, $F(4,80)=9.07$, $p<.001$, Example, $F(4,80)=27.76$, $p<.001$, Efficiency X Example, $F(4,80)=7.07$, $p<.001$, Trial, $F(3,60)=107.39$, $p<.001$, Feedback X Trial, $F(3,60)=3.92$, $p=.013$, Efficiency X Trial, $F(3,60)=3.48$, $p=.021$, and Example X Trial, $F(12,240)=7.00$, $p<.001$, were significant. The main effect of Problem resulted from a decrease in average response time from 1.52 ln (x+1) seconds on Problem 1 to 1.01 ln (x+1) seconds on Problem 5. The Example X Trial interaction reveals that the response time to the probes decreased across the five blank trial sequences within a problem (see Figure 3). The time to respond to the first probe in each blank trial sequence decreased the most across a problem. Inspection of the Efficiency X Example (see Figure 4) interaction reveals a greater decrease in the average response time across the five blank trial sequences within a problem for the efficient than the inefficient problem solvers. Inspection of the Efficiency X Trial (see Figure 5) interaction reveals that the efficient problem solvers responded faster than the inefficient problem solvers to all probes within a blank trial sequence. The greatest difference between the efficient and inefficient problem solvers in the time taken to respond was to the first probe. The response times for both groups of subjects decreased across the remaining three probes within a blank trial sequence. Inspection of the Feedback X Trials interaction (see Table 9) reveals that subjects in the complete feedback condition took longer to respond to each probe within a blank trial sequence than subjects in the partial feedback condition. The difference between the subjects in the two feedback conditions was greatest on the first probe. Since the feedback manipulation was introduced after Problem 3, and given there was no significant interaction between Feedback, Problem and Trials, this result probably reflects individual differences in the two groups of subjects. This conclusion is supported in subsequent response time analyses as no Feedback effects were evident.

A 2 X 2 X 2 X 5 X 4 (Efficiency X Feedback X Problem X Example X Trial) analysis of variance was performed on the response time data for Problems 5 and 6. The effects of Efficiency, $F(1,20)=7.91$, $p<.01$, Example, $F(4,80)=16.18$, $p<.001$, Trial, $F(3,60)=84.34$, $p<.001$, and Example X Trial, $F(12, 240)=2.60$, $p=.003$, were significant. The efficient problem solvers responded faster (0.90 ln (x+1) seconds) to the probes for Problems 5 and 6 than the inefficient problem solvers (1.30 ln (x+1) seconds). The Example X Trial interaction was similar to the equivalent interaction obtained on Problems 1 to 5 (see Figure 3 and Table 10). The only difference was that the response times were slightly faster for Problems 5 and 6 compared to Problems 1 to 5.

A 2 X 2 X 5 X 5 X 4 (Efficiency X Feedback X Problem X Example X Trial) analysis of variance was performed on the response time data for Problems 8 to 12. The effects of Efficiency, $F(1,20)=15.17$, $P=.001$, Problem, $F(4,80)=3.65$, $p=.009$, Example, $F(4,80)=27.70$, $p<.001$, Efficiency X Example, $F(4,80)=3.90$, $p=.006$, Trial, $F(3,60)=140.30$, $p<.001$, Example X Trial, $F(12, 240)=5.66$, $p<.001$, and Efficiency X Example X Trial, $F(12, 240)=2.44$, $p=.005$, were significant. The Problem effect reveals that the average response time decreased across Problems 8 to 12 from 0.99 ln (x+1) seconds to 0.84 ln (x+1) seconds. The Efficiency X Example X Trial interaction is presented in Figure 6. The curves in this figure are similar to those in Figure 3 with two exceptions. Subjects responded to all the probes faster across Problems 8 to 12 than Problems 1 to 5. The time taken by the efficient problem solvers to respond to the first probe of the second blank trial sequence (1.66 ln (x+1) seconds) was significantly longer than the time taken to respond to the first probe of the third blank trial sequence (1.014 ln (x+1) seconds); $F(1, 960)=15.95$, $p<.01$.

Discussion

Hypothesis testing and set. Set was easily established by Problem 4 in 72 of the 74 subjects tested. Over 70% of the blank trial response patterns for Problems 4 and 5 were consistent with a conjunctive rule. This finding was similar to the results of Lane et al. (1976), with the exception that subjects in the present study needed to be exposed to a greater number of problems before producing response patterns close to the proportion (i.e., 90%) found by Lane et al.. One possibility for this lower proportion of conjunctive hypothesis sampling may reflect differential problem solving skill between the two populations of subjects. The decrease from eight blank trial sequences within a problem, as used by Lane et al., to the five used in the present study may also have contributed to this difference.

One error per problem in the Lane et al. study would have produced a 12.5% reduction in the proportion of blank trial response patterns scored as consistent with a conjunctive, versus 20% reduction in the present study.

Subjects in both feedback conditions continued to sample an equivalent proportion of conjunctive hypotheses in Problems 4 and 5. The removal of complete feedback after Problem 3 did not affect the hypothesis testing behavior. Subjects had clearly developed a set to respond in a particular way before the fourth problem.

Examination of the response time patterns within the blank trial sequences provides further clarification of the hypothesis testing behavior. Responses to the probes became increasingly faster across a blank trial sequence. The greatest decrease in response time occurred from the first to the second probe of the blank trial sequence. This response time pattern reflects two components that are consistent with the hypothesis testing behavior. First, subjects select an hypothesis prior to responding to the first probe of a blank trial sequence. Second, prior to responding to the remaining probes, subjects check for the presence or absence of the selected hypothesis. These response time patterns appear to be consistent with the blank trial assumption suggested by Levine et al. (1964), and Philips and Levine (1974). When subjects are exposed to the contingencies of a blank trial procedure, their responses will be consistent with a selected hypothesis until feedback is encountered.

Response to the probes also became increasingly faster across a problem. This decrease in response time across a problem is consistent with the findings of Gholson (1980) and Gholson and Tumblin (1981) that subjects use strategies to search systematically for the specific attributes that specify the solution to a concept attainment problem. If subjects receive feedback enabling them to disconfirm a sampled hypothesis, then the number of remaining hypotheses that can specify the solution decreases on the next blank trial sequence.

Since exhaustion of the H-domain is dependent upon the number of hypotheses specified by a particular rule (i.e., conjunctive), a single attribute H-domain should be exhausted in less trials than a conjunctive H- domain. Consequently, response times corresponding to single attribute response patterns should decrease at a faster rate across blank trial sequences than response times corresponding to conjunctive response patterns because on each subsequent trial there are fewer remaining single attribute hypotheses to be tested then conjunctive hypotheses. The response time patterns for the efficient and inefficient problem solvers on Problems 8 to 12 appear to correspond with this assessment. The majority of the response patterns of the efficient problem solvers on Problems 8 to 12 was consistent with a single attribute rule, whereas a larger proportion of the response patterns of the inefficient problem solvers was consistent with a conjunctive rule. This hypothesis testing behavior was reflected in the response time patterns presented in Figure 6. The efficient problem solvers took less time to respond to the first probe of the third and fourth blank trial sequence within a problem than the inefficient problem solvers.

<u>Hypothesis testing and strategy efficiency</u>. Given the size of the conjunctive H-domain, the preliminary problems could be solved consistently only by subjects using all the available information in a logical manner. One such strategy is focusing as outlined by Gholson (1980). References to other possible strategies that could be applied to yield this efficient level of concept identification have not appeared in the literature. Gholson (1980) also outlined some concept identification strategies that if used by subjects in this study would

not consistently lead to solution. Amongst these are the hypothesis checking and dimension checking strategies. The efficient subjects in this study were probably using a focusing, or some comparable, strategy, whereas the inefficient subjects were probably using a less efficient strategy such as dimension checking.

The differences in problem solving efficiency reflected in the differential ability of subjects to solve the conjunctive problems should be correlated with other aspects of their behavior. If an efficient strategy such as focusing is used, the conjunctive H-domain can be exhausted in fewer trials than if a less efficient strategy such as dimesnion checking is used. Fewer hypotheses need to be sampled on each subsequent blank trial sequence by those subjects who use an efficient versus an inefficient strategy. Therefore, their responses to the probes would be faster. The response times of the efficient problem solvers in this study did decrease faster across a problem than the response times of those subjects who used a less efficient strategy.

Strategy efficiency and Einstellung. The hypothesis testing behavior of the efficient and inefficient problem solvers provides evidence that supports Levine's (1974; 1975) transfer hypothesis, but contradicts Lewis' (1979) composition hypothesis as an explanation of Einstellung. The crucial evidence is provided by the finding that the majority of the efficient problem solvers solved the first critical problem. According to Levine's hypothesis, the duration of Einstellung is dependent upon exhaustion of the H-domain. Once the H-domain is exhausted then subjects will sample hypotheses that are consistent with a new rule. In order for the efficient problem solvers to exhaust the H-domain within fewer than five blank trial sequences they had to use a focusing strategy. This finding is further dramaticized in that efficient problem solvers in the partial feedback condition who did not solve the first critical problem had no difficulty breaking set on subsequent problems. This was not the case with the inefficient problem solvers in the partial feedback condition. The strategy used by the efficient problem solvers provided them with information that enabled them to exhaust the conjunctive H-domain and to detect the change in solution criteria.

If a strategy similar to focusing can be assumed to involve the execution of more procedures than a less efficient strategy such as dimension checking, it can be argued that Lewis' (1979) composition hypothesis does not account for the results of the various analyses based on problem solving efficiency. According to the composition hypothesis, as a problem solving method is learned, the procedures, which are initially executed independently, become composed into larger collections of autonomous procedures that are executed in an all or none fashion. Upon encountering a change in solution criteria whereby a method containing fewer procedures is needed to solve the problem, the procedures in the old method must be decomposed before a new method can be developed. According to the composition hypothesis, the duration of Einstellung should be directly related to the number of procedures contained in the method. The efficiency results reflect a contrasting position. The efficient problem solvers were more likely to break set on the first critical problem than subjects who used a less efficient strategy (inefficient problem solvers). Indeed, a large proportion of the inefficient problem solvers in this study never broke the conjunctive set.

Interruption of problem solving activity. Breaking the conjunctive set was only affected by the related interruption activity in one particular situation. More subjects in the related interruption condition solved Problem 8 than subjects in the other two interruption conditions. This finding is consistent with

Silveira's hypothesis that an interruption provides an opportunity for solution related information to be discovered. More specifically, this finding may indicate that the opportunity to refine search strategies was of some benefit, but could only show itself after at least one opportunity to consolidate or debug the refined strategy (e.g., during Problem 7). The question then arises: Why did these subjects not continue to demonstrate superior problem solving skill on the last four critical problems? One possibility is that the effect of the related interruption was eliminated by the efficiency differences between the subjects. Since the efficient problem solvers developed their skills prior to the interruption, and since some subjects from all interruption conditions demonstrated efficient problem solving, any beneficial effect the related interruption might have had was short lived. Alternatively, the one significant effect may simply have been due to chance.

Conclusions. In conclusion, analyses of blank trial response patterns and response time patterns revealed that subjects developed hypothesis testing strategies, of varying degrees of efficiency, in order to search systematically for the solution to concept attainment problems. The duration of Einstellung was found to be influenced by strategy efficiency which, in turn, appeared to determine the rate of exhaustion of an H-domain. Use of an efficient strategy enabled subjects to exhaust the conjunctive H-domain and detect the change in solution criterion within the constraints of the problems used in this study. In contrast, use of an inefficient strategy did not enable subjects to exhaust the conjunctive H-domain, or to detect the change in solution criterion. Subjects who used an inefficient strategy continued to sample conjunctive hypotheses even after they had been informed through feedback that the solution was specified by a single attribute.

They appeared to be reluctant to break the conjunctive set. If this information was not provided they continued to sample conjunctive hypotheses, in most cases, for the duration of the critical problems. Since all subjects in the present study were provided with enough information to develop an efficient strategy, a related avenue for future research may be to investigate why and how subjects choose a particular strategy.

Table 1

Sample Concept Attainment Problem

BLANK TRIAL SEQUENCE 1.

Example 1:	X1	K2	D2	M1	Y2
Blank trials 1:	X1	K1	D2	M1	Y2
2:	X2	K2	D2	M1	Y2
3:	X1	K2	D2	M2	Y2
4:	X1	K2	D1	M1	Y2
5:	X1	K2	D2	M1	Y2

BLANK TRIAL SEQUENCE 2.

Example 2:	X1	K1	D2	M1	Y2
Blank trials 1:	X1	K2	D2	M1	Y2
2:	X2	K1	D2	M1	Y2
3:	X1	K1	D2	M1	Y1
4:	X1	K1	D2	M2	Y2
5:	X1	K1	D1	M1	Y2

BLANK TRIAL SEQUENCE 3.

Example 3: X1 K1 D2 M1 Y1

Blank trials ...

BLANK TRIAL SEQUENCE 4.

Example 4: X1 K1 D2 M2 Y1

Blank trials ...

BLANK TRIAL SEQUENCE 5.

Example 5: X2 K1 D2 M2 Y1

Blank trials ...

Solution: D2

Table 2

Number of efficient (E1) and inefficient (E2) subjects from the total sample who solved (S) or did not solve (NS) Problems 6 and 12.

Problem	Efficiency	Solution	
		S	NS
6	E1	15	11
	E2	1	45
12	E1	25	1
	E2	17	29

Table 3

Number of efficient (E1) and inefficient (E2) subjects from the total sample in the complete (CF) and partial (PF) feedback conditions who solved (S) or did not solve (NS) Problems 7 and 12.

Problem	Feedback	Solution S	Solution NS
7	CF	21	15
	PF	10	26
12	CF	30	6
	PF	12	24

Table 4

Number of efficient (E1) and inefficient (E2) subjects in the complete (CF) and partial (PF) feedback conditions who solved (S) or did not solve (NS) Problem 12.

Problem	Efficiency	Feedback	Solution	
			S	NS
12	E1	CF	16	0
		PF	9	1
	E2	CF	14	6
		PF	3	23

Table 5

Number of subjects from the total sample in the no interruption (NI), related interruption (RI), and unrelated interruption (UI) conditions who solved (S) or did not solve (NS) Problems 7 to 9.

Problem	Solution	Interruption NI	RI	UI
7	S	7	11	8
	NS	17	13	16
8	S	8	17	9
	NS	16	7	15
9	S	7	11	8
	NS	17	13	16

Table 6

Percent conjunctive hypotheses sampled by subjects from the subsample in the complete (CF) and partial (PF) feedback conditions across Problems 1 to 12.

Feedback	Problems											
	1	2	3	4	5	6	7	8	9	10	11	12
CF	43	68	67	78	76	62	35	33	21	23	13	12
PF	42	42	70	82	87	70	55	45	42	48	37	43

Table 7

Percent conjunctive hypotheses sampled by efficient (E1) and inefficient (E2) subjects from the subsample across Problems 1 to 12.

Efficiency	Problems											
	1	2	3	4	5	6	7	8	9	10	11	12
E1	52	65	87	88	87	53	35	28	28	28	12	12
E2	33	45	50	72	77	78	55	50	40	43	38	43

Table 8

Number of efficient (E1) and inefficient (E2) subjects from the subsample in the complete (CF) and partial (PF) feedback conditions who solved problems 1 to 12 (Maximum score per cell = 6).

Efficiency	Feedback	1	2	3	4	5	6	7	8	9	10	11	12
E1	CF	3	5	5	6	6	4	6	4	4	5	6	6
	PF	2	3	3	6	5	5	6	6	6	6	6	6
E2	CF	0	0	0	0	0	1	2	1	1	4	4	3
	PF	0	0	0	0	0	0	0	0	0	0	0	0

Table 9

Response times in ln (x+1) seconds of subjects from the subsample in the complete (CF) and partial (PF) feedback conditions for Probes 1 to 4 collapsed across Problems 1 to 5.

Feedback	Probes			
	1	2	3	4
CF	1.95	1.27	1.09	1.01
PF	1.47	1.04	0.91	0.79

Table 10

Mean response times in ln (x+1) seconds of subjects from the subsample for Probes 1 to 4 across the five blank trial sequences for Problems 5 and 6.

Blank Trial Sequences	Probes			
	1	2	3	4
1	2.30	1.54	1.25	1.10
2	1.90	1.29	1.05	0.95
3	1.62	1.08	0.98	0.85
4	1.42	0.95	0.90	0.85
5	1.28	0.91	0.72	0.69

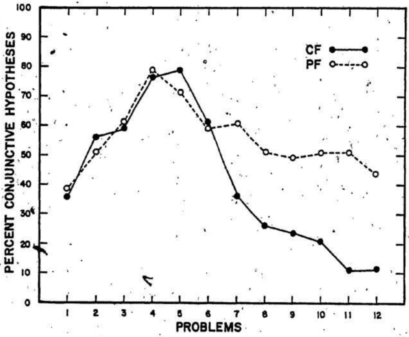

Figure 1: Percent conjunctive attribute hypotheses sampled by subjects from the total sample in the complete (CF) and partial (PF) feedback conditions across Problems 1 to 12.

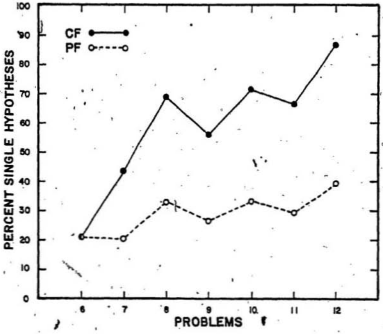

Figure 2: Percent single attribute hypotheses sampled by subjects from the total sample in the complete (CF) and partial (PF) feedback conditions across Problems 1 to 12.

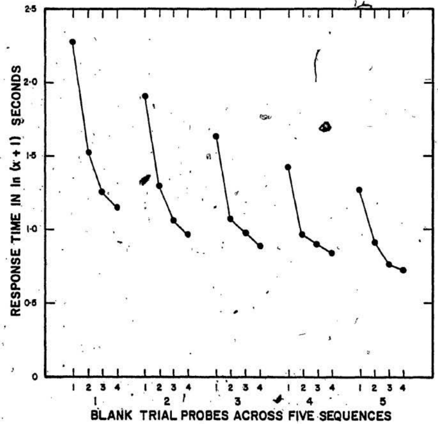

Figure 3: Mean response times in ln (x+1) seconds of subjects from subsample for Probes 1 to 4 across five blank trial sequences collapsed across Problems 1 to 5.

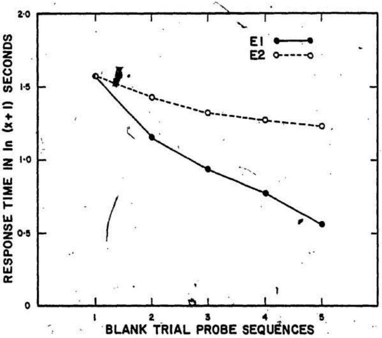

Figure 4: Mean response times in ln (x+1) seconds of efficient (E1) and inefficient (E2) subjects from the subsample for the five blank trial sequences collapsed across Problems 1 to 5.

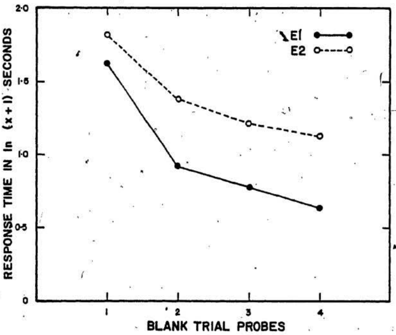

Figure 5: Mean response times in ln (x+1) seconds of efficient (E1) and inefficient (E2) subjects from the subsample for Probes 1 to 4 collapsed across Problems 1 to 5.

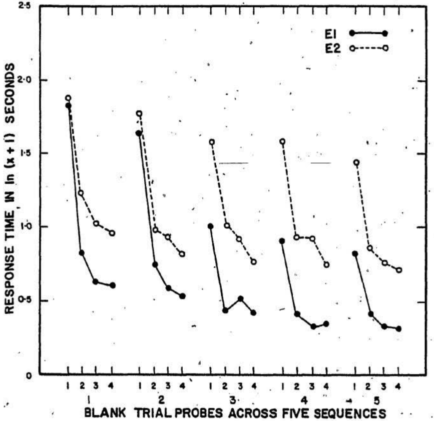

Figure 6: Mean response times in ln (x+1) seconds of efficient (E1) and inefficient (E2) subjects from the subsample for Probes 1 to 4 across the five blank trial sequences collapsed across Problems 8 to 12.

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Appendix A.

Problem Instructions. During this experiment you will be given a number of concept attainment problems to solve. The presentation of the problems are as follows. For each problem you will be presented with five Examples. Each Example is an illustration of a stimulus which contains the Solution Concept for the problem you are working on. The Example will remain on the screen for 10 seconds, and will be followed, one at a time, by five response Trials. The stimulus presented for each response Trial will be a variation of the preceding Example. Your task as to respond 'YES' if you think the presented Trial stimulus contains the Solution Concept, 'NO' if you think it does not. After you have responded to the last Trial stimulus, you will be told whether all of your responses were correct, or that one or more of your responses was incorrect. At the end of the problem you will be told what the correct solution concept was. You will now be given two practice problems to solve. These practice problems are not the same as the problems you will later receive. The purpose of these is to make you familiar with the Example/response Trial presentation procedure.

Practice problems:

1. Example : 6+3=9..
   Trials : 2+5=7, 4X2=8, 6X1=6, 3+5=8, 2+7=9.
   Solution: The correct Solution Concept was an Addition Equation.

2. Example : 5-4=1.
   Trials : 8-4=4, 3X2=6, 9-6=3, 7-5=2, 5X1=5.
   Solution: The correct Solution Concept was a Subtraction Equation.

In order for you to have solved the first practice problem you had to respond 'YES' to each Trial stimuli that was an Addition Equation, and 'NO' to each Trail stimuli that was a Multiplication Equation. In order to have solved the second practice problem you had to respond 'YES' to each Subtraction Equations, and 'NO' to each Multiplication Equation. These practice problems are different to the problems that follow. The only similarity was the presentation of an Example followed by the response Trials.

Now you will receive instructions about the following problems. Each stimulus is a string of five Letter/Number pairs. Each letter is randomly selected from the alphabet and paired with either the number '1' or '2'. A typical string might be: A1 G2 Z2 Q2 L1. During each problem the letters and their position in the string remains the same. Five new letters are chosen for each problem.

The Solution Concept for each problem consists of some combination of Letter/Number pairs that is present in the Examples. Each Letter will have the Number that was paired with it in the Example change on one of the response Trials; either from '1' to '2', or '2' to '1'. On the response Trial after a Letter had its Number change, the Number will return to what it was prior to the change. Your task is to respond 'YES' if you think the Trial stimulus contains the Solution Concept, 'NO' if you think it does not. After you have responded to the fifth Trial stimulus, you will be told whether all of your responses were correct, or that one or more of your response are incorrect. In order to solve the problem you must respond correctly on two consecutive sets of response Trials. If you solve a problem you will be told what the Solution Concept was, and then be given another problem to solve. If you do not solve a problem, you will also be told what the correct