1967

Selection Strategies in Cooperative Group Concept Attainment as a Function of Memory Requirements and Concept Rule

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by

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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

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Acknowledgments

The author wishes to express his gratitude to Dr. Patrick R. Laughlin for his kind guidance and assistance throughout the execution of this study.

He is also grateful to Miss Kathy Palumbo and Mr. Everett S. Jacobson for their generous technical assistance.

Table of Contents

List of Tables

List of Tables-Cont.

List of Figures

List of Appendices

Abstract

Concept attainment performance and strategies were compared for two-person cooperative groups for five concept rules in two memory conditions. A 5 x 2 x 3 repeated measures factorial design was used with the variables: (a) concept rule (conjunctive, exclusive, disjunctive, bi-conditional, and conjunctive absence); (b) memory (use of paper and pencil allowed or not allowed); (c) problems (three for each pair of subjects). Major results were: (1) concept rules ranked in the same ascending order of difficulty for all five response measures; conjunctive, conjunctive absence, exclusion, biconditional, and exclusive disjunctive; (2) focusing strategy was used less for disjunctive concepts than for conjunctive or conjunctive absence; (3) scanning strategy was used less for disjunctive and biconditional concepts than for conjunctive or conjunctive absence; (4) there was a significant effect for problems such that performance improved on the second and decreased on the third problem; and (5) no effects were found for the memory variable.

Selection Strategies in Cooperative Group Concept Attainment as a Function of Memory Requirements and Concept Rule

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Bruner, Goodnow, and Austin (1956) introduced a concept attainment task which has been subsequently adapted for the study of many variables in individual cognitive processes. Typically, an array of cards varying in a number of attributes (shape, color, etc.) with two or more values of each attribute (triangle, or square, red or green, etc.) is presented to the subject. The experimenter arbitrarily designates two or more values in some logical combination (red triangle, red or triangle, etc.) as a concept, and indicates to the subject one of the cards which satisfied this concept. The subject must then determine which attributes have been designated by selecting any succession of cards he wishes, learning whether or not each card exemplifies the concept, and thus reasoning to a solution in as few card choices as possible. The sequence of card choices may be analyzed to determine the strategy used by the subject.

As Bruner, Goodnow, and Austin (1956) note, a strategy need not be a conscious plan for obtaining and utilizing information. Rather, an ideal strategy or set of strategies is theoretically determined, and an analysis of the actual performance strategy used by the subject is made by comparing his sequence of card choices against the demands of the ideal strategies.

Two basic concept attainment strategies, scanning and focusing have been both theoretically and empirically distinguished in this way. In scanning strategy the subject tests specific hypotheses (e.g. red triangle, large square, etc.) either all at once (simultaneous scanning), individually (sucessive scanning), or some intermediate number. In focusing strategy attributes rather than specific hypotheses are tested by selecting a card differing in only one value from the initial card (conservative focusing) or in more than one value (focus gambling).

Laughlin (1965; Laughlin and Jordan, in press) has formulated quantitative rules for scoring scanning and focusing in conjunctive, disjunctive, and biconditional concept attainment. The present study extends these scoring rules to cover two additional concept types.

Three studies by Laughlin and his associates have recently extended the basic Bruner situation to the study of group problem solving processes. Laughlin (1965) found that

two person cooperative groups used the focusing strategy more, required fewer card choices to solution, and required more time than individuals. The Taylor and McNamar (1955) correction model indicated that group superiority in card choices was merely an artifactual function of the better individual in each pair. However, the greater use of focusing strategy by groups remained even with the correction. Laughlin and Dougherty (in press) compared cooperative pairs in which discussion was allowed in half the groups and prohibited in the other groups. Groups allowed discussion, solved the problems in fewer card choices, and had fewer untenable hypotheses than those not allowed in the discussion. The use of scanning and focusing strategies showed complex relationships with the discussion variable, as well as with a memory variable and two stimulus variables. Laughlin and McGlynn (in press) found cooperative pairs held the same edge over competitive pairs as they had over individuals (Laughlin, 1965): more use of focusing strategy, fewer card choices to solution, fewer untenable hypotheses. However, groups again required more time to solution.

Earlier considerations of different kinds of concepts (Bruner, Goodnow, and Austin, 1956; Hunt and Hovland, 1960) typically classified concepts as either conjunctive (A and B), or relational (A must be related to B in some specified way). However, more recent attempts at classification have been

more specific. Neisser and Weene (1962) postulated three basic logical operations (negation, conjunction, and disjunction) and derived ten different concept types. Hunt (1962) adopted a more elaborate system of operators to describe the same ten concept types. Haygood and Bourne (1965) mapped the four contingencies of two focal attributes onto a two-response system of examples and non-examples of the concept and obtained sixteen binary partitions of the stimulus population, two of which are trivial because they place the entire population in either the positive or negative response category. Of the fourteen remaining partitions, four are eliminated because they duplicate other partitions except for a change in relevant attributes. The ten remaining mappings fall into five complementary pairs with the property that any instance which is positive under one member of the pair is negative under the other. These ten remaining mappings each represent one of Neisser and Weene's concept types.

These ten concept types which have been identified by the various writers in the last half decade may be described as follows: 1) Affirmation: the value A must be present for the instance to be an example of the concept. 2) Negation: the value A must not be present for the instance to be an example. 3) Conjunction: both A and B must be present for the instance to be an example. 4) Disjunctive Absence:

either A or B must be absent for the instance to be an example. 5) Inclusive Disjunction: either A or B or both must be present for the instance to be an example. 6) Conjunctive Absence: both A and B must be absent for the instance to be an example. 7) Conditional: if A is present, then B must be present for the instance to be an example; if A is absent, the instance is an example independent of B. 8) Exclusion: A must be present and B must be absent for the instance to be an example. 9) Biconditional: A must be present if and only if B is also present for the instance to be an example. 10) Exclusive Disjunction: either A or B must be present, but not both for the instance to be an example.

According to Neisser and Weene (1962) these ten concepts may be hierarchically classified on three levels. The simplest level (Level I) is simple affirmation or negation. Level II consists of the six concept types which involve single conjunctions or disjunctions of both attributes. The biconditional and exclusive disjunction concept types comprise the most complex level (Level III), and involve both conjunctive and disjunctive operations.

There has been a recent upsurge in interest in the concept rule as a variable affecting concept attainments. Kepros and Bourne (1963) found that for biconditional and conjunctive concepts, the effect of the number of relevant

and irrelevant dimensions remained the same. Most research, however, has found the concept rule to be an important factor in concept attainment.

Haygood and Bourne (1965) analyzed conceptual behavior into attribute identification and rule learning. In the former, the rule is given and the relevant attributes must be identified. In rule learning, the relevant attributes are given and the concept rule must be learned. A third procedure, complete learning, involves both attribute identification and rule learning. Although an experiment testing these three tasks over four concept rules revealed no interaction between concept rule and task, the distribution of the three processes may still be helpful in reviewing studies involving different concept rules.

Another important distinction is that between reception procedures and selection procedures in concept attainment (Bruner, Goodnow and Austin, 1956). In the former, the experimenter programs the instances to be presented to the subject, while in the latter the subject selects his own instances from the entire population of instances. Laughlin and Jordan (in press) invoke this distinction to explain the difference between their results and those of Haygood and Bourne on the relative difficulty of concept rules.

Three studies employing the reception procedure bring evidence to bear on the relative difficulty of concept rules.

In an experiment involving complete learning, Hunt and Hovland (1960) found that conjunctive and relational solutions were offered more often than disjunctive when all three solutions were possible. In one experiment, Haygood and Bourne (1965) found that conditional concepts were more difficult (over attribute identification, rule learning, and complete learning) than conjunctive absence and inclusive disjunction, while conjunctive concepts were less difficult than any of the others. In a second experiment involving rule learning, and subsequently rule identification, conditional and biconditional concepts were found to be more difficult than inclusive disjunction and conjunction. In general, the results of Haygood and Bourne agree with those of Neisser and Weene (1962) and support the hierarchical interpretation of three levels of rules. The latter investigators demonstrated that in a complete learning situation, the ascending order of difficulty (for the five rules to be used in the present study) was conjunction, exclusion, conjunctive absence, exclusive disjunction, and biconditional. These differences were significant, however, only for the last two rules versus the first three.

In studies involving selection procedures, Bruner, Goodnow, and Austin (1956) first observed that disjunctive concepts were more difficult to attain than conjunctives. Conant and Trabasso (1964) replicated this finding under

equal information conditions, noting that subjects learned to select positive instances in conjunctive sets more readily than they learned to select negative instances in inclusive disjunctive sets. Laughlin and Jordan (in press) reported that for both card choices and time to solution inclusive disjunction concepts proved more difficult than conjunctive and biconditional, between which there was no difference.

Several explanations of the differential difficulty of concepts may be found in the literature. Neisser and Weene (1962) believe that concepts are hierarchically organized on three levels such that level I concepts are necessary for the attainment of level III concepts. In such a system level III concepts are not learned as such, but are induced from their components. Haygood and Bourne (1965) propose that the differences in difficulty among different levels of concepts may be a result of the ratio of positive and negative instances. With a two-attribute, two-value concept universe, all level II concepts involve a 3:1 split of contingencies, whereas level III concepts are based on a 2:2 split which yields more stimulus uncertainty.

Another factor in differential rule difficulty may be the lack of familiarity with the more complex rules. Wells (1963) demonstrated that the preference for conjunctive concepts (Hunt and Hovland, 1960; Bruner, Goodnow, and Austin, 1956) may be modified by preliminary training. Haygood and

Bourne (1965) explain some of their results in terms of subjects being unable to fully understand more complex rules. Hunt and Hovland (1960) suggest that the preference for conjunctive concepts is learned and may not be found in children. Another factor may be the difficulty that subjects have in utilizing negative instances (Hovland and Weiss, 1953) coupled with the necessity of using them in the attainment of concepts such as disjunctives (Conant and Trabasso, 1964).

Only three studies have made an attempt to analyze strategies for different concept rules. Conant and Trabasso (1964) found that more negative and more redundant instances were chosen in disjunctive concept attainment. Bruner, Goodnow, and Austin (1956) discussed several appropriate and inappropriate strategies for disjunctive concepts. Laughlin and Jordan (in press), using quantitative methods, found more focusing with conjunctive concepts than with inclusive disjunctives and more with these than with biconditionals. There was significantly less scanning with inclusive disjunctive concepts than with the other two types.

The properties of the stimulus display may also affect the relative difficulty of concept rules. Most often a four-attribute, three-value concept universe is used (Haygood and Bourne, 1965), and in such a universe the complementariness of the concepts discussed by Haygood and Bourne holds perfectly. However, in a six-attribute, two-value universe the absence

of one value necessarily implies the presence of its opposite. Laughlin and Jordan (in press) offer this as an explanation for the difference between their results and those of Haygood and Bourne, noting that the relative difficulty of biconditional concepts probably increases as the number of values per attribute increases. It should be pointed out that, theoretically, the six-attribute two-value universe used in the present study reduces exclusion and conjunctive absence concept to conjunctives.

Bruner, Goodnow, and Austin (1956) list the excessive memory demands of scanning strategy as one of the reasons many persons resort to focusing. Memory requirements were also shown to be important in a number of other studies. Whitman and Garner (1963) found less interference and hence better performance in concept learning with either all positive or all negative instances as compared to mixed instances of the concept. Cahill and Hovland (1960) found that simultaneous (all instances presented at once) presentation was superior to successive (only one instance at a time) presentation. Bourne, Goldstein, and Link (1964) extended this finding and observed that performance varied with availability of preceeding stimuli.

In two studies previously cited, the effects of memory have been reduced or eliminated entirely. In both the Conant and Trabasso (1964) and Haygood and Bourne (1965) experiments

previous instances and appropriate feedback were constantly available to the subject. Laughlin and Doherty (in press) studied the memory variable by allowing or forbidding paper. There was no main effect for paper, but significant interactions with strategies emerged.

The question of interproblem transfer in concept attainment has not been resolved. Neisser and Weene (1962) found a general improvement over two successive problems of the same concept type, with the differences between concepts remaining after two problems. Similar findings are reported by Haygood and Bourne (1965) over all three types of conceptual tasks. However, in addition, they obtained a problem by rule interaction which reflected the fact that conjunctive absence, inclusive disjunction, and conditional concepts changed markedly in relation to conjunctives. Wells (1963) and Wells and Watson (1965) also found positive interproblem transfer. Laughlin and Jordan (in press) noted that all these studies entailed reception procedures. Studies employing selection procedures, on the other hand, usually fail to show improvement over problems (Laughlin, 1966; Bruner, Goodnow, and Austin, 1956; Laughlin and Doherty, in press; Laughlin and Jordan, in press). Conant and Trabasso (1964) could draw no conclusion on transfer as their date was confounded with the class of example cards. Laughlin and McGlynn (in press) give contrary evidence on this point, but

their results are said to be due to a social facilitation effect in both cooperative and competitive pairs.

Five concept rules were used in the present investigation: conjunction, exclusive disjunction, biconditional, exclusion, and conjunctive absence. Since a six-attribute, two-value concept universe and a selection procedure were employed, it was expected that the results would more closely parallel those of Laughlin and Jordan (in press) than those of Haygood and Bourne (1965). Since the cooperative groups under study were comparable to those of Laughlin and McGlynn (in press) an improvement over problems was hypothesized.

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, exclusive, disjunctive, biconditional, and conjunctive absence); (b) memory (use of paper and pencil allowed or not allowed); (c) problems (three for each subject). Subjects were 80 like-sex pairs of college students in introductory and experimental psychology courses. Eight pairs of subjects were randomly assigned to each of the ten experimental conditions.

<u>Stimulus display and problems.</u> The stimulus display was a 28 x 44 inch white posterboard containing an array of

64 $2\frac{1}{2}$ x 4 inch cards drawn in colored ink with dark outlines. The 64 cards represented all possible combination of six plus and/or minus signs in a row. In order to facilitate reference to the six positions each was a different color. Each color was thus, one attribute. The value of each attribute was either plus or minus. The cards were arranged systematically on the board such that each attribute had a unique arrangement (e.g. the top four rows were blue plus and the bottom four blue minus).

The concept rules used were: (a) conjunction (e.g., "black plus and yellow minus"), (b) exclusive disjunction (e.g., "black plus or yellow minus but not both black plus and yellow minus together"), (c) biconditional (e.g., "if black plus then yellow minus, and, if yellow minus then black plus," hence, "black plus and yellow minus or neither black plus nor yellow minus"), (d) exclusion (e.g., "black plus and not yellow minus," hence, "black plus and yellow plus"), (e) conjunctive absence (e.g., "neither black plus nor yellow minus," hence, "black minus and yellow plus"). Corresponding problems for the five concept rules had the same relevant attributes and values. Each problem and initial card were selected from the total set of two attribute concepts and the subject of possible initial cards for each concept.

<u>Procedure.</u> The instructions thoroughly explained with

examples the meaning of the particular concept rule, which was typed on an index card with an example for reference throughout the experiment. The systematic arrangement of the attributes and values on the display was pointed out and the instructions emphasized that the problems were to be solved in as few card choices as possible, regardless of time (Laughlin, 1964). The pair of subjects sat adjacent to each other before the display and were instructed to discuss the problem and their card choices and hypotheses throughout the experiment. Subjects were instructed to give one and only one hypothesis after every card choice. The complete text of the instructions may be found in the appendix.

Only data from subjects solving three complete problems was used. Subjects unable to solve the first problem in 60 minutes, provided they had made 20 card choices, were arbitrarily designated non-solvers, and their data was discounted from further analysis. Two subjects were thus eliminated; one in the paper disjunctive condition, and one in the paper conjunctive absence condition.

Results

Five response measureswere analyzed: Numbers of card choices to solution, focusing strategy, scanning strategy, percentage of untenable hypotheses, and time to solution.

Card choices to solution. The mean number of card choices to solution for the ten treatment group for each of the three problems are given in Table 1. A summary of the analysis of variance is presented in Table 2.

Table 1

Mean Card Choices for Two Memory Conditions and Five Concept Rules for Three Problems

		Problems			
		1	2	3	Total
Paper	Conjunction	4.63	2.88	4.38	3.96
	Exclusive Disjunction	6.38	3.88	4.38	4.88
	Biconditional	8.13	5.00	6.13	6.42
	Exclusion	6.88	3.75	5.12	5.25
	Conjunctive Absence	4.00	2.75	3.63	3.46
No paper	Conjunction	3.63	2.88	3.25	3.25
	Exclusive Disjunction	13.63	6.38	6.38	8.80
	Biconditional	6.38	5.00	5.75	5.71
	Exclusion	6.13	2.88	5.00	4.67
	Conjunctive Absence	4.38	4.63	3.13	4.04
	Total	6.41	4.00	4.71	5.05

Table 2

Summary of Analysis of Variance: Card Choices To Solution

Source	df	SS	MS	F
Memory	1	15.00	15.00	
Rule (R)	4	383.71	95.93	4.01*
M x R	4	189.29	47.32	1.98
Error (B)	70	1674.25	23.92	
Problems (P)	2	245.81	122.91	10.77*
P x M	2	8.42	4.21	
P x R	8	136.69	17.09	1.50
P x M x R	8	81.41	10.18	
Error (W)	140	1598.00	11.41	

* $p < .01$

The effect of the concept rule was significant at the .01 level, $F(4,70) = 4.01$. Since there was no effect for paper and no paper conditions, Duncan multiple range comparisons were performed on the five concept rules summing over memory. Table 3 presents the results of these comparisons.

Table 3

Card Choices: Duncan Multiple Range Comparisons

for Concept Rules Summing Over Memory Conditions

Concepts	Means	3.60	3.75	4.96	6.06	6.83	Shortest Sign. Range (P .01)
C	3.60		ns	1.36	2.46*	3.23**	2.66
A	3.75			ns	2.31*	3.08**	2.82
E	4.96				ns	1.87	2.85
B	6.06					ns	2.90

**p <.01 *p <.05

Note - The following abbreviations are used: D-exclusive disjunction; B-Biconditional; E-Exclusion; A-Conjunctive Absence; C-Conjunctive.

Disjunctive concepts proved to be significantly more difficult than both conjunctive and conjunctive absence concepts ($p < .01$). Biconditional concepts likewise required significantly more card choices than both conjunctive and conjunctive absence concepts ($p < .05$).

The analysis of variance also revealed a significant effect for problems, F (2, 140) = 10.77, p .01. The linear component of the overall trend was significant, F (1,140) = 10.13, $p < .01$, as was the quadratic component, F (1,140) = 11.41, $p < .01$. Figure 1 is a plot of the mean number of card choices for each of the three problems for the five concept rules. Table 4 presents the results of Duncan multiple-range comparisons between problems.

Figure 1

Mean Number of Card Choices Plotted Against Problems
for Each of Five Concept Rules

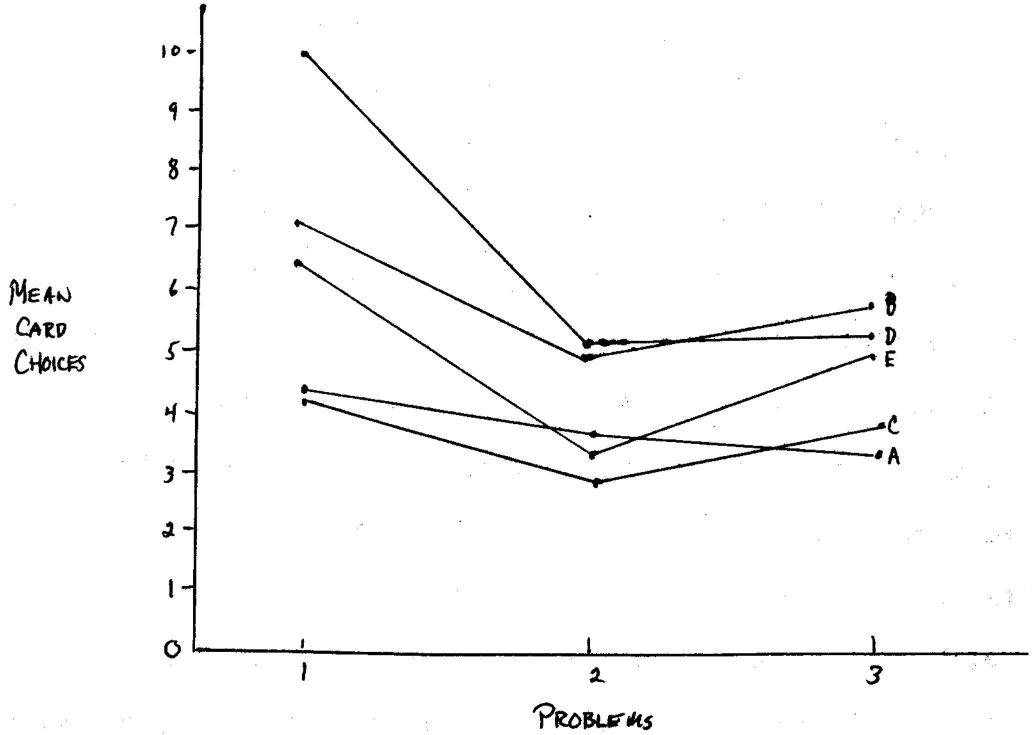


Table 4

Card Choices: Duncan Multiple-Range Comparisons
for Problems

Problems		2	3	1	shortest sign. range
	Means	4.00	4.71	6.41	($p < .01$)
2	4.00		0.71	2.41**	1.40
3	4.71			1.70**	1.56

** $p < .01$

The first problem required significantly more card choices than either of the other two (p .01) which did not differ significantly from each other.

All of the interactions for card choices to solution were non-significant.

Focusing strategy. The rules for scoring focusing strategy were adapted from Laughlin (1965) and Laughlin and Jordan (in press). They are given in detail below.

1) Conjunction. Each card choice had to obtain information on the 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: (a) a hypothesis for a value of an attribute when the other value had previously occured on a positive instance, or (b) a hypothesis for a value which had previously occured on a negative instance. A repetition of a hypothesis was always untenable. Each card choice and accompanying hypothesis that satisfied these rules was counted as an instance of focusing, and the total number of such instances was divided by the total number of

card choices to give a continuous focusing score from .00 to 1.00.

2) Conjunctive absence. Conjunctive scoring rules apply without exception.

3) Exclusion. Since the correct concept could be stated in two equivalent ways, only one of which was counted as correct (e.g. "black plus and not yellow minus" is equivalent to "yellow plus and not black minus"), credit was given for an additional attribute eliminated when the correct concept was hypothesized in its equivalent form. Otherwise, conjunctive scoring rules apply to exclusion.

4) Biconditional. Each card choice had to obtain new information on one new attribute, either by changing one attribute at a time, as per conjunctive, or changing five attributes at a time. In the latter case, the unchanged attribute is either essential or irrelevant if not proven so previously. Only conservative focusing was scored for positive instances; positive focus gambling does not apply to biconditional concepts. If a card choice was not positive and more than one and less than five attributes were changes, ambiguous information could be resolved on the next card by changing one or five attributes.

A hypothesis had to be tenable considering the information available. Untenable hypotheses could be of two types: (a) a hypothesis for a value of an attribute

when the opposite of one of the values but not both had previously occured on a positive instance, or (b) a hypothesis for a value when both value or the opposite of both values had previously occured on a negative instance.

Credit for eliminating an additional attribute was given when the direct opposite (non-contradictory) form of the concept was given.

5) Exclusive disjunction. Focusing strategy for exclusive disjunctions is identical with that used for biconditionals, except for untenable hypotheses, which could be of two types: (a) a hypothesis for a value of an attribute when the opposite of one of the values but not both had previously occured 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 positive instance.

The mean focusing scores for the ten treatment groups for each of the three problems are given in Table 5. A summary of the analysis of variance is presented in Table 6.

Table 5

Mean Focusing Scores for Two Memory Conditions and Five Concept Rules for Three Problems

		Problems			
		1	2	3	Total
Paper	Conjunction	.40	.61	.52	.51
	Exclusive Disjunction	.38	.46	.22	.35
	Biconditional	.27	.35	.44	.35
	Exclusion	.29	.58	.66	.51
	Conjunctive Absence	.63	.76	.52	.63
No paper	Conjunction	.58	.71	.71	.67
	Exclusive Disjunction	.14	.22	.22	.19
	Biconditional	.43	.77	.73	.65
	Conjunctive Absence	.47	.43	.73	.54
	Total	.41	.53	.52	.49

Table 6

Summary of Analysis of Variance: Focusing

Source	df	SS	MS	F
Memory (M)	1	0.06	0.060	
Rule (R)	4	3.88	0.970	8.15*
M x R	4	1.02	0.255	2.14
Error (B)	70	8.30	0.119	
Problems (P)	2	0.76	0.380	4.87*
P x M	2	0.24	0.120	1.54
P x R	8	0.87	0.109	1.40
P x M x R	8	0.67	0.084	1.08
Error (W)	140	10.98	0.078	

* $p < .01$

The effect of the concept rule was significant at the .01 level, $F(4, 70) = 8.15$. Since there was no effect for paper and no paper conditions, Duncan multiple-range comparisons were performed on the five concept rules summing over memory. Table 7 presents the results of these comparisons.

Table 7

Focusing: Duncan Multiple-Range Comparisons for Concept Rule Summing over Memory Conditions Concepts

Concepts		D	B	E	A	C	shortest sign. range
	Means	.271	.410	.578	.587	.588	($P < .01$)
D	.271		.139	.307**	.316**	.317**	.187
B	.410			ns	.177*	.178*	.198
E	.578				ns	ns	.200
A	.587					ns	.204

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

There was significantly less focusing for disjunctive concepts than for exclusion, conjunctive absence, or conjunction ($p < .01$). Focusing strategy was used less with biconditional than with conjunctive and conjunctive concepts ($p < .05$).

The analysis of variance also revealed a significant problems effect, F (2, 140) = 4.87, $p < .01$. The linear component of the overall trend was significant, F (1, 140) = 2.72. Figure 2 is a plot of the mean focusing scores for each of the three problems for the five concept rules. Table 8 presents the results of Duncan multiple-range comparisons between problems.

Figure 2

Mean Focusing Scores Plotted Against Problems

for Each of Five Concept Rules

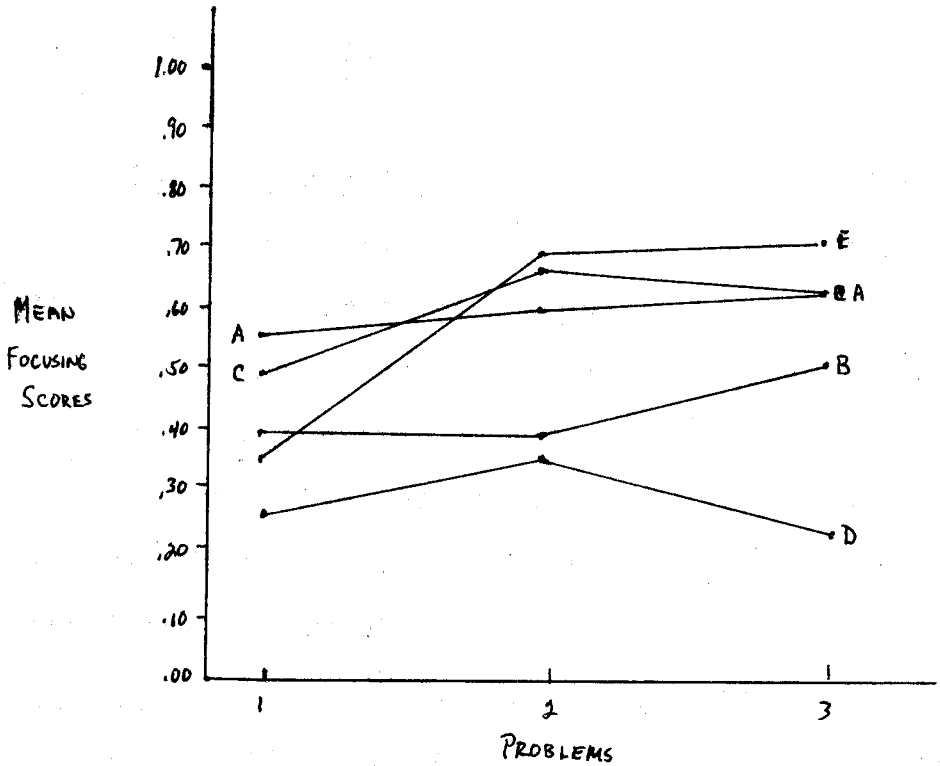


Table 8

Focusing: Duncan Multiple-Range Comparisons for Problems

Problems		1	3	2	shortest sign. range
	Means	.407	.524	.529	(p <.01)
1	.407		.117*	.122**	.116
3	.524			ns	.120

** p <.01 * p <.05

Focusing increase across problems such that the first problem differed significantly from the second ($p < .01$) and from the third ($p < .05$). The difference between the last two problems was non-significant.

All of the interactions for focusing stratety were non-significant.

Scanning strategy. The rules for scoring scanning strategy were adapted from Laughlin and Jordan (in press). They are given in detail below.

1) Conjunction. Each card selected by the pair of subjects was compared with the initial 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 given and selected cards were eliminated. The total number of concepts thus eliminated plus concepts eliminated by direct hypothesis were divided by the total number of card choices to give the average number of cards eliminated per card choice.

2) Conjunctive Absence. Conjunctive scoring rules apply without exception.

3) Exclusion. The number of possible hypotheses to be eliminated is doubled because of the equivalent wordings of the concept. The formula hypotheses eliminated minus one divided by total card choices times two, (H-1)/2c, was used to make the scanning coefficient comparable with that of the

conjunctive problems. When subjects eliminated a concept via scanning, they were given credit for eliminating both equivalent forms of it, while a concept eliminated via direct hypotheses did not eliminate the equivalent form.

4) Biconditional. Each card selected by the pair of subjects was compared with the initial card. If the selected card was positive, only concepts involving combinations of differing and identical attributes or combinations of identical attributes on given and selected cards were eliminated. If the selected card was negative, all identical hypotheses between given and selected cards were eliminated.

Since the initial card could have represented the actual form of the concept (e.g. if the black plus then yellow minus and vice versa) or the corresponding non-contradictory form (if black minus then yellow plus and vice versa), and subjects were not informed which was the case, the direct opposite of each tenable hypothesis was itself tenable. The formula (H-1)/2c was employed to make the scanning coefficient comparable with that of conjunctive concepts. When subjects eliminated a concept via scanning, they were given credit for eliminating both the actual and non-contradictory forms. Concepts eliminated via direct hypothesis were given credit for eliminating the actual form only.

5) Exclusive Disjunction. Since the original problem card could have contained either one of the two values, and each negative card could have contained either both or neither of the values (subjects were not informed which was the case), the direct opposite of each tenable hypothesis was itself tenable. The formula (H-1)/2e was used to make the scanning coefficient comparable with that of conjunctive problems. Subjects were given credit for eliminating both the actual concept and its direct opposite (non-contradictory) form when eliminating a concept via scanning.

Table 9

Mean Scanning Scores for Two Memory Conditions and Five Concept Rules for Three Problems

		Problems 1	2	3	Total
Paper	Conjunction	2.90	5.01	4.28	4.07
	Exclusive Disjunction	2.60	3.27	2.70	2.86
	Biconditional	2.32	3.33	2.48	2.71
	Exclusion	2.03	4.14	3.05	3.07
	Conjunctive Absence	4.30	4.00	3.97	4.09
No paper	Conjunction	4.28	5.14	4.21	4.63
	Exclusive Disjunction	1.55	2.64	2.54	2.24
	Biconditional	2.96	2.86	2.92	2.91
	Exclusion	2.15	4.28	3.26	3.23
	Conjunctive Absence	4.21	2.96	4.28	3.82
	Total	2.95	3.76	3.37	3.36

The mean scanning scores for the ten treatment groups for each of the three problems are given in Table 9. A summary of the analysis of variance is presented in Table 10.

Table 10

Summary of Analysis of Variance: Scanning

Source	df	SS	MS	F
Memory (M)	1	0.00	0.00	
Rule (R)	4	111.73	27.93	7.27**
M x R	4	9.99	2.50	
Error (B)	70	268.52	3.84	
Problems (P)	2	26.06	13.03	6.03**
P x M	2	4.51	2.26	1.05
P x R	8	38.63	4.83	2.24*
P x M x R	8	10.77	1.35	
Error (W)	140	302.75	2.16	

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

The effect of the concept rule was significant at the .01 level, $F(4, 70) = 7.27$. Since there was no effect for paper and no paper conditions, Duncan multiple-range comparisons were performed on the five concept rules summing over memory. Table 11 presents the results of the comparisons.

Table 11

Scanning: Duncan Multiple-Range Comparisons

for Concept Rules Summing Over Memory Conditions

Concepts

Concepts		D	B	E	A	C	Shortest Sign. Range
	Means	2.55	2.81	3.15	3.95	4.35	(p .01)
D	2.55		ns	ns	1.40**	1.80**	1.06
B	2.81			ns	1.14**	1.54**	1.11
E	3.15				0.80	1.20**	1.14
A	3.95					0.40	1.16

** $p < .01$

Scanning was used significantly more with conjunctive concepts than with disjunctives, biconditionals, or exclusions, and with conjunctive absence more than with disjunctive or biconditional ($p < .01$).

The analysis of variance also revealed a significant problems effect, F (2, 140) = 6.03, $p < .01$. The linear component of the overall trend was not significant, F (1,140) = 3.16, while the quadratic component was significant, F (1, 140) = 8.90, $p < .01$. Figure 3 is a plot of the mean scanning scores for each of the three problems for the five concept rules. Table 12 presents the results of Duncan multiple-range comparisons between problems.

Figure 3

Mean Scanning Scores Plotted Against Problems for Each of Five Concept Rules

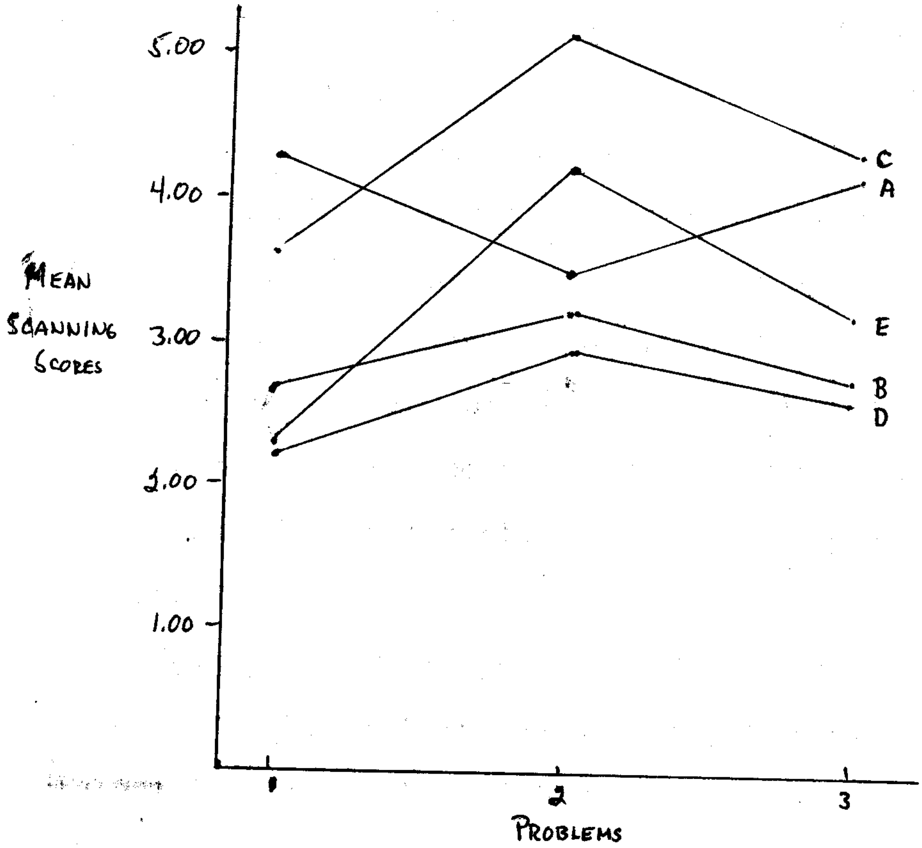


Table 12

Scanning: Duncan Multiple-Range Comparisons for Problems

Problems		1	3	2	Shortest sign. range ($p < .01$)
	Means	2.95	3.37	3.75	
1	2.95		0.42	0.81**	0.61
3	3.37			0.39	0.64

** $p < .01$

Scanning increased significantly from the first to the second problem ($p < .01$), but there was no difference between the third problem and either the first or the second.

A significant interaction between problems and concept rule was found, $F(8, 140) = 2.24$, $p < .05$. As seen in Figure 3, this interaction is a result of the decrease in scanning strategy on the second conjunctive absence problem. For all other concept rules, there is a substantial increase in scanning on the second problem. There was then an increase in scanning on the third conjunctive absence problem, whereas there was a decrease for the four other concept rules.

All other interactions for scanning strategy were nonsignificant.

Untenable hypotheses. The total number of hypotheses made by a subject which were not consistent with all the information available at the time was divided by the total number of hypotheses (number of card choices) to give a ratio of untenable hypotheses. The mean ratio of untenable hypotheses for the ten treatment groups for each of the three problems are given in Table 13. A summary of the analysis of variance is presented in Table 14.

Table 13

Mean Untenable Hypotheses Ratios for Two Memory Conditions and Five Concept Rules for Three Problems

		1	2	3	Total
Paper	Conjunction	.37	.19	.33	.30
	Exclusive Disjunction	.34	.19	.18	.23
	Biconditional	.46	.33	.28	.36
	Exclusion	.46	.18	.22	.29
	Conjunctive Absence	.27	.14	.37	.26
No paper	Conjunction	.16	.15	.08	.13
	Exclusive Disjunction	.54	.30	.33	.39
	Biconditional	.27	.21	.23	.24
	Exclusion	.37	.02	.19	.19
	Conjunctive Absence	.35	.20	.23	.26

The main effects for the memory variable, $\underline{F}$ (1, 70) = 1.36, and for the concept rule, $\underline{F}$ (4,70) 1, were both non-significant.

The problems effect was significant, $\underline{F}$ (2, 140) = 8.67, $\underline{p} < .01$. The linear component of the overall trend was significant, $\underline{F}$ (1,140) = 9.38 as was the quadratic component, $\underline{F}$ (1,140) = 7.54. Figure 4 is a plot of the means untenable hypotheses ratios for each of the three problems for the five concept rules. Table 15 presents the results of Duncan multiple-range comparisons between problems.

Table 14

Summary of Analysis of Variance: Untenable Hypotheses

Source	df	SS	MS	F
Memory (M)	1	0.17	0.170	1.36
Rule (R)	4	0.36	0.090	
M x R	4	0.76	0.190	1.52
Error (B)	70	8.75	0.125	
Problems (P)	2	1.04	0.520	8.67*
P x M	2	0.05	0.003	
P x R	8	0.38	0.047	
P x M x R	8	0.48	0.060	
Error (W)	140	8.53	0.061	

* p .01

Table 15

Untenable Hypotheses: Duncan Multiple-Range

Comparisons for Problems

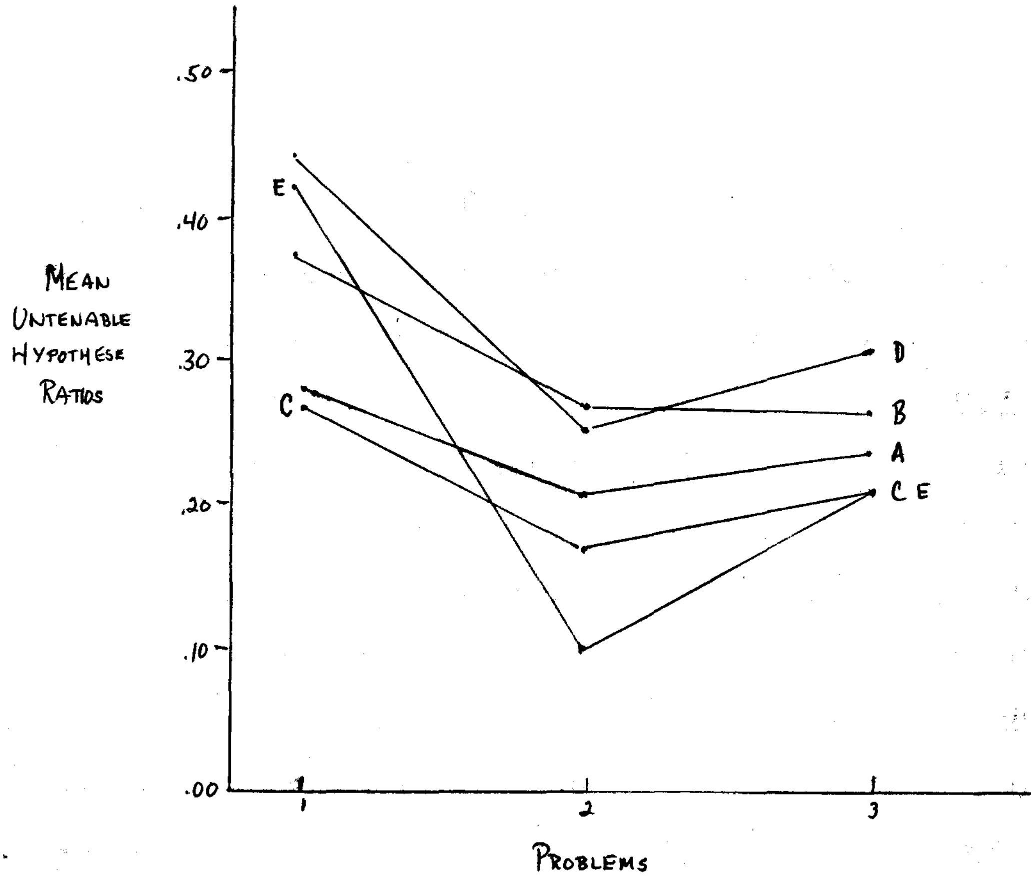
Problems	Means	2	3	1	Shortest sign. range ($p < .01$)
		.197	.231	.350	
2	.197		.034	.153**	.102
3	.231			.119**	.106

** $p < .01$

There proved to be significantly more untenable hypotheses on the first problem than on either the second or the third ($p < .01$), between which there was no difference. There were no significant interactions for untenable hypotheses.

Figure 4

Mean Untenable Hypotheses Ratios Plotted Against Problems for Each of Five Concept Rules



Time to solution. The mean time to solution in minutes for the ten treatment groups for each of the three problems are given in Table 16. A summary of the analysis of variance is presented in Table 17.

Table 16

Mean Times to Solution for Two Memory Conditions and Five Concept Rules for Three Problems

		Problems			
		1	2	3	Total
Paper	Conjunction	8.88	3.25	4.25	5.46
	Exclusive Disjunction	23.38	13.13	11.88	16.14
	Biconditional	15.50	9.12	11.13	11.93
	Exclusion	18.50	7.38	9.75	11.88
	Conjunctive Absence	8.50	8.50	6.13	7.71
No paper	Conjunction	6.00	3.25	3.50	4.25
	Exclusive Disjunction	26.38	13.88	11.50	17.26
	Biconditional	20.00	10.13	8.50	12.89
	Exclusion	16.50	6.63	6.38	9.84
	Conjunctive Absence	13.88	7.88	7.00	9.59
	Total	15.75	8.31	8.00	10.69

Table 17

Summary of Analysis of Variance: Time to Solution

Source	df	SS	MS	F
Memory (M)	1	1.20	1.20	
Rule (R)	4	3702.83	925.71	12.90*
M x R	4	134.74	33.69	
Error (B)	70	5024.79	71.78	
Problems (P)	2	3079.37	1539.69	19.25*
P x M	2	81.37	40.69	
P x R	8	652.55	81.57	1.02
P x M x R	8	153.38	19.17	
Error (W)	140	11196.33	79.97	

* $p < .01$

The effect of the concept rule was significant at the .01 level, F (4,70) = 12.90. Since there was no effect for paper and no paper conditions, Duncan multiple-range comparisons were performed on the five concept rules summing over memory. Table 18 presents the results of these comparisons.

Table 18

Time: Duncan Multiple-Range Comparisons for Concept Rules Summing Over Memory Conditions

Concepts	Means	C 4.85	A 8.65	E 10.85	B 12.40	D 16.69	Shortest sign. range (p .01)
C	4.85		ns	6.00**	7.55**	11.84**	4.60
A	8.65			2.20	3.75*	8.04**	4.88
E	10.85				ns	5.84**	4.93
B	12.40					4.29*	5.03

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

Disjunctive concepts required more time to solution than any of the other four concept types. These differences were significant at the .01 level, except for biconditional concepts, where the level of significance was .05. Biconditional concepts required more time than conjunctives ($p < .01$) and conjunctive absence ($p < .05$). Exclusion concepts required more time than conjunctives at the .01 level. Other differences were not significant.

The analysis of variance also revealed a significant effect for problems, F (2, 140) = 19.25, $p < .01$. The linear component of the overall trend was significant, F (1, 140) = 30.04, $p < .01$, as was the quadratic component, F (1, 140) = 8.46, $p < .01$. Figure 5 is a plot of the mean times to solution for each of the three problems for the five concept rules. Table 19 presents the results of Duncan multiple-range comparisons between problems.

Figure 5

Mean Time to Solution Plotted Against Problems for Each of Five Concept Rules

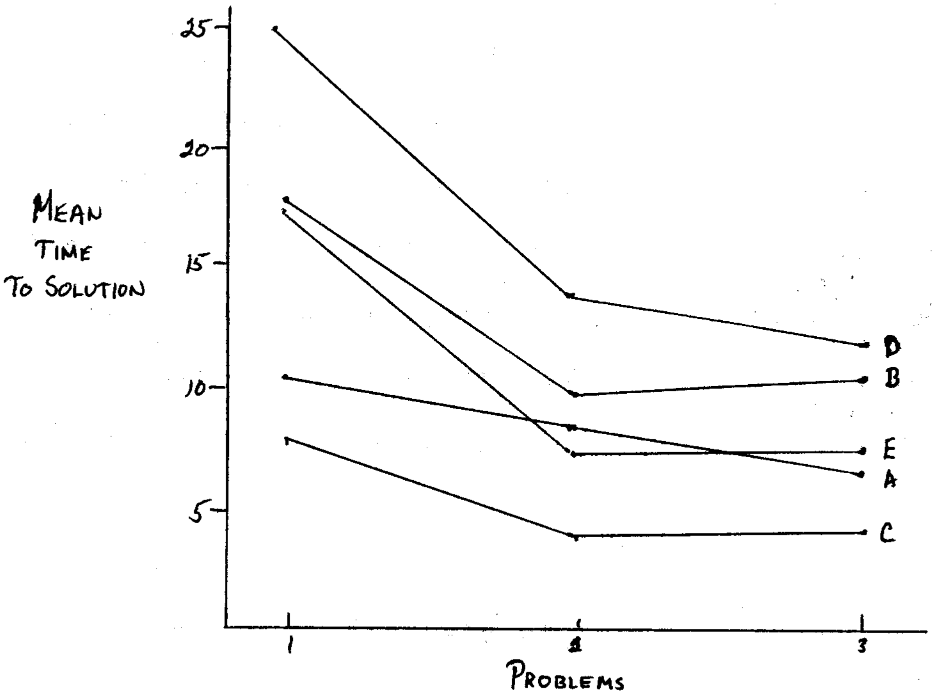


Table 19

Time: Duncan Multiple-Range Comparisons for Problems

Problems		3	2	1	shortest sign. range
	Means	8.00	8.31	15.75	($p < .01$)
3	8.00		0.31	7.75**	3.70
2	8.31			7.44**	3.85

** $p < .01$

The first problem required significantly more time ($p < .01$) than either the second or the third which did not differ from each other significantly.

All of the interactions for time to solution were nonsignificant.

Since none of the dependent measure showed any effect for memory, the analysis of variance for card choices, focusing, untenable hypotheses, and time were performed again summing over memory. The results of these analyses are presented in Table 20.

Table 20

Summary of Analysis of Variance Ignoring Memory

Card choices

Source	df	SS	MS	F
Rule	4	383.71	95.93	4.30**
Error (B)	75	1674.25	22.32	
Problems	2	245.81	122.91	11.54**
P x R	8	136.69	17.09	1.60
Error (W)	150	1598.00	10.65	

Table 20 - Cont.

Source	df	SS	MS	F
Focusing				
Rule	4	3.88	0.970	8.74**
Error (B)	75	8.30	0.111	
Problems	2	0.76	0.380	5.21**
P x R	8	0.87	0.109	1.49
Error (W)	150	10.98	0.073	
Untenable Hypotheses				
Rule (R)	4	0.36	0.090	
Error (B)	75	8.75	0.116	
Problems (P)	2	1.04	0.520	9.12**
P x R	8	0.38	0.047	
Error (W)	150	8.53	0.057	
Time				
Rule	4	3702.83	925.71	13.82**
Error (B)	75	5024.79	67.00	
Problems	2	3079.37	1539.69	20.63**
P x R	8	652.55	81.57	1.09
Error (W)	150	11196.33	74.64	

** $p < .01$

The results of these new analyses showed no new significant main effects or interaction effects.

Each concept rule was ranked with respect to difficulty for each of the five response measures in order to provide a summary of the results. These ranks and the mean rank of each concept rule are presented in Table 21.

Table 21

Ranked Difficulty of Each of Five

Concept Rules for Five Response Measures

	Rule	Measure	Rank	Mean Rank
(C)	Conjunction	Card choices	1	1.00
		Focusing	1	
		Scanning	1	
		Untenable hypotheses	1	
		Time	1	
(A)	Conjunctive Absence	Card choices	2	2.00
		Focusing	2	
		Scanning	2	
		Untenable hypotheses	2	
		Time	2	
(E)	Exclusion	Card choice	3	3.00
		Focusing	3	
		Scanning	3	
		Untenable hypotheses	3	
		Time	3	
(B)	Biconditional	Card choices	4	4.00
		Focusing	4	
		Scanning	4	
		Untenable hypotheses	4	
		Time	4	
(D)	Exclusive Disjunction	Card choice	5	5.00
		Focusing	5	
		Scanning	5	
		Untenable hypotheses	5	
		Time	5	

Note - 1 implies least difficult

Each of the five response measures ranked the difficulty of the concept rules in the same order: conjunction, conjunctive absence, exclusion, biconditional, and exclusive disjunction. It should be noted that Table 21 is to be read as a gross measure as many of the ranks are not clearly supported by significance tests.

Correlations between the five response measures overall concept rules and for each of the five concept rules are given in table 22.

Table 22

Intercorrelations of Response Measures

<u>Overall</u>

	<u>CC</u>	<u>F</u>	<u>S</u>	<u>T</u>
F	-.54			
S	-.67	.71		
T	.49	-.39	-.49	
UH	.66	-.65	-.62	.18

<u>Conjunctive</u>

	<u>CC</u>	<u>F</u>	<u>S</u>	<u>T</u>
F	-.87			
S	-.85	.86		
T	.54	-.56	-.44	
UH	.70	-.76	-.72	.54

Table 22 - Cont.

Disjunctive

	CC	F	S	T
F	-.34			
S	-.70	.66		
T	.32	-.08	-.06	
UH	.61	-.67	-.77	-.07

Biconditional

	CC	F	S	T
F	-.70			
S	-.90	.78		
T	.53	-.20	-.33	
UH	.88	-.73	-.83	.33

Exclusion

	CC	F	S	T
F	-.57			
S	-.86	.61		
T	.11	-.20	-.14	
UH	.83	-.60	-.80	.12

Conjunctive Absence

	CC	F	S	T
F	-.24			
S	-.77	.51		
T	.54	.06	-.63	
UH	.43	-.64	-.29	-.18

Note: The following abbreviations are used:
CC - card choices - F-focusing
S - Scanning - T-time
UH- Untenable hypotheses

Discussion

The ascending order of difficulty as measured by all five dependent measures in the present study (conjunctive, conjunctive absence, exclusion, biconditional, and esclusive disjunction) differs from that found by Neisser and Weene (1962): conjunctive, exclusion, conjunctive absence, exclusive disjunction, and biconditional. However, if one considers only those differences between concept rules which were significant, there is substantial agreement between the two sets of data.

In this light, the main difference between the two studies is that exclusion concepts were relatively less difficult in the Neisser and Weene study. This might be explained by the more complex (625 distinguishable stimuli) concept universe employed by the former authors, although why this complexity should have affected exclusion concepts more than others is not readily apparent.

The findings of Bruner, Goodnow, and Ausin (1956); Haygood and Bourne (1965); Conant and Trabasso (1964); and Laughlin and Jordan (in press) that inclusive disjunctive concepts are more difficult than conjunctive concepts were replicated in the present study with exclusive disjunctive concepts. Haygood and Bourne (1965) found no difference between conjunctive and disjunctive concepts, but the study involved a rule identification task.

Finally, with respect to gross performance measures, the present findings conflict with those of Haygood and Bourne (1965) who found a significant difference reflecting the greater difficulty of conjunctive absence concepts relative to conjunction. No significant difference was found in the present study.

On strategy measures, the present findings also conflict somewhat with those of Laughlin and Jordan (in press). These experimenters foumd more use of focusing with conjunctive concepts than with either inclusive disjunctive or bi-conditional, and more with disjunctive than with biconditional. In the present study there was no difference between bi-conditional concepts and exclusive disjunctive. It might be concluded, then, that exclusive disjunctive concepts are more difficult than inclusive disjunctives. In fact, theories of concept difficulty predict this.

For scanning, however, the present study found less use of this strategy with biconditional concepts than with conjunctive concepts, while Laughlin and Jordan found no such difference.

In general, Laughlin and Jordan found focusing to be a more sensitive measure whereas the present study found scanning to be more sensitive. Perhaps the greater tendency of cooperative groups to employ focusing (Laughlin, 1965; Laughlin and McGlynn, (in press) is responsible for this

difference.

The differential difficulty of concept types can be explained in any of four ways, none of which are contradictory to the present results. The hierarchical theory of Neisser and Weene (1962) would predict that the level III concepts (biconditional and esclusive disjunction) could be significantly more difficult than the level II concepts (conjunction, conjunctive absence, and exclusion). The results of this investigation are in agreement with these predictions.

Similar predictions would be made by a theory based on stimulus uncertainty. Biconditional and exclusive disjunctive concepts involve a 2:2 split in contingencies while the other three concept types all involve a 3:1 split. In view of the lack of experimental evidence on the question, one can only surmise that the difficulty of concept types predicted from a theory based on initial subject familiarity with the concepts would parallel the results of this study. It does seem, however, that disjunctive concepts, even of the exclusive variety, should be more familiar to subjects than biconditionals. Finally, since biconditional and disjunctive concepts require greater utilization of negative instances, a prediction based on this criterion would also fit the obtained data.

Although, the present study has no direct evidence on

the point, it should be noted that the Laughlin and Jordan (in press) assertion that biconditional concepts probably increase in difficulty with the number of values per attribute was given some support by the fact that biconditional concepts ranked above disjunctive concepts in the present study which used a six attribute two-value concept universe. If so, this may explain the difference between the results of this study and those of Neisser and Weene (1962) who found exclusive disjunctive concepts less difficult than biconditionals using more complex stimuli.

The memory variable as manipulated in the present experiment had absolutely no effect. Laughlin and Doherty (in press) likewise found no effect for paper and no paper conditions, although, two significant third order interactions did arise for both focusing and scanning (display x memory x discussion; and number of relevant attributes x memory x discussion). In his review of the effects of memory on concept attainment, Dominowski (1965) notes that only two studies have failed to show impaired performance with increased memory requirements. One of these is relevant to the present discussion. Sechrest and Wallace (1962) used a procedure like that of the present study and varied the memory aids available to help subjects remember what information had been transmitted by the first instance. The memory aids had no effect, but it could not be

determined to what extent they had actually been used by subjects. In the present experiment, some subjects failed to use the paper at all, and many did not use it consistently.

Two more reasons may be advanced to explain the failure of the memory manipulation to produce results. First, the constant availability of all 64 stimuli cards, the systematic arrangement of the cards, and the characteristics of the display itself all served to reduce memory requirements. The failure of many subjects to use the paper provided them supports this view. Secondly, memory requirements were further reduced by the presence of two subjects cooperating in solving the problem. What one subject forgot, the other was likely to have remembered.

This is not to say that the results of the present experiment are unconfounded with memory requirements. Often, for example, the interaction between the cooperating subjects served to reinforce the misinformation of one of them. There is no evidence that this confound was random across conditions. What is needed, then, is a more effective way of either controlling or manipulating the memory requirements.

Although this study employed a selection procedure which usually produces no inter-problem transfer (Laughlin and Jordan, in press), improvement over problems was hypothesized on the basis of the results of Laughlin and

McGlynn (in press). All five dependent measures indicated positive interproblem transfer. Still the results are confusing.

For both card choices to solution and untenable hypotheses, the first problem was significantly more difficult than either the second or the third which did not differ significantly, although performance was better on the second problem by both measures. Both measures also showed significant quadratic and linear trends. Results for focusing strategy were identical except that the quadratic trend was not significant. It is quite possible that the great improvement from the first to the second problem led subjects to experiment (perhaps with unsuccessful focus gambling) on the third problem, which in turn caused a decrement in performance.

The time to solution measure revealed an only slightly different pattern. Here both the linear and quadratic trend components were significant, and the first problem required significantly more time that the other two, but there was no decrement in performance on the third problem. In fact, because of a great improvement on the third disjunctive problem, overall the third problem required less time than the second. Actually, time, which subjects were instructed to ignore, may be taken as a measure of organization and coordination within the two person group as much as a measure of performance. In this sense an improvement on

the third problem would be expected.

For scanning strategy, the first problem was significantly more difficult than the second, but the third problem differed from neither the first nor the second. Only the quadratic component of the trend was significant. Both these findings reflect the significant interaction between rules and problems which was a result of a large decrease in scanning on the second conjunctive absence problem and a large increase on the third.

An interesting finding emerges from an analysis of the second conjunctive absence problem. The large decrease in scanning was accompanied by slight improvements on the card choices, time, and focusing measures, and a relatively good improvement on the untenable hypotheses measure. From this it appears that on this problem, subjects in the conjunctive absence condition adopted some effective effective strategy which was not detected by any of the measures used. The fact that the correlation between focusing and card choices was only -.24, and that between scanning and card choices was only -.77 (lower than three of the other four concept rules) supports this interpretation.

Although none of the other rule by problems interactions were significant, some comments can be made about the plots shown in Figures 1 through 5. For the gross performance measure, card choices to solution, the plots for the

other four concept types (excluding conjunctive absence) are somewhat similar, showing an improvement on problem two and a decrement on problem three. The same may be stated for these four concept rules on the other four measures with these exceptions. For focusing strategy subjects with biconditional concepts did not improve until the third problem, while there was a decrease in focusing on the third disjunctive problem. Biconditional concepts failed to induce more untenable hypotheses on the third problem, and exclusive disjunctive concepts required less time on the third problem.

The pattern that emerges from these comparisons is one of similarity among the level II concepts (conjunctive, conjunctive absence, and exclusion) and one of eratic changes among the level III concepts (biconditional and exclusive disjunction). While on the one hand supporting the hierarchical interpretation of the organization of concepts, this view leads one to believe that the basic scanning and focusing strategies may break down when more difficult level III concepts are encountered.

The correlations between response measures reported in this study are generally somewhat higher than those found in Laughlin (1966), Laughlin and Doherty (in press), and Laughlin and Jordan (in press). The overall correlations are closest to those reported by Laughlin and Jordan.

Although it would seem reasonable to attribute this to the fact that both that study and the present one deal with more complex concepts, the exceptionally high correlations found in the conjunctive condition dispute this interpretation, especially since the correlations in the exclusion and conjunctive absence conditions do not follow this pattern. Perhaps these correlations would parallel those of Laughlin and Jordan if the latter considered only two attribute concepts.

The correlations reported here for the five concept rules show considerable differences. However, there is no perceptible pattern to these differences.

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Appendix I

Instructions

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 six colors, each color being either a plus or a minus. (Point out the 6 colors, each a plus or 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 a blue minus and 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 or yellow plus but not both." Or, all the cards which have a blue minus or 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 yellow plus, then black 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 and 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 an example 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 select 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 it must exactly satisfy the rule.

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 thinkthink 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, although it might be partially correct.

(Give a parallel example of a partially correct hypothesis to the one you gave 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.

Reiterate the concept rule.

APPROVAL SHEET

The thesis submitted by Richard P. McGlynn has been read and approved by the director of the thesis. Furthermore, the final copies have been examined by the director 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 7, 1967
Date

Patrick R. Laughlin, PhD
Signature of Adviser