1967

A Factor Analytic Study of Ability and Personality Tests Currently Used in the Philippines

Isabel R. Juan
Loyola University Chicago

SELECTION STRATEGIES IN CONCEPT ATTAINMENT AS A
FUNCTION OF CONCEPT RULE AND MEMORY

By
Everett S. Jacobson

A Thesis Submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment of
the Requirements for the Degree of
Master of Arts

June
1967

LIFE

Everett S. Jacobson was born in Chicago, Illinois on August 3, 1944.

He was graduated from the Chicago Jewish Academy in Chicago, Illinois in June of 1961. He attended Loyola University in Chicago, Illinois from September, 1961 through June, 1965 and there received his Bachelor of Science degree. His graduate studies in psychology were begun at Loyola University in September, 1965.

ACKNOWLEDGEMENTS

The author wishes to express his indebtedness to Dr. Patrick Laughlin, who directed this thesis. His encouragement and guidance were greatly appreciated. The constructive criticisms and helpful suggestions of Dr. Homer Johnson and Dr. Patricia Barger also helped in writing the finished product.

Appreciation is due also to Mr. Richard McGlynn, Mr. Donald Betz, and Mr. Sol Goodman for their gracious technical assistance.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
II.	METHOD	14
III.	RESULTS	20
IV.	DISCUSSION	48
V.	SUMMARY	56
REFERENCES		58
APPENDIX 1		60
APPENDIX 2		63

LIST OF TABLES

Table Page

1. Mean Card Choices to Solution for Three Problems................ 21
2. Analysis of Variance for Card Choices to Solution................ 22
3. Mean Focusing Strategy over Three Problems...................... 27
4. Analysing of Variance for Focusing Strategy...................... 28
5. Mean Scanning Strategy over Three Problems...................... 33
6. Analysis of Variance for Scanning Strategy...................... 34
7. Mean Time to Solution in Minutes for Three Problems.............. 36
8. Analysis of Variance for Time to Solution in Minutes............ 37
9. Mean Number of Untenable Hypotheses for Three Problems........... 40
10. Analysis of Variance for Untenable Hypotheses.................... 41
11. Intercorrelations of Response Measures, All Conceptual Rules..... 43
12. Intercorrelations of Response Measures, Conjunctive Rule......... 43
13. Intercorrelations of Response Measures, Disjunctive Rule......... 43
14. Intercorrelations of Response Measures, Biconditional Rule....... 44
15. Intercorrelations of Response Measures, Exclusion Rule........... 44
16. Intercorrelations of Response Measures, Conjunctive Absence Rule.. 44
17. Ranks for Concept Rules According to Difficulty.................. 46

LIST OF FIGURES

Figure | Page

1. Mean Card Choices to Solution Plotted Against Three Problems (Summing over Paper-No Paper) 23
2. Mean Focusing Strategy Plotted Against Three Problems (Summing over Paper-No Paper) 29
3. Mean Scanning Strategy Plotted Against Three Problems (Summing over Paper-No Paper) 35
4. Mean Time to Solution in Minutes Plotted Against Three Problems (Summing over Paper-No Paper) 38
5. Mean Untenable Hypotheses Plotted Against Three Problems (Summing over Paper and no Paper) 42

CHAPTER I

INTRODUCTION

In discussing the field of human thinking and problem solving it is of interest to define the process of forming concepts and determining the ways in which these concepts are applied once formed. Bruner, Goodnow, and Austin (1956) discuss these topics at length. The process of forming concepts is basically one of categorizing, which enables an individual to render discriminably different stimuli equivalent; this in turn lessens the confusion stemming from many sources of environmental stimulation. Specifically, concept attainment could be defined as the process of finding predictive defining attributes distinguishing exemplars from non-exemplars of a class one seeks to discriminate. In the process of concept attainment an individual learns to isolate and use defining attributes of a positive instance of the concept - that is, instances which exemplify the concept. These attributes are used as criterial bases for usable concept categories. It can be said that a good deal of the interaction between an individual and his environment involves dealing with classes or categories of things rather than with unique objects or events.

In defining concepts, certain dimensions on which the stimuli belonging to a conceptual class vary are important; these are termed relevant, as opposed to irrelevant dimensions. Dimensions have at least two values or attributes or values; for instance, blue and green are two different values in the color dimension.

Investigations of human conceptual behavior can be divided into two general groupings - reception procedures and selection procedures. Reception procedures generally involve getting a subject to learn how to categorize many patterns of stimuli; in many cases they are also told the relevant stimulus dimensions. The selection procedure is more recent and was given impetus by Bruner, Goodnow, and Austin. The subject is presented with a stimulus population, with one member taken as illustrative of the concept to be attained. He then proceeds to make hypotheses about the solution, selecting instances and revising incorrect hypotheses until the correct concept is attained. This procedure allows the experimenter to determine if the subject is using any systematic strategy or plan of attack to attain the solution. Each selection of an instance, positive or negative, contains the crucial elements of stimulus, response, and informative feedback (Bourne, 1966).

Bruner et al. have gone farther and have broken down concept attainment into hypotheses, strategies, and decision making. Decisions are made in sequence, and later decisions are contingent upon earlier ones. Regular modes of doing this were identified and labelled as strategies. Two basic selection strategies were named--focusing and scanning. Generally, focusing involves testing the relevance of all possible hypothese involved in a particular attribute or attributes by selecting an instance differing in one (conservative focusing) or more than one (focus gambling) attributes from a particular focus card. Scanning involves testing specific hypotheses singly (successive scanning) or all at once (simultaneous scanning) or some intermediate number (Laughlin, 1965). The scanning strategies place a large demand upon memory, for to use successive scanning effectively a subject must remember all hypotheses tested and rejected upon earlier instances plus all instances encountered, to keep new hypotheses in accord with them. Simultaneous scanning involves remembering a large number of possible solutions. Reception designs have also isolated partist and wholist approaches; wholists focus upon all attributes of the first positive instance and modify their hypotheses on the basis of information obtained upon succeeding instances. Partists' initial hypotheses contain one or more, but no all, attributes of the first positive instance. These strategies are analogous to focussing and scanning in the selection papradigm (Bourne, 1966). It should be noted that strategies as ideally formulated are not necessarily utilized by the subject, the way the strategies were actually used in practice could be determined by comparing the subject's actual performance with the standards set by ideal strategies.

Also involved in the formation and attainment of concepts are conceptual rules; these specify how relevant attributes are combined to classify stimuli. Bourne emphasizes that rules and attributes define specific concepts but are definitely independent. For example, "green and triangular" is a specific concept; but these same attributes could be combined by the rule "green and/or triangular." Using this distinction, Haygood and Bourne (1965) have divided all conceptual behavior into two basic components-Rule Learning (RL), in which the relevant attributes are known, and Attribute Identification (AI), wherein subjects begin their tasks knowing the rule under consideration. These investigators have performed experiments to demonstrate both types of conceptual behavior. In addition, they have added a third type - Complete Learning (CL), in which both relevant attributes and relevant rule are unknown. Performance on four different concept rules was compared; these rules were conjunction (both A and B are required), disjunction (either A or B is required), joint denial (neither A nor B can be present), and conditional (if A is present, then B must be also). Each subject had to work on five successive problems of the same type; the reception procedure, as outlined previously, was used. Haygood and Bourne found that, on the first problem, the rules differed markedly in difficulty, with conditional and disjunctive showing the most errors and most trials to solution. Since these differences diminished over successive problems, the authors felt that the differences could have been due, at least in part, to relative familiarity of the subjects with the different conceptual rules. After all five problems, performance on AI and CL was almost identical, suggesting that over trials the rules were learned and remaining differences were due to the process of identifying relevant attributes. Since many theoretical interpretations of conceptual learning have been based upon the identification of relevant attributes regardless of the rule condition dealt with, the authors offer the attribute-rule distinction as a useful one for future research.

Because rules represent such an important dimension in the determination of conceptual behavior, much research has been devoted to differentiating among them. In an important pioneering study using the selection procedure, Bruner, Goodnow, and Austin (1956) found disjunctive concepts more difficult to attain than conjunctive. Another early study of possible differential difficulty of conceptual rules was that of Hunt and Hovland (1960). The procedure used was to determine which rule a subject would choose if given a choice of three rules which were consistent within a stimulus grouping. The rule choices were conjunctive, disjunctive, and relational (e.g. A is larger than B). Subjects were shown a series of patterns designated as positive or negative. During the actual test series they were to select those designs they believed to be positive instances of the concept preceding. Under these conditions conjunctive and relational concepts were selected significantly more frequently than disjunctive ones. The investigators, however, question the generality of the population of concepts used in their experiment. The format of presenting the subject with a choice of describing a group of positive and negative instances as one of two possible concept rules was used by Wells (1963). He found that the conjunctive rule was almost always chosen. Some subjects were confronted with a situation in which only the disjunctive solution was correct; this was followed by a case in which either rule could be used. The results showed that subjects given some disjunctive training showed significantly greater preferences for the disjunctive solution than subjects not receiving such training. Wells argued for a natural "set" for conjunctive solutions, which is brought into the experimental situation. There is a definite similarity between Wells' findings and those of Haygood and Bourne, in which differences between conceptual rules declined as a function of practice.

Differences between conjunctive and disjunctive solutions were also studied by Conant and Trabasso (1964). A selection procedure was used; subjects solved both types of concepts, and again disjunctive concepts were significantly more difficult to attain. In addition, more negative and more redundant instances were chosen in disjunctive situations. These investigators believed that the rule differences were due primarily to differences in the required usage of positive and negative instances. Since subjects appeared to utilize information contained in negative instances less readily, disjunctive solutions should logically have been more difficult. This is true because the attainment of a disjunctive concept requires much greater use of negative instances. These explanations of differential rule difficulty also appear plausible in light of the work of Hovland and Weiss (1953), who found that correct concepts were attained more readily when subjects were presented with a series of positive instances. Again, however, these differences appear to be modifiable with suitable training.

One of the most extensive investigations of difficulty of different concept rules was that of Neisser and Weene (1962). This study showed ten separate rules based upon concepts containing two relevant attributes. The authors arrange their rules into three hierarchal levels of complexity. The simplest is level I, featuring only simple affirmation and negation. Level II features conjunctive or disjunctive rules, while Level III contains rules that are composites of conjunctive and disjunctive. Level I concepts include simple affirmation and negation; the relevant attribute is either present or absent. Level II concepts include conjunction, disjunction, exclusion (A and not B), disjunctive absence (not A and/or not B), conjunctive absence (not A and not B), and implication or conditional (if A then B). Level III concepts include exclusive disjunction (either A or B but not both) and biconditional (if A is present then B must be also; if neither is present, the instance is still positive). This threefold hierarchy is based upon levels of structural complexity. On this basis, attainment of a higher concept depends upon attainment and utilization of concepts at lower levels; this is posited by the authors to correspond to a hierarchal arrangement of conceptual processes in the person. In this schema, Level III concepts are not learned as such but are constructed from their component parts at lower levels. The data, based upon verbal consonants, support a hierarchal order of concept difficulty such as the hypothesized one. The processes of negation, conjunction, and disjunction are posited by the experimenters as basic to the hierarchy. Haygood and Bourne point out that differences in difficulty between the three levels could be considered in terms of stimulus uncertainty. Level III concepts show no homogeneity or communality among individual stimulus patterns in either positive or negative categories; thus, highly efficient strategies based upon the discovery of common attributes must be abandoned. Haygood and Bourne define rule complexity in terms of contingencies defined by the presence and absence of focal attributes. For instance, if redness and squareness are selected as focal attributes, the four contingencies so defined are red square, red-not square, not-red square, and not-red not-square. When two focal attributes are selected for relevancy, the four contingencies are mapped upon a two-response system consisting of examples and non-examples of the concept. Using this procedure, Level III concepts could be shown to have a 2-2 split in response contingencies, while Level II concepts are featured by a 3-1 split; the Level III concepts are therefore characterized as possessing more stimulus uncertainty.

A study performed by Laughlin and Jordan (in press) employed conjunctive, disjunctive, and biconditional concepts. For the criteria of number of card choices and time to solution, disjunctive concepts were significantly more difficult than conjunctive, but there were no differences between conjunctive and biconditional. The first finding agrees with those of Bruner et al., Conant and Trabasso, and Hunt and Hovland, but the second is at variance with that of Haygood and Bourne. The latter investigators found conditional and biconditional concepts more difficult than inclusive disjunction and conjunction in respect to rule learning. Laughlin and Jordan trace the differences partly to the differences between selection and reception procedures; since Haygood and Bourne used programmed sequences with equal numbers of positive and negative instances, subjects were more likely to draw negative instances useful for the solution of concept rules other than conjunctive than would be the case for the selection paradigm. Also, Haygood and Bourne's four-attribute and three-value concept universe could be contrasted with Laughlin and Jordan's six-attribute and two value universe; biconditional concepts could become relatively more difficult than other types as number of values per attribute increases. Another experiment found no differences between conjunctive and biconditional rules in regard to relevant and irrelevant stimulus dimensions (Keptos and Bourne, 1963); this indicates an element of similarity between them.

The foregoing discussion illustrates the importance of conceptual rules for grouping relevant attributes in the concept attainment process. Another important dimension is the amount of strain that the conceptual process places upon the memory of the subject. In their original work Bruner, Goodnow, and Austin have recognized the differential demands that focusing and scanning strategies make upon memory; they posit the focusing strategy as a generally more efficient one because the process of isolating relevant attributes is less of a memory load than the scanning approach of eliminating irrelevant hypotheses. Bourne (1966) notes that the memory variable arises both in selection and reception designs; typically, in both cases more instances are needed to attain a concept than the bare minimum number dictated by the strategies. This finding in turn is related to individual differences in the ability to retain essential information.

Several studies have attempted to demonstrate the effects of memory requirements upon conceptual tasks by comparing performance on successive and simultaneous presentation of stimulus material. One such study was that of Cahill and Hovland (1960). In general they found that performance was superior in cases where the complete population of stimulus material was available to subjects; most errors were due to a failure to make use of prior instances in the ways necessary to make essential inferences. They also found a recency effect; wrong solutions were likely to occur in accordance with the remoteness in time of previously presented but unavailable stimuli. Such findings seem to be congruent with the theoretical groundwork laid by Underwood (1952); this author spoke in terms of response contiguity in concept learning, which could well be influenced by memory factors.

An extensive review of literature on the topic of memory effects in conceptual tasks was compiled by Dominowski (1965). Among the studies cited by Dominowski were those of Hunt (1961), who performed a series of three studies to test the manner in which intervening concept instances interfere with memory. Subjects derived a concept on the basis of positive and negative instances shown in a training series; several key instances in the training trials were required to identify unknown test instances as positive or negative, depending upon the concept acquired during training. In each experiment the key training instances were separated from the test trials by a different number of intervening instances. The trend of the data was toward a linear relationship between intervening trial-test stimuli and inconsistent test instance hypotheses. This is offered as evidence for the interference with retention of essential information by intervening instances.

The experimental conditions that can add to the subject's cognitive memory load are many and varied. For instance, Laughlin (1965) found that focusing sbrategy was used more with two person groups engaged in a conceptual task than for siggle individuals. Although this difference on number of card choices to solution was not upheld by the Taylor-McNemar correction model, Laughlin suggests that the findings could be due to better memory conditions for the groups, as reflected by fewer card choice repetitions as well as fewer hypothesis repetitions and untenable hypotheses. In addition, the opportunity for group discussion could have aided them in realizing that focusing is a strategy that reduces memory loads and allows a constant increment of information with every new card choice. However, Laughlin and Doherty (1967) found that group discussion did lead to fewer card choices, fewer untenable hypotheses and more time to solution, but memory as measured by the use of paper and pencil had no significant effects; no main effects were found for focusing and scanning strategies as well.

In discussing the role of memory in conceptual processes, including the simultaneous and successive presentation methods referred to earlier, Bourne, Goldstein, and Link (1964) characterize the results as being on an availability dimension, defined as number of previously exposed stimuli available to the subject for inspection on any given trial. By systematically varying the number of stimuli available on any given trial, Bourne et al. hoped to obtain an estimate of the effects of the availability dimension. Their overall finding was that greater requirements for retaining information lead to poorer conceptual performance; this effect can even overshadow inferential mistakes. Finally, those memory errors due to lack of availability of previously exposed stimulus material are a function of task complexity;

more complex conceptual tasks lead to greater interference from memory errors.

The present state of research in the area of concept attainment is such that the differences between conceptual rules, though evident in some cases, have not been thoroughly delineated. As Haygood and Bourne have emphasized, future research designs in the field must take account of rule differences regardless of whether attributes, rules, or some combination of both are being explored. The application of selection strategies to different conceptual rule types should aid in the precise determination of conceptual rule difficulty. Virtually all experiments up till the present have restricted this application of selection strategies to conjunctive and disjunctive conditions. Laughlin and Jordan (in press) have formulated quantitative scoring rules for the focusing and scanning strategies in conjunctive, disjunctive, and biconditional types. In doing so they found more focusing for conjunctive problems than disjunctive, and more focusing for biconditional than disjunctive. In addition significantly less scanning was found with inclusive disjunction than with the other two types used in the experiment. The present study has extended quantitative scoring rules for selection strategies to two additional rule types. The full range of conceptual types covered in the present study was as follows: 1) Conjunction- concepts are defined by the joint presence of two or more values. "Both values A and B must be present." 2) Exclusive disjunction- two alternatives are implied, but there is a restriction. "Either A or B must be present, but both cannot be present at the same time." (If neither value is present, than the result is the same as when they are both present- the conceptual conditions are not satisified). 3) Biconditional- a double implication is present, insofar as the presence of one relevant value implies the presence of the other. "If A is present than B must be present, and if B is present then A must be present." If neither A nor B is present, then the instance is positive because the conceptual rule conditions have not been violated. 4) Exclusion- joint presence is required, but one of the values is stated in negative terms. "A must be present but B must not be." Every exclusion concept can be stated two ways; the above concept could also be stated: "non-B must be present and non-A must not be." 5) Conjunctive absence- joint presence of two values is required, but both values are stated in negative terms. "A must not be present and B must not be present." Of these conceptual rule types, all belong to the second level of Neisser and Weene's hierarchy except for biconditional and exclusive disjunction.

In addition to applying the focusing and scanning strategies to the above rules, the present study also investigated further the effect of differential memory burdens in concept attainment by utilizing two different memory conditions. It was hypothesized that a difficulty differential for different rules would appear both in performance in using the two selection strategies, as well as performance upon the gross efficiency measures of card choices to solution, untenable hypotheses, and time to solution. If the differences in memory load were factors in performance, as memory load is manipulated in this study, then the same measures would have reflected them as well. More specificially, since focusing and scanning as measured by the scoring rules used in this study are efficiency measures based upon number of card choices to solution, their relative effectiveness as strategies should have decreased in more difficult conceptual rules and experimental conditions calling for a heavier memory load. Finally, on the basis of studies utilizing the selection procedure previously, no positive inter-problem transfer effect was hypothesized (Laughlin and Jordan, in press; Laughlin, 1965). Possible significant interactions among the independent variables were also investigated in this study.

CHAPTER II

METHOD

<u>Design and subjects</u>.-- A 5 X 2 X 3 repeated measures factorial design was used with the variables: a) concept rule (conjunctive, disjunctive, biconditional, exclusion, conjunctive absence); b) use of paper and pencil (allowed and not allowed); c) problems (three per subject).

Subjects were 80 Loyola University undergraduate students enrolled in psychology courses. They were randomly assigned to the various experimental conditions in equal numbers per condition.

<u>Non-solvers</u>. Two criteria were used to deine non-solvers of problems whose data was not included in the analyses. These criteria were as follows: a) the Subject did not attain the required concept for the first problem in sixty minutes time or less. b) The Subject did not attain the required concept for the first problem in twenty card choices or less. Both criteria were used to define a non-solver; if a Subject exceeded one of the criterion standards, he was allowed to continue with the full series of three problems.

Using the above criteria, two Subjects were excluded from the exclusive disjunction cell and one was excluded from the exclusion cell.

Those subjects given wrong information by the experimenter (e.g. were told that a positive instance was negative) were dropped and their data was considered invalid. Nine subjects were dropped for this reason, regardless of whether they were solvers or non-solvers.

Stimulus display and problems.--The stimulus display was a 28 X 44 inch white posterboard containing an 8 X 8 array of 64 2 1/2 X 4 inch cards drawn in colored ink with dark outlines. The 64 cards represented all possible combinations of six plus and minus signs in a row. Each position had a different color (e.g. first position was always blue). The name of the color was the attribute, while plus or minus represented the value of each color; e.g. attribute red: value: minus.

The cards were systematically arranged upon the display board. Thus, the top four rows were blue plus and the bottom four rows were blue minus.

The following concept rules were used:

1) conjunction-concepts are defined by the joint presence of two values. For instance, black plus and yellow minus.

2) Exclusive disjunction-conceptual type implies an either/or relationship, but has a restriction upon it; for instance, either black plus or yellow minus but not both.

3) Biconditional-double implication; the presence of one value implies the presence of the other. For instance, if black plus then yellow minus. The concept allows for a non-contradictory positive instance; this occurs when the opposite of both stated values appears on the positive card. For instance, the combination black minus and yellow plus on a positive instance of the above example.

4) Exclusion-the joint presence of two values is required, but one of them is stated negatively. For instance, Black plus and not yellow plus. This concept can also be stated as yellow minus and not black minus.

5) Conjunctive absence-the joint presence of two values is required, and both values are stated negatively. For instance, neither black minus nor yellow plus.

Corresponding problems for the five concept rules had the same relevent attributes and values. The number of relevant attributes was always two. Within each rule-memory condition, 8 subjects were used, with each S required to solve three problems. Required problems and initial cards were randomly selected. Each S's problems were of the same concept rule type; e.g. black and green minus, red minus and orange plus, and blue plus and orange minus could represent the triad of problems an S assigned to the conjunctive condition had to solve. Instructions to use or not use pencil and paper remained the same throughout each S's series of three problems.

Procedure--Each S was given a 3 X 5 inch typed index card which thoroughly explained the concept rule. Each card contained an example of the concept under consideration, to which S could refer throughout the course of his three problems. The complete text of the instructions was as follows:

"This is an experiment in thinking. There are 64 cards on this board, arranged in 8 rows of 8 cards each and numbered from 1 to 64. These cards are all the possible combinations made by taking 6 colors, each color being either a plus or a minus. (The 6 colors were pointed out, each a plus or a minus). The colors are called attributes, and the plus or minus are called values.

These cards can be grouped together or categorized in a large number of possible ways by following a specified rule. This rule defines a concept, and a concept is the group of all cards that satisfy the rule.

(Conjunction) The rule is that the card must have both a particular value (plus or minus) on one color and a particular value on another color. For example, all the cards with a black plus and a yellow plus are the concept, "black plus, yellow plus." Or, all the cards with both a blue minus or a red plus are the concept "blue minus, red plus."

(Exclusive disjunction) The rule is that the card must have either a value (plus or minus) on one color or a value on another color but not both. For example, all the cards which have a black plus or a yellow plus but not both a black plus and a yellow plus are the concept "black plus and yellow plus but not both." Or, all the cards which have a blue minus or a red plus but not both a blue minus and a red plus are examples of the concept "blue minus or red plus but not both."

(Biconditional) The rule is that if the card has a value (plus or minus) on one color, then it must have a value on a second color and vice-versa. For example, if the card has a yellow plus then it must have a black plus to be a member of the concept "if black plus, then yellow plus, and vice-versa," and if it has a black plus, then it must have a yellow plus to be a member of the concept "if yellow plus then black plus and vice-versa." Finally, if the card has neither a black plus nor a yellow plus, then it still satisfies the rule "if yellow plus then black plus." Or, if the card has a blue minus, then it must have a red plus to be a member of the concept "if blue minus then red plus and vice-versa;" and likewise, if the card has a red plus, then it must have a blue minus to be a member of the concept "if blue minus then red plus and vice-versa."

(Exclusion) The rule is that the card must have a particular value (plus or minus) on one color and must not have a particular value on another color. For example, the cards which have a black plus and do not have a yellow plus are the concept "black plus and not yellow plus." Or, all the cards which have the blue minus and do not have a red plus are an example of the concept "blue minus and not red plus."

(Conjunctive absence) The rule is that the card must not have a value (plus or minus) on one color and must not have a value on another color. For example, all the cards which do not have a black plus or a yellow plus are examples of the concept "neither black plus nor yellow plus." Or, all the cards which do not have a blue minus or a red minus are an example of the concept "neither blue minus nor red minus."

In the problems I will have some concept in mind and your job will be to determine what it is. I'll start you off by giving you the number of one of the cards that is included in the concept; that is, one of the group of cards that exemplify the concept I have in mind. Then you will select any card you wish to in order to get information as to whether the card you selected is also included in the concept. If the card you selected is included in the concept, I will say "yes," and if the card you selected is not included in the concept, I will say "no." To be included in the rule, it must exactly satisfy the concept. (Give examples of a card that possibly satisfies one aspect of the rule, but not entirely the rule.)--a card that is half right). Then, you will make a hypothesis as to what concept you then think I have in mind. If your hypothesis is correct, I'll say yes and you've solved the problem. If your hypothesis is not correct, I'll say no. A "no" means that your hypothesis is not entirely correct, althought it might be partially correct. (Give a parallel example of a partially correct hypothesis to the one given above). If I say "no" you select another card and again I'll say yes or no depending upon whether the card you select is included in the concept, and again you will make a hypothesis and I'll say "yes" or "no" to the hypothesis. So, you keep repeating the procedure of selecting a card and making a hypothesis until you've solved the problem. The object is to solve the problem in as few card choices as possible, regardless of time.

For paper subjects - You can use this paper if you wish to take notes and help your memory."

Then the concept rule was reiterated and further examples were given if necessary.

CHAPTER III

RESULTS

The data were analyzed for the dependent variables card choices to solution, focusing strategy, scanning strategy, mean time to solution, and untenable hypotheses. Throughout the results section, the following abbreviations were used: C - conjunction, D - exclusive disjunction, B - biconditional, E - exclusion, and A - conjunctive absence.

Card choices to solution. The mean card choices to solution for conjunctive, disjunctive, biconditional, exclusion, and conjunctive absence rules for three problems are in Table 1. Results of the analysis of variance for card choices are in Table 2. The graph of mean number of card choices, summing over paper and no paper groups, plotted against the three problems is in Figure 1.

Table 1

Mean Card Choices to Solution for Three Problems

Paper

Problem	C	D	B	E	A	Total
One	5.13	10.8	9.63	9.00	10.9	45.39
Two	7.13	6.75	10.5	3.50	5.13	33.01
Three	2.88	8.38	4.25	7.38	3.75	26.64
Total	15.1	25.9	24.4	19.9	19.8	

No Paper

Problem	C	D	B	E	A	Total
One	8.63	9.75	12.5	11.4	9.38	51.64
Two	6.00	6.25	13.8	6.25	5.00	37.25
Three	4.38	5.50	8.88	8.13	8.50	35.39
Total	19.0	21.5	35.1	25.8	22.9	

Table 2

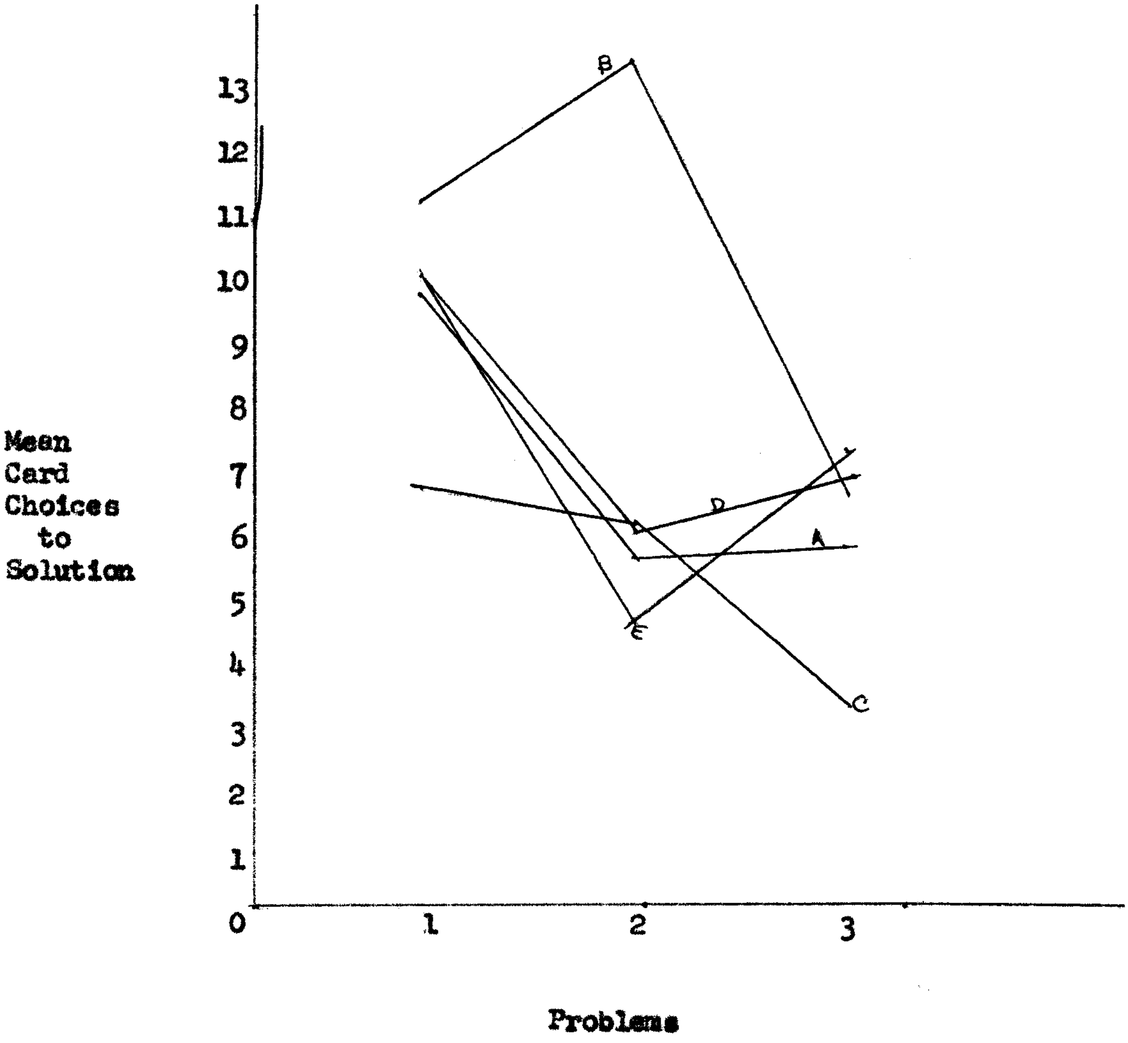
Analysis of Variance for Card Choices to Solution

Source	d.f.	MS	*F*
Memory (M)	1	98.82	1.34
Rule (R)	4	112.19	1.53
M X R	4	39.90	
Error (B)	70	73.47	
Problems	2	267.82	7.12**
P X M	2	4.06	
P X R	8	54.39	1.44
P X M X R	8	18.73	
Error (W)	140	37.64	

$^{**}p < .01$

Figure 1

Mean Card Choices to Solution Plotted Against Three Problems (Summing over Paper- No Paper)



The only significant effect for the card choices to solution measure was for problems, with card choices needed for solution decreasing over three problems ($\underline{F}$ (1, 140)- 7.12, $\underline{p}$ <.01). Since there were no significant differences between memory conditions, rule, nor any significant interactions between these variables, Duncan Multiple Range Comparisons were performed on the three problems summing over the other variables. There were significant differences between performance on problems three and one and between problems two and one ($\underline{p}$ <.01), but not between problems two and three. (See Appendix 1). Trend analysis was then performed to assess the linearity of the trend toward improvement across problems; the linear trend was significant ($\underline{F}$ (1, 140)- 13.02, $\underline{p}$.< 01). The quadratic effects was nonsignificant ($\underline{F}$ (1, 140)- 2.72). (See Appendix 2).

Focusing strategy. Focusing strategy was scored in the following manner. For conjunctive problems, each new card choice had to obtain information on one new attribute. New information was obtained if the card choice altered only one attribute not previously proven irrelevant (conservative focusing), or, if more than one attribute was altered (focus gambling), the instance was either positive or the ambiguous information was resolved on the next card choice by altering only one attribute. Second, if a hypothesis was made it had to be tenable considering the information available. Untenable hypotheses were of two types: 1) a hypothesis for a value of an attribute when the other value had occured on a positive instance; for example, the hypothesis "green plus and red plus" would be untenable if green minus had occured on a previous positive instance. Or, 2) a hypothesis for a value which had occured on a previous negative instance. For example, the hypothesis "green plus and red plus" when green plus had occured on a previous negative instance.

For biconditional problems, information had to be obtained on new attribute on a card choice, either by changing one attribute at a time, as per conjunctive focusing, or by changing five attributes at a time. For example, if the subject selected a positive instance changing every attribute from the problem card except for green plus, then the attribute green has been shown to be irrelevant. Only conservative focusing was scored for biconditionals; positive focus gambling cannot apply. For example, if the correct concept was "if red plus then green plus and vice-versa," a card containing the combination red minus and green minus would also be positive; thus, a subject could eliminate both relevant attributes by eliminating more than one attribute on a positive instance. If a card choice was negative and more than one and less than five attributes were changed, ambiguous information could have been resolved via focusing by changing one or five attributes on the following card choice. A hypothesis had to be tenable considering the information available. Untenable hypotheses were of two types: a) a hypothesis for a value of an attribute when the opposite of one of the values b ut not both had previously occured on a positive instance. For example, the hypothesis "if red plus then green plus and vice-versa" would be untenable if only red minus had appeared on a positive instance. Or, b) a hypothesis for a value when both values or the opposite of both values had previously occured on a negative instance. For example, the hypothesis "red plus and green plus" would be untenable when red minus and green minus occured together on a previous negative instance. Finally, credit for eliminating an additional attribute was scored when the direct opposite (non-contradictory) form of the concept to be attained was given by the subject. Since the presence of one relevant attribute in a biconditional concept implies the presence of the other, the presence of neither relevant attribute on an instance would not contradict the conceptual conditions for a positive instance. For example, if the concept to be attained was "if red plus then green plus and vice-versa," and the subject made the hypothesis "if red minus then green minus and vice-versa," he was given credit for eliminating an additional attribute because his hypothesis was tenable considering the information available.

For exclusive disjunction problems, focusing strategy is scored in the same way it is scored for biconditional problems, except for untenable hypotheses which could have been of two types: a) same as first rule for biconditionals; b) a hypothesis for a value when both values had previously occured together on a positive instance. For example, the hypothesis "red plus or green plus but not both" when either the combination of red plus-green plus or the combination red minus-green minus had appeared together on a previous positive instance.

For exclusion concepts, scoring of focusing strategy was identical with that for conjunctives with one addition. As noted previously, every exclusion concept can be stated two ways, both of which are equivalent. For instance, the exclusion concept "red plus and not green minus" can be stated green plus and not red minus" and both are equal. Therefore, if the subject had to attain the concept "red plus and not green minus" and gives the hypothesis "green plus and not red minus," he was given credit for eliminating an additional attribute because his hypothesis was tenable considering the information available.

For conjunctive absence problems, focusing strategy was scored the same way as it is for conjunctive problems in every respect. The only condition for doing this was translating each absence hypothesis into a conjunctive hypothesis; for example, "not red plus and not green plus" must be translated into "red minus and green minus" and can then be scored as a conjunctive problem.

The mean focusing scores for conjunctive, disjunctive, biconditional, exclusion, and conjunctive absence rules for three problems are in Table 3. Results of the analysis of variance for focusing are in Table 4. The graph of mean focusing strategy, summing over paper and no paper, is in Figure 2.

Table 3

Mean Focusing Strategy over Three Problems

Paper

Problem	C	D	B	E	A	Total
One	.425	.175	.239	.129	.049	1.02
Two	.373	.205	.261	.691	.425	1.96
Three	.595	.279	.534	.466	.324	2.20
Total	1.38	.659	1.03	1.29	.798	

No Paper

Problem	C	D	B	E	A	Total
One	.393	.130	.239	.331	.236	1.33
Two	.540	.361	.215	.541	.214	1.75
Three	.574	.421	.405	.443	.353	2.19
	1.51	.912	.859	1.31	.803	

Table 4

Analysis of Variance for Focusing Strategy

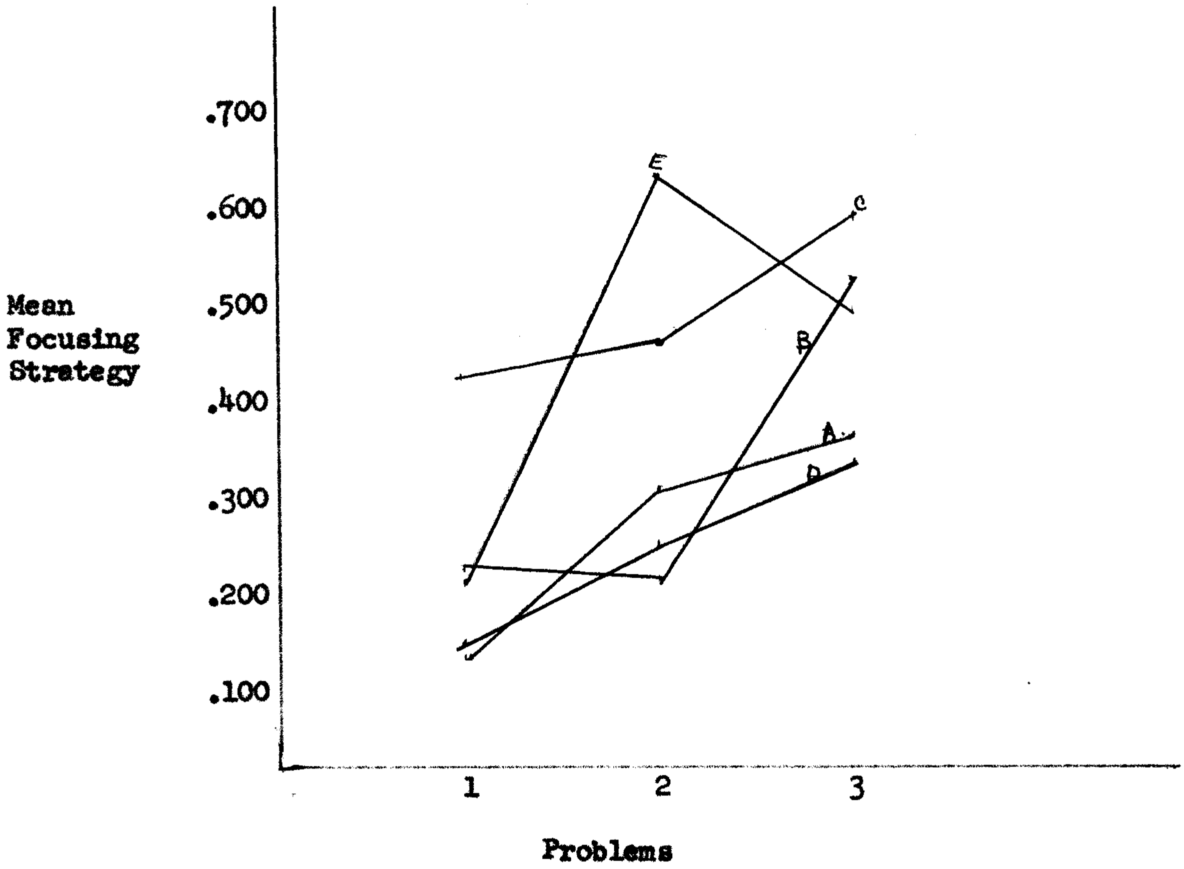
Source	*d.f.*	MS	*F*
Memory(M)	1	.01	
Rule(R)	4	.49	3.77*
M X R	4	.03	
Error(B)	70	.13	
Problems	2	.90	10.00**
P X M	2	.04	
P X R	8	.12	
P X M X R	8	.09	
Error(W)	140	.09	

*$p < .05$ **$p < .01$

Figure 2

Mean Focusing Strategy Plotted Against

Three Problems (Summing over Paper-No Paper)



The effect for rule was significant ($F(4, 70) = 3.77$, $p < .05$). The problems effect was also significant, with an increase in focusing from problem one to problem three ($F(2, 140) = 4.76$, $p < .01$). Duncan Multiple Range Comparisons were performed for differences between rules, summing over paper-no paper conditions and over problems. Significantly more focusing was found for conjunctive than for disjunctive rules ($p < .01$), more for conjunctive than for conjunctive absence ($p < .01$), more for conjunctive than for biconditional ($p < .05$), more for exclusion than disjunctive ($p < .05$), and more for exclusion than for conjunctive absence ($p < .05$). (See Appendix 1).

The Duncan Comparisons for problems, summing over memory and rules, showed the differences between problems three and one and between problems two and one to be significant ($p < .01$). (See Appendix 1). Trend analysis showed the problems effect to be significantly linear ($F(1, 140) = 18.62$, $p < .01$). The quadratic effect was non-significant ($F(1,140) = 1.23$). (See Appendix 2).

Scanning strategy. Scanning strategy was scored in the following manner. For conjunctive problems, each card selected by the subject was compared with the original problem card. If the selected card was positive, all concepts differing on the given and selected cards were eliminated; if the selected card was negative, all hypotheses identical on the given and selected cards were eliminated. The total number of concepts thus eliminated plus concepts eliminated by direct hypothesis was divided by the total number of card choices to give the average number of hypotheses eliminated per card choice.

For exclusive disjunction problems, each selected card was compared with the original problem card. If the selected card was positive, then only concepts which involved combinations of attributes differing from and identical with the given card were eliminated. Concepts involving combinations of attributes identical with the given card and combinations of attributes differing between given and selected cards were not eliminated. For example, if the original card contained the combination orange minus and blue minus and the subject chose a card containing the combination orange plus and blue plus or orange minus and blue minus, and the card was positive, then orange and blue remained as a tenable combination. If the selected card was negative, then all hypotheses identical between given and selected cards were eliminated.

Since the original problem card could have contained either one of the two values (e.g. either red plus or green plus) and each negative card could have contained either both or neither of the values, e.g. either red plus and green plus or red minus and green minus, and subjects were not informed which was the case, the direct opposite of each tenable hypothesis was itself tenable. For instance, if the correct concept was, "red plus or green plus but not both," then the hypothesis "red minus or green minus but not both" is tenable considering the information available. To rectify this, the formula hypotheses eliminated minus one divided by twice the number of card choices $(h-1)/2c$ was used, and the scanning coefficient became comparable to that for conjunctive problems. Subjects were given credit for eliminating the hypothesis as stated and its non-contradictory opposite when using the scanning strategy; concepts eliminated by direct hypothesis eliminated the stated form only.

For biconditional problems, scanning strategy was scored in the same manner in which it was scored for exclusive disjunctive problems. Since the original problem card could have represented the stated form of the concept (e.g. if orange minus then blue minus and vice versa) or its corresponding non-contradictory form (the combination orange plus and blue plus applied to the above example), and subjects were not informed which was the case, the formula (h-1)/2c was again used to make the scanning coefficient comparable with that of conjunctive problems.

For exclusion problems, scanning was scored in the same way in which it was scored for the conjunctive problems, with one modification. Since, as noted previously, every exclusion concept could be stated two equivalent ways (e.g. orange plus and not blue plus or blue minus and not orange minus), it follows that every tenable exclusion hypothesis could be stated two equivalent ways. Thus, the formula (h-1)/2c was used to make the coefficient comparable to that obtained for conjunctive problems.

For conjunctive absence problems, scanning was scored in the same way in which it was scored for the conjunctive problems, Again, the negative statement of the concept had to be translated into a conjunctive concept, and it was scored as a conjunctive concept.

The mean scanning scores for conjunctive, exclusive disjunctive, biconditional, exclusion, and conjunctive absence rules are found in table 5. Results of the analysis of variance for scanning strategy are found in Table 6. The graph of the mean scanning scores, summing over paper and no paper, plotted against the three problems is in Figure 3.

Table 5

Mean Scanning Strategy over Three Problems

Paper

Problem	C	D	B	E	A	Total
One	3.09	2.24	1.89	1.44	1.65	10.31
Two	3.29	2.59	1.80	3.73	2.95	14.36
Three	5.04	2.85	4.39	2.23	3.69	18.2
Total	11.4	7.68	8.08	7.40	8.29	

No Paper

Problem	C	D	B	E	A	Total
One	3.19	2.65	1.45	2.13	2.95	12.37
Two	3.71	2.68	2.21	2.91	3.64	15.15
Three	3.43	2.91	2.63	1.95	2.83	13.77
Total	10.3	8.24	6.29	6.99	9.42	

Table 6

Analysis of Variance for Scanning Strategy

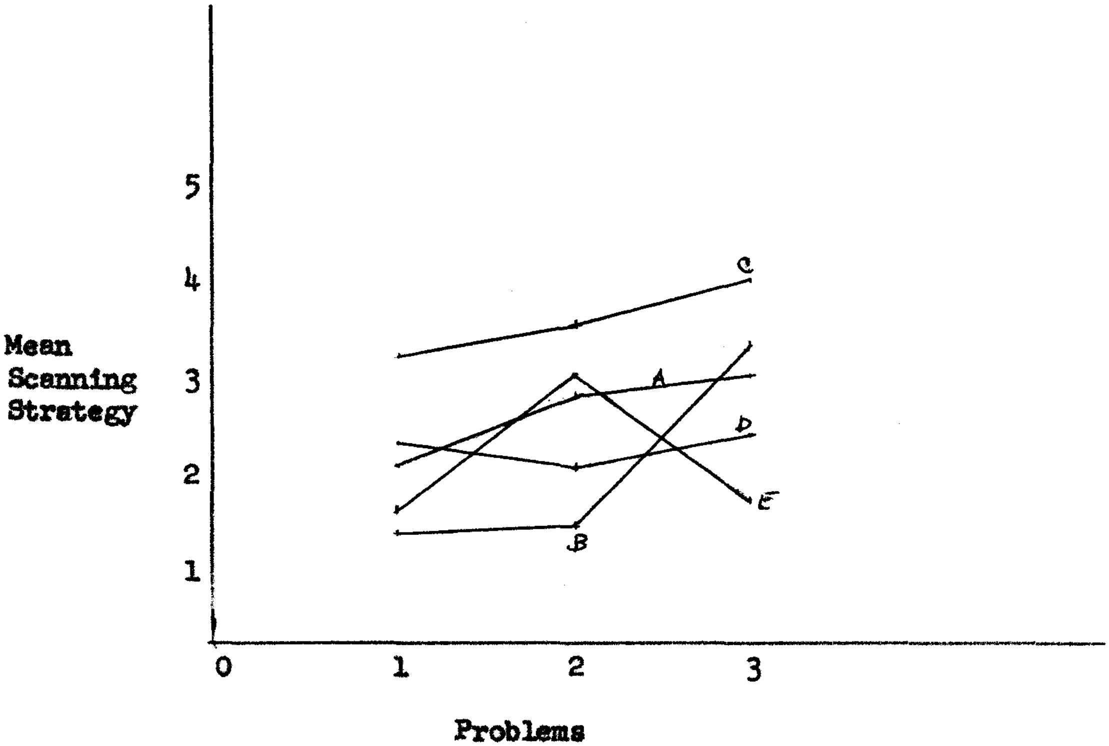
Source	*d.f.*	MS	*F*
Memory(M)	1	.67	
Rule(R)	4	12.64	3.53*
M X R	4	1.88	
Error(B)	70	3.58	
Problems	2	18.42	4.15**
P X M	2	9.48	2.14
P X R	8	4.56	1.03
P X M X R	8	1.86	
Error (W)	140	4.44	

*$p < .05$ **$p. < .01$

Figure 3

Mean Scanning Strategy Plotted Against

Three Problems (Summing over Paper-No Paper)



The effect for differential performance for concept rules was significant (F (4, 70)- 3.53, $p < .05$). The effect for incremental performance over three problems was also significant (F (2, 140)- 4.15, $p < .01$). Since the effect for memory was nonsignificant ($F < 1$), Duncan Multiple Range Comparisons were performed for rule effects, summing over memory and problems. There was significantly more scanning with conjunctive than with biconditional concepts ($p < .01$); also, more scanning for conjunctive than for exclusion ($p < .01$), and more for conjunctive than for disjunctive ($p < .05$). Duncan Comparisons were also performed for problem effects summing over the other variables; significantly better performance was found for problem two than for problem one ($\underline{p} < .05$), and significantly better performance for problem three than for problem one ($\underline{p} < .01$). (See Appendix 1). Trend analysis was performed to assess the linearity of the trend for the problems effect; this effect was significantly linear ($\underline{F}$ (1, 140)- 7.72, $\underline{p}. < .01$), and was not signifiaantly quadratic ($\underline{F}$ (1, 140) $<$ 1) (See Appendix 2).

<u>Time to solution</u>. The mean time to solution in minutes for conjunctive, exclusive disjunctive, biconditional, exclusion, and conjunctive absence rules for three problems is in Table 7. Results of the analysis of variance for time to solution in minutes are in Table 8. The graph of mean time to solution in minutes, summing over paper and no paper, plotted against the three problems is in Figure 4.

Table 7

Mean Time to Solution in Minutes for Three Problems

Paper

Problem	C	D	B	E	A	Total
One	5.38	32.38	16.88	15.38	26.50	96.52
Two	6.38	21.00	19.00	5.38	9.25	61.01
Three	2.13	22.13	10.50	9.00	5.38	49.14
Total	13.89	75.51	46.38	29.76	41.13	

No Paper

Problem	C	D	B	E	A	Total
One	6.50	31.8	20.75	14.50	15.13	88.68
Two	4.13	11.88	23.63	7.63	5.13	52.40
Three	2.75	8.75	15.13	8.13	5.75	40.51
Total	13.38	52.43	59.51	30.26	26.01	

Table 8

Analysis of Variance for Time to Solution in Minutes

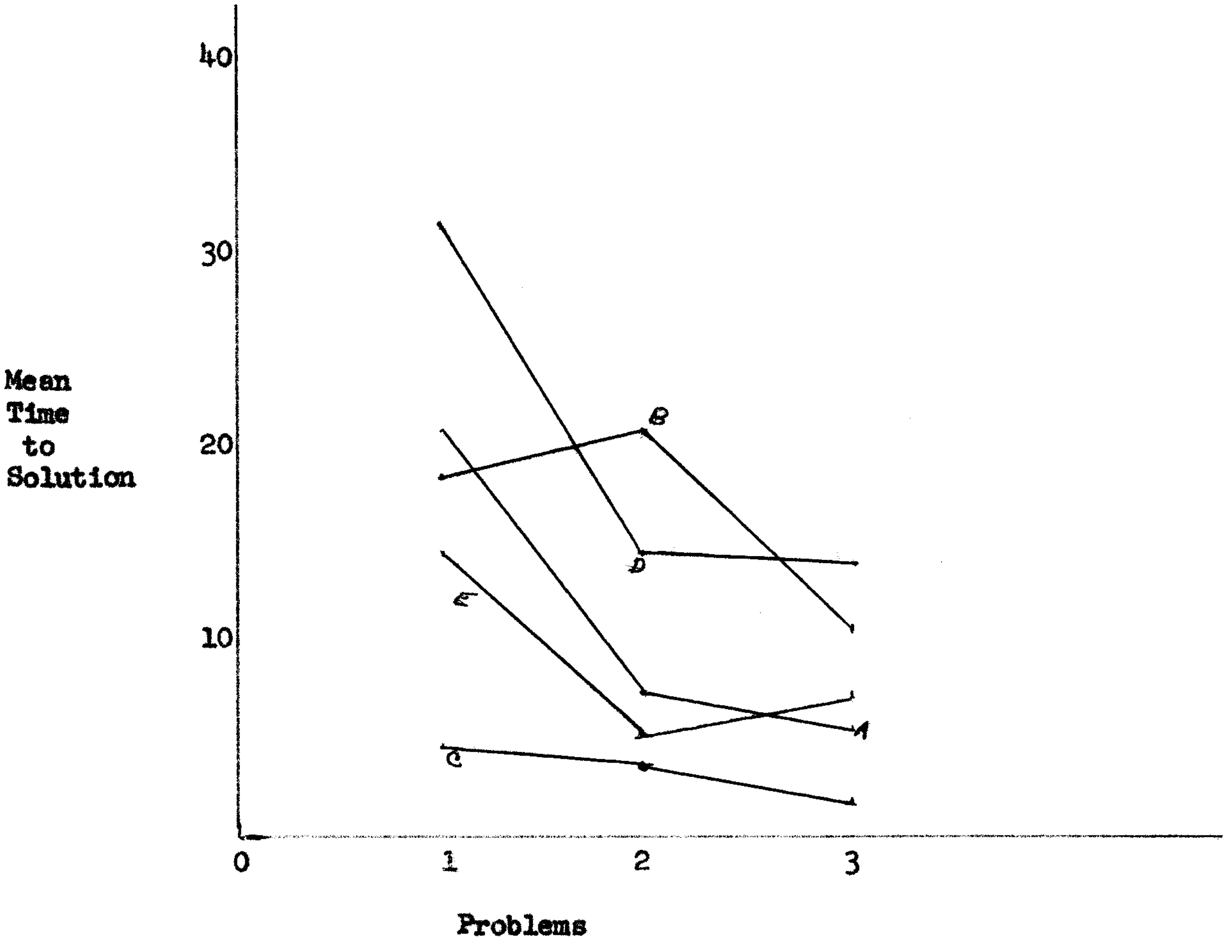
Source	d.f.	MS	F
Memory(M)	1	168.34	1.02
Rule(R)	4	2093.88	12.71**
M X R	4	270.02	1.64
Error(B)	70	164.74	
Problems(P)	2	1977.65	11.66**
P X M	2	.15	
P X R	8	301.32	1.78
P X M X R	8	83.95	
Error(W)	140	169.60	

**$p < .01$

Figure 4

Mean Time to Solution in Minutes Plotted Against

Three Problems (Summing over Paper and No Paper)



The effect for rule was highly significant (F (4, 70)- 3.60, p <.01). The effect for problems was also significant (F (2, 140)- 11.66, p <.01). Again, an improvement across successive problems was reflected, by virtue of decrease in time taken to solution.

Duncan Multiple Range Comparisons indicated that differences between disjunctive and conjunctive, disjunctive and exclusion, disjunctive and conjunctive absence, biconditional and conjunctive, and biconditional and exclusion were all significant ($p < .01$). (See Appendix 1). Trend analysis was performed to assess the trend of the improvement across problems; this trend was significantly linear (F (1, 140) = 21.51, $p < .01$). The quadratic effect was non-significant (F (1, 140) = 1.81). (See Appendix 2).

<u>Untenable hypotheses</u>. Untenable hypotheses have already been defined for focusing (see above). Any hypotheses made after being eliminated previously via scanning is also untenable. Repetitions of hypotheses are untenable ipso facto from the focusing rules.

The mean number of untenable hypotheses per problem for three problems for conjunctive, disjunctive, biconditional, exclusion, and conjunctive absence rules are in Table 9. Results of the analysis of variance for untenable hypotheses are in Table 10. The graph of the mean number of untenable hypotheses, summing over paper and no paper, plotted against the three problems is in Figure 5.

Table 9

Mean Number of Untenable Hypotheses for Three Problems

Paper

Problem	C	D	B	E	A	Total
One	.335	.508	.576	.644	.665	2.73
Two	.424	.351	.486	.128	.371	1.76
Three	.213	.308	.139	.346	.354	1.36
Total	.972	1.17	1.20	1.12	1.39	

No Paper

Problem	C	D	B	E	A	Total
One	.351	.566	.625	.599	.456	2.60
Two	.299	.403	.374	.395	.239	1.71
Three	.235	.173	.408	.361	.380	1.56
Total	.885	1.14	1.41	1.36	1.08	

Table 10

Analysis of Variance for Untenable Hypotheses

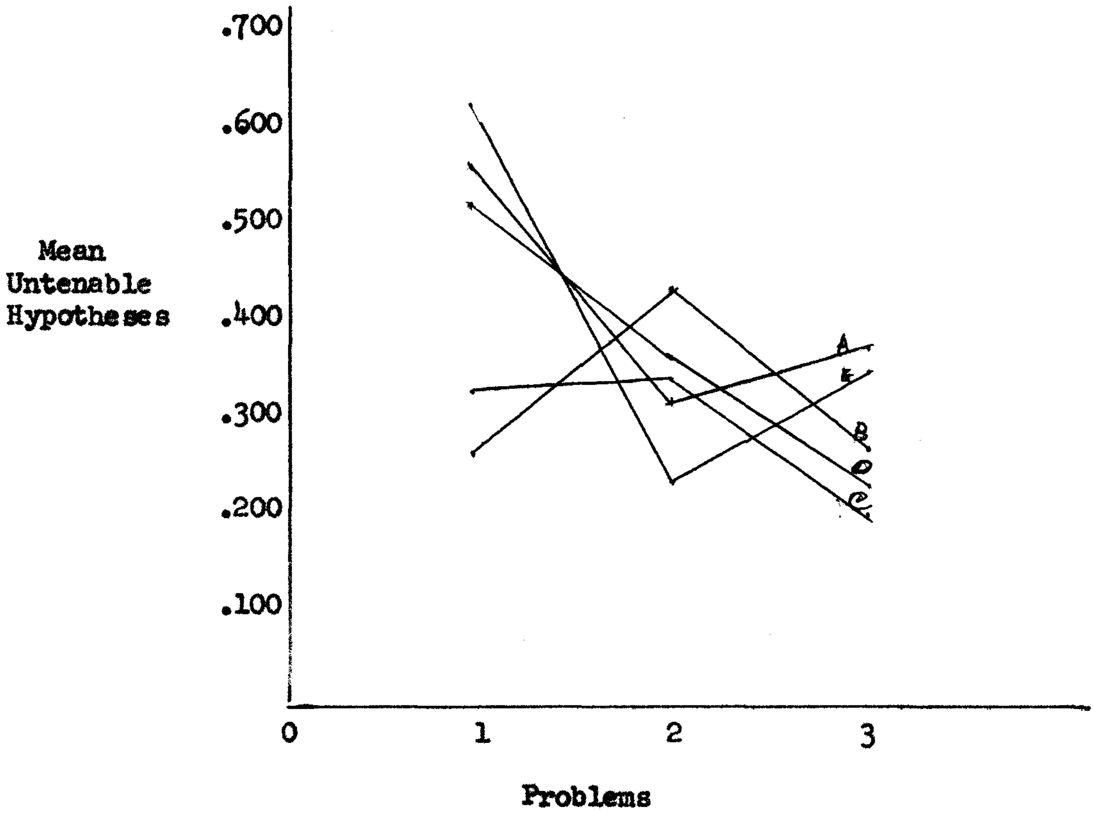
Source	*d.f.*	MS	*F*
Memory(M)	1	.000	
Rule(R)	4	.112	
M X R	4	.068	
Error(B)	70	.151	
Problems	2	1.275	15.36**
P X M	2	.020	
P X R	8	.110	1.33
P X M X R	8	.094	
Error(W)	140	.083	

**$p < .01$

Figure 5

Mean Untenable Hypotheses Plotted Against Three

Problems (Summing over Paper and no Paper)



The only significant effect was for problems; this was a highly significant effect (F (2, 140) - 15.36, $p < .01$). Improvement across successive problems was reflected in decreasing untenable hypotheses.

Duncan Multiple Range Tests were performed for the problems effect, summing over memory and rule. The differences between problems three and one and between problems two and one were significant ($p < .01$). (See Appendix 1). Trend analysis was performed to assess the linearity of the improvement across problems; the linear trend was significant (F (1, 140) - 27.95, $p < .01$). The quadratic trend was non-significant (F (1, 140) - 2.12). (See Appendix 2).

Table 11

Intercorrelations of Response Measures, All Conceptual Rules

	CC	Time	UH	Focusing
Time	.333			
UH	.714	.226		
Focusing	-.482	-.317	-.666	
Scanning	-.614	-.411	-.616	.615

Table 12

Intercorrelations of Response Measures, Conjunctive Rule

	CC	Time	UH	Focusing
Time	.800			
UH	.642	.514		
Focusing	-.469	-.564	-.758	
Scanning	-.731	-.695	-.674	.709

Table 13

Intercorrelations of Response Measures, Disjunctive Rule

	CC	Time	UH	Focusing
Time	.121			
UH	.761	.092		
Focusing	-.362	-.023	-.432	
Scanning	-.669	-.347	-.530	.26[illegible]

Table 14

Intercorrelations of Response Measures, Biconditional Rule

	CC	Time	UH	Focusing
Time	.228			
UH	.786	.037		
Focusing	-.650	-.217	-.828	
Scanning	-.691	-.318	-.600	.768

Table 15

Intercorrelations of Response Measures, Exclusion Rule

	CC	Time	UH	Focusing
Time	.600			
UH	.847	.481		
Focusing	-.724	-.421	-.881	
Scanning	-.800	-.399	-.886	.846

Table 16

Intercorrelations of Response Measures, Conjunctive Absence Rule

	CC	Time	UH	Focusing
Time	.486			
UH	.562	.314		
Focusing	-.460	-.135	-.558	
Scanning	-.296	-.350	-.361	.638

Note: CC stands for card choices and UH stands for untenable hypotheses.

Table 11 shows the intercorrelations between the five response measures across all five of the conceptual rules. Tables 12-16 show the inter-correlations between the five response measures within each of the five conceptual rules. Over all rules, the two selection strategies (focusing and scanning) correlate .615 with one another. Within the individual rules, the only case in which the intercorrelation between the two strategies is below .638 is the disjunctive, in which the coefficient is .262. The highest correlations between the two strategies was in the exclusion rule (.846). The largest discrepancy between the two strategies in terms of correlation with a common third measure was in the disjunctive rule condition, in which focusing correlated -.362 with card choices, while scanning correlated -.669 with this measure. The second largest discrepancy was also in the disjunctive condition, in which focusing correlated -.023 with time to solution while scanning correlated -.347 with time. The conjunctive absence rule condition also featured large discrepancies between the strategies in terms of correlations with the other response measures; the correlations of focusing and scanning with card choices, time to solution, and untenable hypotheses respectively are -.460 and-.296, -.135 and -.350, and -.558 and -.361.

Table 17 presents a summary of the mean ranking of concept rules on the five response measures.

Table 17

Ranks for Concept Rules According to Difficulty

Rule	Measure	Total and Rank (Paper and No Paper)	Mean Rank for Rule
Conjunctive	Card Choices	34.14- 1	
	Focusing	2.89 - 1	
	Scanning	21.75- 1	1.00
	Time	27.27- 1	
	Untenable Hypotheses	1.86 - 1	
Disjunctive	Card Choices	47.38- 4	
	Focusing	1.57 - 5	
	Scanning	15.92- 3	3.80
	Time	127.94- 5	
	Untenable Hypotheses	2.31 - 2	
Biconditional	Card Choices	59.51- 5	
	Focusing	1.89 - 3	
	Scanning	14.37- 5	4.40
	Time	105.89- 4	
	Untenable Hypotheses	2.61 - 5	

Table 17 (continued)

Exclusion	Card Choices	45.64- 3	
	Focusing	2.60- 2	
	Scanning	14.39- 4	3.00
	Time	60.02- 2	
	Untenable Hypotheses	2.48- 4	
Conjunctive Absence	Card Choices	42.64- 2	
	Focusing	1.60- 4	
	Scanning	17.7- 2	2.80
	Time	67.14- 3	
	Untenable Hypotheses	2.47 - 3	

Ranks were assigned on the basis of measures of difficulty; the rank of 1 represented the easiest, the rank of 5 was the most difficult. For example, less card choices to solution represented the easier level; higher focusing and scanning scores also represented easier solutions; more untenable hypotheses and more time to solution represented more difficult solutions. The mean ranks of the various rule types on these measures shows conjunctive to represent the easiest level of solution across all measures, while the biconditional rule represented the most difficult series of solutions as reflected by mean ranks. Intermediate in difficulty were conjunctive absence, exclusion, and exclusive disjunction, in that order.

CHAPTER IV

DISCUSSION

The major results of this study are as follows: a) the effect of concept rule is significant for three response measures- scanning, focusing, and time to solution. b) No response measure reflectdd a significant effect for memory. c) There is a consistent and significant positive interproblem transfer effect across all concept types. This positive transfer is reflected in practically every response measure as a linear increase in efficiency. d) No second or third order interactions attained significance.

In general, the results showed that conjunctive concepts were easiest for subjects to attain. The table of difficulty ranking showed that conjunctive concepts were attained most readily, as reflected by each of the five response measures. Biconditional concepts were most difficult to attain, having a mean difficulty rank of 4.40 (5 is most difficult); the biconditional rule featured the most difficult solution on three response measures (card choices, scanning, and untenable hypotheses). The next most difficult solution was exclusive disjunction, with a mean difficulty rank of 3.80. The easiest solution after conjunctive was conjunctive absence (mean rank - 2.80). Intermediate in difficulty among all the rules was exclusion (mean rank - 3.00). The finding that biconditional and exclusive disjunction rules represented the most difficult solutions is consistent with the conceptual hierarchy posited by Neisser and Weene; biconditional and exclusive disjunction were placed at the third (highest) level because they combine the basic processes of conjunction and disjunction. The finding that disjunctive solutions are more difficult to attain than conjunctive is in accord with the research of Bruner, Goodnow, and Austin (1956), Hunt and Hovland (1960), Wells (1963), Conant and Trabasso (1964), Haygood and Bourne (1965), and most recently, Laughlin and Jordan (in press). Of these, the experimental designs of Bruner et al., Conant and Trabasso, and Laughlin and Jordan were selection paradigms comparable to the present one. The finding that conjunctive absence and exclusion rules were easier to attain than biconditional and exclusive disjunction appears plausible in view of the fact that focusing and scanning strategies for these rules are practically identical with those used to attain conjunctive concepts. In terms of the analysis of variance, rule effects were significant for the response measures of focusing, scanning, and time to solution. (See Tables 4, 6, and 8). Duncan Multiple Range Comparisons showed that for scanning, differences for conjunctive versus exclusion, conjunctive versus biconditional, and conjunctive versus disjunctive were significant. (See Appendix 1). Thus, the easier level of conjunctive attainment is particularly evident for scanning strategy. The Duncan Comparisons for focusing showed that differences for conjunctive versus disjunctive, conjunctive versus conjunctive absence, conjunctive versus biconditional, exclusion versus exclusive disjunctive, and exclusion versus conjunctive absence were significant; the trend toward less difficulty in attaining the conjunctive rule was therefore shown here also. (See Appendix 1). For time to solution in minutes, rule differences were significant for disjunctive versus conjunctive, disjunctive versus exclusion, disjunctive versus conjunctive absence, biconditional versus conjunctive, biconditional versus exclusion, and conjunctive absence versus conjunctive were significant. (See Appendix 1). Thus, the time response measure shows that the disjunctive is very difficult to attain, in addition to supporting the above-mentioned trend toward the relative simplicity of the conjunctive solutions.

The correlations between the two selection strategies is of sufficient magnitude to suggest that there is much overlap between them; the correlation between focusing and scanning across all rule conditions was .615. This does not hold true for one case- the exclusive disjunction rule condition, in which the correlation between the strategies was .262. In addition, the disjunctive condition featured large differences in the correlations of focusing and scanning with the other response measures, as follows: Focusing correlated -.362 with card choices while scanning correlated -.669 with card choices. Focusing correlated -.023 with time, while scanning correlated -.347 with time. Another rule condition in which the correlations followed a similar pattern was for conjunctive absence; here, the correlations were as follows: focusing correlated -.460 with card choices, while scanning correlated -.296 with card choices. Focusing correlated -.135 with time to solution, while scanning correlated -.350 with the same measure. Focusing correlated -.558 with untenable hypotheses, while scanning correlated -.361 with the same measure. However, for the conjunctive absence condition, focusing and scanning correlated .638 with each other. Thus, the strongest evidence that focusing and scanning operate differentially comes from the disjunctive rule condition, with some partial support from the conjunctive absence condition. However, in the other three rule conditions the two strategies appeared to be operating in a similar manner, since the correlations of focusing and scanning with the other response measures were rather comparable with each other.

In discussing the foregoing differences in rule difficulty, a procedural variation in this study not present in prior experiments must be mentioned. Most of the previous research in differential difficulty of conceptual rules dealt with simple conjunctive or disjunctive rules; a study that extended the investigation further was that of Laughlin and Jordan. This study is most comparable to the present one in terms of selection procedure used. This study differed from the present one, however, in terms of problem cards used to exemplify the concept to be attained. Laughlin and Jordan used only "pure" examples to exemplify the concept while the present one did not. For instance, a biconditional concept could have had two types of positive instances. If the concept to be attained was "if orange minus then blue minus and vice-versa," a card containing the combination orange plus and blue plus would be positive because it contains neither relevant value and cannot contradict the concept to be attained. In the exclusive disjunction rule condition a similar situation occurs; if the concept to be attained was "orange minus or blue minus but not both," then a card containing the combination orange plus and blue minus or the combination orange minus and blue plus would be positive. Similarly, a negative card could be such because it has neither of the relevant values (orange plus and blue plus) or both of the relevant values (orange minus and blue minus). In either event, subjects in the present study were not told which was the case. The rationale for doing this was the fact that a certain amount of cognitive ambiguity is built into these concepts; Haygood and Bourne would characterize such situations as a rather even split in mapped response contingencies. When such a "non-pure" but non-contradictory positive instance was given as an example of a concept to be attained, subjects were informed that their given problem card need not have necessarily contained the concept as it had to be stated to solve the problem. Thus, the greater amount of cognitive uncertainty probably contributed to the differential difficulty of the conceptual rules as yielded by the results, and this uncertainty could have been reduced by presenting subjects with "pure" examples of the concept and informing them of this. However, the procedure of this study can be justified on the grounds that the greater cognitive uncertainty of certain rules contributes to their position in the conceptual hierarchy (e.g. Neisser and Weene) and should be preserved in studying them.

Such non-pure examples were not present in the exclusion and conjunctive absence cells, yet they were more difficult to attain than conjunctive rules. The negative terminology in which they were stated apparently was a confounding factor for some subjects, although the divergence from the conjunctive rule was more semantic than logical. Several subjects persisted in stating their hypotheses as conjunctive, and had to be reminded that they had to state the concepts negatively, in the language of the concepts they were attaining, in order for their hypotheses to be recorded. Althoughtthe negative terminology presented to subjects in exclusion and conjunctive absence cells gave them more difficulty than conjunctive subjects, it would appear that this difficulty level should not have reached that of the biconditional and disjunctive subjects who had much more cognitive uncertainty to deal with. The results bear out this explanation.

The findings of this study agree with those of Laughlin and Doherty (1967) in respect to the memory variable. Using a comparable selection design with similar paper and pencil groups for concept attainment, these investigators found no significant effects for memory. The explanation for this is offered in terms of the manner in which the variable was measured. Bourne, Goldstein, and Link (1964) found differences in concept attainment with different memory loads by systematically varying the amount of previously presented stimulus material available to their subjects. The present study merely offered the use of paper and pencil to subjects assigned to the "paper" cells; very few subjects actually recorded the previously presented material that could have aided them in attaining the required concept in fewer card choices. It is proposed that if the recording of previously chosen cards, their status as positive or negative instances, and hypotheses previously made were made mandatory for "paper" subjects, the situation would be more comparable to that of Bourne et al., and memory differences likely would have emerged.

Finally, the consistent and highly significant positive interproblem transfer effects are findings that are novel to research designs of the selection type. Nevertheless, the finding is plausible in view of the work of Haygood and Bourne (1965) and Wells (1963), who found that initial difficulty of different conceptual rules tends to decrease with training on a particular type of rule. The following reasons are offered for the findings of the present study: a) Subjects became more familiar with the terminology and mechanics of the conceptual rule; b) Subjects clarify their set for concept attainment during the course of three problems; that is, they tend to solidify their manner of approach. c) Subjects become more conservative across a three problem series and acquire less of a tendency to give untenable hypotheses and choose cards of little information value on "impulse;" d) The instructions become more coherent after some practice in attaining the concept type called for. The trend of the positive transfer effects was such that performance on conjunctive problems began at a relatively high level and did not necessarily show the drastic improvement across problems showed by other rule types (see figures 1-5, Results). This points to a "ceiling effect" in which the demonstrably easier conjunctive problems had less room for improvement than other types. Thus, the results of the present study suggest that conditions of greater cognitive uncertainty in selection type experiments may be more conducive to positive interproblem transfer than less ambiguous situations; this is offered as a possible hypothesis for future research.

In summary, this study found some significant differences in difficulty between conceptual rules; these results are at least somewhat in accord with previous research. The conjunctive rule was definitely easiest to attain, and biconditional most difficult. These differences were related to differences in cognitive uncertainty among conceptual rules that were emphasized by the design of this study. These procedures were defended as following from the nature of the concepts studied. Some of the rule differences were probably due to semantic as well as logical factors.

The results corroborated those of a previous experiment which found no significant differences between paper and no paper groups. This was traced primarily to the way in which this study measured the memory variable; availability of previously obtained information was not systematically controlled for different subjects.

The present study also found a significant positive interproblem transfer effect, which was novel for a design of this type. It was suggested that experimental conditions featuring greater cognitive uncertainty could be more conducive to positive interproblem transfer than designs not featuring this element. This is offered as a potential hypothesis for future research.

CHAPTER V

SUMMARY

In order to determine the relative difficulty of five conceptual rules under two conditions of memory demands, the performance of individual Loyola University undergraduate students was investigated in three concept attainment problems per subject. A 5 X 2 X 3 repeated measures factorial design was used with the variables: 1) Concept Rule (conjunctive, exclusive disjunctive, exclusion, biconditional, and conjunctive absence), 2) Memory (paper allowed or not allowed), 3) problems (three per subject). Five response measures were used to measure the relative difficulty of concepts- a) card choices to solution, b) focusing strategy, c) scanning strategy, d) time to solution in minutes, and e) untenable hypotheses. The rules for scoring focusing and scanning strategies were modified and added to, in order to extend them to conceptual rules not previously investigated. A differential effect for rule difficulty was found on three response measures- focusing, scanning, and time to solution. The mean rank order for rule difficulty also reflected the differences; conjunctive concepts were found to be easiest to attain, and biconditional solutions were found to be most difficult to attain. These effects were explained in terms of cognitive ambiguity and semantic difficulties inherent in the various conceptual rules. No significant memory effects were found; this finding was explained in terms of the procedure of the present study, which did not systematically vary the amounts of previously presented stimulus material available to the subjects. Finally, a consistent and highly significant positive interproblem transfer effect was reflected by all the response measures; this finding was unique for research designs of this type. It was proposed that experimental designs imposing much cognitive uncertainty upon subjects could have contributed to the positive interproblem transfer. This suggestion was offered as a proposal for future research.

References

Bourne, L. E. Jr. Factors affecting strategies used in problems of concept of concept formation. American Journal of Psychology, 1963, 76, 229-38.

Bourne, L. E. Jr. Human Conceptual Behavior. Boston: Allyn and Bacon, 1966.

Bourne, L. E. Jr., Goldstein, S. & Link, W. E. Concept learning as a function of availability of previously presented information. Journal of Experimental Psychology, 1964, 67, 439-48.

Bruner, J. S., Goodnow, J. J. & Austin, G. A. A Study of thinking. New York: Wiley, 1956.

Cahill, H. E. & Hovland, C. I. The role of memory in the adquisition of concepts. Journal of experimental Psychology, 1960, 59, 137-44.

Conant, M. B. & Trabasso, T. Conjunctive and disjunctive concept formation under equal information conditions. Journal of experimental Psychology, 1964, 67, 250-55.

Dominowski, R. L. The role of memory in concept learning. Psychological Bulletin, 1965, 63, 271-80.

Haygood, R. C. & Bourne, L. E., Jr. Attribute and rule learning aspects of conceptual behavior. Psychological Review, 1965, 72, 157-95.

Hovland, C. I. & Weiss, W. Transmission of information concerning concepts through positive and negative instances. Journal of experimental Psychology, 1953, 45, 175-82.

Hunt, E. B. Memory effects in concept learning. Journal of experimental Psychology, 1961, 62, 598-604.

Hunt, E. B. and Hovland, C. I. Order of consideration of different types of concepts. Journal of experimental Psychology, 1960, 59, 220-25.

Kepros, P. G. & Bourne, L. E., Jr. The identification of biconditional concepts. American Psychologist, 1963, 17, 424 (Abstract).

Laughlin, P. R. Selection strategies in concept attainment as a function of number of persons and stimulus display. Journal of experimental Psychology, 1965, 70, 323-7.

Laughlin, P. R. & Doherty, M. A. Discussion versus memory in cooperative group concept attainment. Journal of Educational Psychology, 1967, 58, 123-8.

Laughlin, P. R. and Jordan, R. M. Selection strategies in conjunctive, disjunctive, and biconditional concept attainment. Journal of experimental Psychology, in press.

References (continued)

Neisser, U., & Weene, P. Hierarchies in concept attainment. Journal of experimental Psychology, 1962, 64, 645-50.

Underwood, B. J. An orientation for research on thinking. Psychological Review, 1952, 59, 209-19.

Wells, H. Effects of transfer and problem structure in disjunctive concept formation. Journal of experimental Psychology, 1963, 65, 63-4.

Appendix 1 - Duncan Multiple Range Comparisons for Significant Effects for Dependent Variables Card Choices, Focusing Strategy, Scanning Strategy, Time to Solution, and Untenable Hypotheses

Card Choices to Solution- Effect for Problems (1, 2, 3)

Mean	Problem 3-6.20	Problem 2-7.03 Difference	Problem 1-9.58 Difference
Problem 3-6.20		.80	3.38**
Problem 2-7.03			2.55**
Problem 3-9.58			

Focusing Strategy- Effect for Rule

Mean	D-.786	A-.800	B-.946 Difference	E-1.30 Difference	C-1.45 Difference
D-.786			.169	.554**	.664**
A-.800			.146	.500**	.650**
B-.946				.354	.504**
E-1.30					
C-1.45					

Focusing Strategy- Effect for Problems (1, 2, 3)

Mean	Problem 1-1.17	Problem 2-1.91 Difference	Problem 3-2.20 Difference
Problem 1-1.17		.74	1.03**
Problem 2-1.91			0.29
Problem 3-2.20			

Appendix 1. (continued)

Scanning Strategy- Effect for Rule

Mean	B-7.18	E-7.19	D-7.96	A-8.85	C-10.88
			Difference	Difference	Difference
B-7.18			0.78	1.67	3.70**
E-7.19			0.77	1.66	3.69**
D-7.96				0.89	2.92**
A-8.85					2.03
C-10.88					

Scanning Strategy- Effect for Problems (1, 2, 3)

Mean	Problem 1-2.27	Problem 2-2.95	Problem 3-3.19
		Difference	Difference
Problem 1-2.27		0.68**	0.92**
Problem 2-2.95			0.23
Problem 3-3.19			

Time to Solution- Effect for Rule

Mean	C-18.62	E-30.00	A-33.56	B-52.94	D-63.94
		Difference	Difference	Difference	Difference
C-13.62		16.38	29.94	49.32**	50.32**
E-30.00			3.56	22.94**	33.94**
A-33.56				19.28	30.28**
B-52.94					11.00
D-63.94					

Appendix 1. (continued)

<u>Untenable Hypotheses- Effect for Problems (1, 2, 3)</u>

	Problem 3-.292	Problem 2-.347	Problem 1-.533
Mean		**Difference**	**Difference**
Problem 3-.292		.155*	.241**
Problem 2-.347			.186**
Problem 1-.533			

** $p < .01$

* $p < .05$

Note: C - conjunctive, D - exclusive disjunctive, E - exclusion, B - biconditional, A - conjunctive absence.

Appendix 2.- Analysis for Linear and Quadratic Trends of Significant Problem Effects for Dependent Variables Card Choices to Solution, Focusing Strategy, Scanning Strategy, Time to Solution, and Untenable Hypotheses.

Card Choices to Solution - Problems 1, 2, 3

F_{lin} (1, 140) - 13.02**

F_{quad} (1, 140) - 1.21

Focusing Strategy - Problems 1, 2, 3

F_{lin} (1, 140) - 18.62**

F_{quad} (1, 140) - 1.23

Scanning Strategy - Problems 1, 2, 3

F_{lin} (1, 140) - 7.72**

F_{quad} (1, 140) - .581

Time to Solution - Problems 1, 2, 3

F_{lin} (1, 140) - 21.51**

F_{quad} (1, 140) - 1.81

Untenable Hypotheses - Problems 1, 2, 3

F_{lin} (1, 140) - 27.95**

F_{quad} (1, 140) - 2.72

**$p < .01$

* $p < .05$

APPROVAL SHEET

The thesis submitted by Everett S. Jacobson has been read and approved by the director of the thesis. Furthermore, the final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

June 2, 1967
Date

Patrick R. Laughlin, Ph.D.
Signature of Adviser