Winter 1972

Intradimensional Variability with Numbers and Alphabetical Letters in Conceptual Rules

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INTRADIMENSIONAL VARIABILITY WITH NUMBERS AND ALPHABETICAL LETTERS IN CONCEPTUAL RULES

A Thesis

Presented to

the Graduate Faculty

Central Washington State College

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

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February 1972

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ACKNOWLEDGEMENTS

I wish to express a sincere thanks to Dr. Donald E. Guy for his guidance, interest, advice, and dedication to my study. Thanks also to Dr. James G. Green and Dr. Terry L. DeVietti for their assistance and cooperation. A special word of appreciation goes to my wife, Gini for her understanding, encouragement, and help.

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Subjects were assigned to bidimensional rule problems that contained either 5, 10, or 15 levels of intra-dimensional variability. The stimuli consisted of numbers and alphabetical letters. There were no performance differences by either males or females when the number of levels within each rule was increased. There was a significant difference in performance among the three rules (disjunctive, conditional, and biconditional), however, the conditional was more difficult than the biconditional which is inconsistent with earlier research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

In psychology the term "concept" defines the relationship between two or more distinguishable objects that are grouped together because they share some common feature (s). Conceptual activity in the human organism includes a wide range of cognitive skills that will, in part, be determined by the way man interacts with his environment. In an attempt to illuminate some of the processes involved in goal-directed activity the psychologist studies different variables associated with human conceptual behavior.

When dealing with a conceptual problem. the subject (S) is typically presented a closed stimulus population that is designated by the number of dimensions selected, as well as the number of levels or attributes within these dimensions. Such an example is illustrated when the experimenter (E) chooses the two dimensions of number and alphabetical letter, specifying that the stimulus population will be defined as letters A through M and numbers one through thirteen. In this example there are 169 unique patterns which result from combining one attribute from each dimension (e.g., eleven, B). These 169 unique patterns thus comprise the entire stimulus population.

A conceptual learning task can be either unidimensional or bidimensional. A unidimensional task is one in which only one relevant dimension must be identified for the concept to be learned. For example, if red was designated as the relevant attribute then all red objects would be an example of the concept, while non-red objects would not. A bidimensional task requires S to deal with two relevant dimensions (i.e., number, letter) and one attribute from each of these dimensions (i.e., six, B). In this example the relevant attributes are six and B and all other letters and numbers are irrelevant in that they are not correlated in any way with the problem solution.

In dealing with bidimensional concept learning tasks, Haygood and Bourne (1965) have found that problems can be separated into two essential components: attribute identification (AI) and rule learning (RL). In attribute identification, S is required to discover unknown physical attributes of a specifiable (finite) stimulus population where the relationship between the attributes has been explained. Rule learning consists of discovering the rule that explains the relationship between the two relevant attributes which have been identified for S by E. The present study is concerned only with RL.

There are four unique and nontrivial rules that pertain to bidimensional classification of all stimuli. The four rules derived from set theory and symbolic logic are known as Conjunction (Cj), Disjunction (Dj), Conditional (Cd), and Biconditional (Bd). If x represents one relevant attribute and y the other, then the rules may be presented as follows: Conjunction (x and y), Disjunction (x and/or y), Conditional (if x then y), and Biconditional (x if and only if y).

Table 1 illustrates the stimulus assignments for each rule which are determined by whether the relevant attribute is present (T) or absent (F). The truth table of logic defines four stimulus classes according to the presence or absence of relevant attributes in the following way: both attributes present (TT), the first but not the second present (TF), the second but not the first present (FT), and neither relevant attributes present (FF). The four classes TT, TF, FT, and FF can then be collapsed into just two categories, either positive or negative instances, (examples or non-examples of the concept) which will be determined by the particular bidimensional rule being learned.

TABLE 1

ASSIGNMENT OF STIMULUS CLASSES TO RESPONSE CATEGORIES (+ and -) FOR FOUR PRIMARY RULES

Stimulus Class	General Notation	Rules			
		Cj	Dj	Cd	Bd
5A	TT	+	+	+	+
$5\bar{A}$	TF	-	+	-	-
$\bar{5}A$	FT	-	+	+	-
$\bar{5}\bar{A}$	FF	-	-	+	+

The following notation is used: T=present; F=absent; a line above ($\bar{5}$) indicates "not".

The ordering of rules from easiest to most difficult has been found to be Cj, Dj, Cd, and Bd, respectively. Research that has found this ordering includes Haygood and Bourne (1965), Bourne and Guy (1968a and 1968b), Guy (1969), and Vodarski (1970). The conjunctive rule which Ss find easiest is characterized by a smaller and less variable (more homogeneous) category of positive instances as compared to the category of negative instances.

On the other hand, Haygood and Bourne (1965) hypothesized that the greater difficulty of the Cd and Bd rules as compared to conjunctive and disjunctive rules may be due to differences in the mapping of the four stimulus contingencies as shown in the truth table. According to Bourne and Guy (1968b) naive Ss who sometimes utilize a positive focusing strategy may find the decrease in category homogeneity of the positive instances for Cd and Bd rules to be a source of rule difficulty.

Haygood, Harbert, and Omlor (1970) explored the effect of increasing intradimensional variability upon rule difficulty. The results of the study using two, four, and six levels of a dimension in a concept identification task, showed that an increase in intradimensional variability led to a significant improvement in performance on unidimensional and bidimensional problems involving the simple Affirmative and Conjunctive rules.

The present study explores the effect of increasing intradimensional variability using five, fifteen, and twenty-five levels of the dimensions number and alphabetical letter. By using numbers and letters it becomes possible to utilize a much larger stimulus population, e.g., the number of stimuli for 25 levels of the two dimensions of number and letter is 625. In concept learning studies where a dimension such as color is used it becomes difficult for Ss to differentiate shades and attach common labels to them after relatively few levels have been utilized.

CHAPTER II

METHOD

Subjects and Design. The Ss were thirty-six Central Washington State College students. They were randomly assigned to one of the eighteen experimental conditions within a 3 x 3 x 2 factorial design presented in Table 2. The various conditions were prescribed by: three levels of intradimensional variability (five, fifteen, or twenty-five); three rules (disjunctive, conditional or biconditional); and a sex variable (male and female). The dependent variables were the number of trials and errors to criterion.

Task and Procedure. Truth table pretraining was given to all Ss to insure relatively equal abilities on the experimental tasks. Haygood and Kiehlbach (1965) found that truth table pretraining seemed to facilitate both RL and AI. The Ss were trained by using a 2 x 2 matrix presented in Table 3 which represents the four classes of stimuli (TT, TF, FT, FF) defined by the presence or absence

TABLE 2

BLOCK DESIGN FOR A 3 x 3 x 2 FACTORIAL.

EXPERIMENTAL CONDITIONS:

INTRADIMENSIONAL LEVELS (A);

RULES (B); AND SEX (C).

	B. RULES		
A. Intradimensional Levels	Disjunctive	Conditional	Biconditional
5 LEVELS	C. male-female 2M / 2F		
15 LEVELS			
25 LEVELS			n=4

TABLE 3

A 2 x 2 MATRIX SHOWING THE STIMULUS ASSIGNMENTS FOR TRUTH TABLE PRE-TRAINING, USING RELEVANT ATTRIBUTES OF 5 and A.

	A	Not A
5	TT (5 and A)	TF (5 but not A)
Not 5	FT (A but not 5)	FF (Not 5 and not A)

of the two relevant attributes. The two attributes used in pretraining differed from those used in the experiment proper and Ss were required to sort stimulus cards into each of the four areas. The criterion for truth table pre-training was ten consecutive correct responses. The stimulus population included at least five examples of each category.

In the experimental phase, the reception paradigm was utilized, which presents S with randomly chosen stimuli and requires him to respond by placing each stimulus in one of the two available categories. The experimenter began by showing each S a card displaying the relevant attributes which were available for Ss' inspection throughout the experiment. The Ss were instructed that their task was to learn the rule which relates the two attributes. The Ss were then presented with a card that pictured one attribute from each of the two dimensions (i.e., six, B) and responded by placing the card into one of the two slots labeled "yes" or "no". Following each response the E gave verbal feed-back to all Ss as to the correctness of that response. The stimulus cards were prearranged randomly in an order that included an example of each of the truth table categories (TT, TF, FT, FF) in each four unit block and insured that no class was repeated since the same truth table category was not presented twice in succession. The criterion for rule learning was twenty consecutive correct responses. Any S who had not reached the criterion of twenty correct responses after either one hour or three-hundred trials was considered a non-solver, and these data were eliminated from the study.

Materials and Apparatus. The stimuli were presented to each S on a 1½" x 2½" card. There were 40 stimulus cards for each of the three intradimensional levels. The stimuli were selected randomly from a sheet which listed all possible combinations of either five, fifteen, or twenty-five numbers and letters. An effort was made to include a sample from each population that was representative of all possible combinations.

The response apparatus was an upright board with two panels; one labeled "yes", and the other "no". Each panel had a slot where S inserted the stimulus card according to his choice. The instructions (presented in Appendix A) were read to all Ss from an instruction sheet and the Ss' responses were recorded manually by E on a data sheet.

CHAPTER III

RESULTS

Two performance measures were used in determining significant effects in the experimental conditions. They were the number of trials to criterion required for each _S_ to complete the task and the number of errors to criterion required for each _S_. Appendix B contains the original data for all _S_s.

Errors to Criterion. The mean number of errors to criterion for all groups is illustrated in Figure 1. It should be noted that the Cd rule was more difficult to solve than the Bd rule for both levels five and twenty-five, a finding that is not in agreement with the traditional rule ordering. The analysis of variance presented in Table 4 indicates that the rule effect was the only significant source of variance ($p < .01$). The sex condition and intradimensional level condition as well as all interactions were not statistically significant ($p > .05$). The data presented in Table 5 were obtained by collapsing the

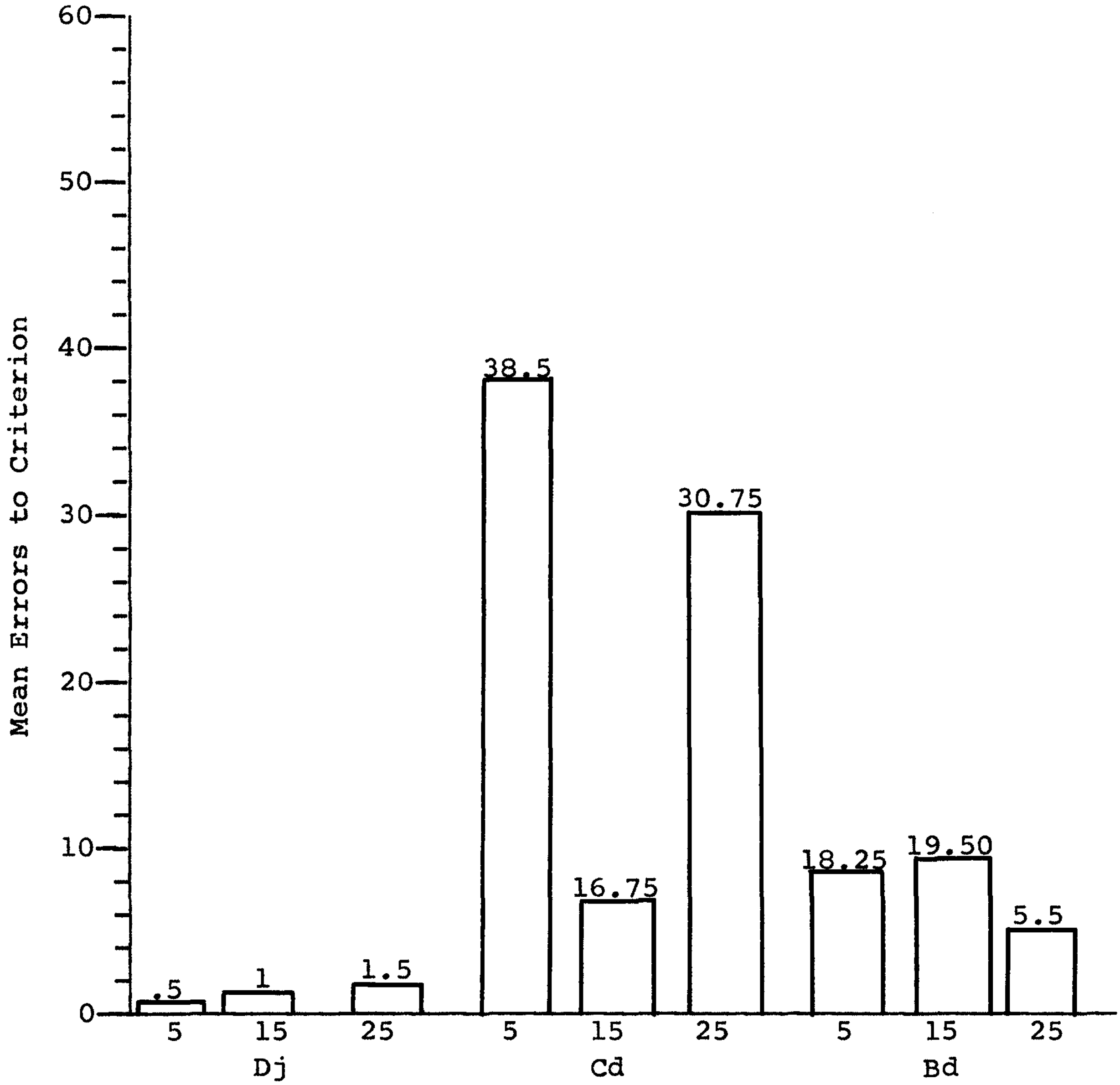

Figure 1. Mean errors to criterion according to five, fifteen, and twenty-five levels for the Dj, Cd, and Bd rules.

TABLE 4

SOURCE TABLE FOR ANALYSIS OF VARIANCE

FOR ERRORS TO CRITERION

Source	df	MS	F
Rules (A)	2	2297.03	16.11*
Levels (B)	2	173.45	1.21
Sex (C)	1	330.03	2.31
A x B	4	276.86	1.94
A x C	2	161.69	1.13
B x C	2	56.78	.40
A x B x C	4	17.95	.10
Ss/grps.	18	170.25	

*$p < .01$

TABLE 5

SOURCE TABLE FOR ANALYSIS OF VARIANCE FOR ERRORS TO CRITERION (WITHOUT SEX CONDITION)

Source	df	MS	F
Rules (A)	2	2297.03	15.89*
Levels (B)	2	173.45	1.20
A x B	4	276.86	1.91
Ss/grps.	27	144.56	

*$p < .01$

sex variable within the other main conditions. This analysis also revealed that only the rule effect was reliable ($p < .01$). Table 6 which lists the results of t-tests performed on the error data, indicates that reliable differences ($p < .05$) occurred between rules Cd, (all levels) vs. Bd, (all levels).

Trials to Criterion. Figure 2 illustrates the mean number of trials to criterion for all groups. This data indicates that the Cd rule was more difficult to solve than the Bd rule for both levels five and twenty-five, a finding that is not in agreement with the traditional rule ordering. The analysis of variance (see Table 7) on the data showed the same pattern of results as found on the errors to criterion measure with the rule effect being the only reliable source of variance ($p < .01$). The other effects of intradimensional levels and sex in addition to all the interactions were not statistically significant ($p > .05$). These data were also analyzed by adding the sex condition in with the other two variables (see Table 8). Again, only the rule effect was found to be significant ($p < .01$). Table 9 which gives the results of t-tests performed on the trials to criterion data, further indicates that reliable differences occurred between rules Cd, all levels vs. Bd, all levels, ($p < .05$) and Cd, level 25 vs. Bd, level 25 ($p < .01$).

TABLE 6

T-TEST RESULTS FOR ERRORS TO CRITERION

Rule and Level	df	t	p
Cd (All levels vs. Bd (all levels)	22	2.14	$< .05$
Cd level 15 vs. Cd level 25	6	1.42	$> .05$
Bd level 15 vs. Bd level 25	6	1.23	$> .05$
Cd level 5 vs. Bd level 5	6	1.03	$> .05$
Cd level 25 vs. Bd level 25	6	2.18	$> .05$

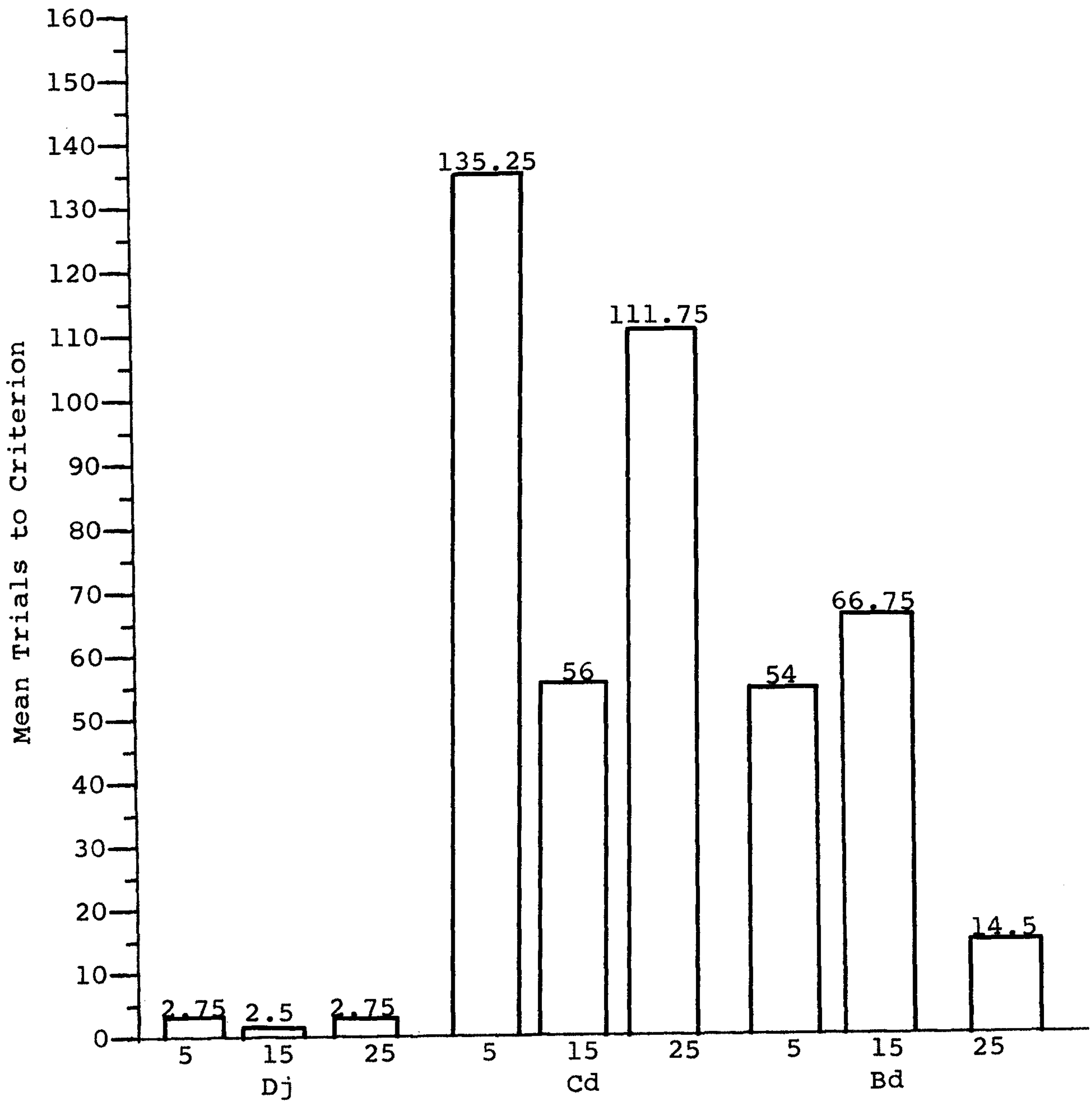

Figure 2. Mean trials to criterion according to five, fifteen and twenty-five levels for the Dj, Cd, and Bd rules.

TABLE 7

SOURCE TABLE FOR ANALYSIS OF VARIANCE FOR

TRIALS TO CRITERION

Source	df	MS	F
Rules (A)	2	29120.59	15.94*
Levels (B)	2	1875.25	1.02
Sex (C)	1	2040.03	1.11
A x B	4	3860.33	2.11
A x C	2	2595.03	1.42
B x C	2	1193.36	.65
A x B x C	4	220.61	.10
Ss/grps.	18	2188.66	

*$p < .01$

TABLE 8

SOURCE TABLE FOR ANALYSIS OF VARIANCE FOR

TRIALS TO CRITERION (WITHOUT SEX CONDITION)

Source	df	MS	F
Rules (A)	2	29190.59	15.80*
Levels (B)	2	1875.25	1.01
A x B	4	3860.33	2.09
Ss/grps.	27	1847.99	

*$p < .01$

TABLE 9

T-TEST RESULTS FOR TRIALS TO CRITERION

Rules and Level		df	t	p
Cd (all levels)	vs. Bd (all levels)	22	2.35	$< .05$
Cd level 15	vs. Cd level 25	6	1.59	$> .05$
Bd level 15	vs. Bd level 25	6	.69	$> .05$
Cd level 5	vs. Bd level 5	6	1.06	$> .05$
Cd level 25	vs. Bd level 25	6	3.96	$< .01$

One of the subjects tested was designated a non-solver since he wanted to stop after one hour and 232 trials.

CHAPTER IV

DISCUSSION

The purpose of the present study was to investigate the effect of increasing intradimensional variability utilizing five, fifteen, and twenty-five attribute levels. The three rules studied were Disjunctive (Dj), Conditional (Cd), and Biconditional (Bd). Two males and two females were assigned to each experimental condition as defined by rules and levels, in order to determine if one sex solved more efficiently than another. In some cases a negative-focusing strategy (attention to and use of negative instances) may be employed by Ss rather than a positive-focusing strategy (attention to and use of positive instances) when the number of attribute levels is increased. Bourne and Guy (1968b) found that with smaller stimulus populations involving the Cj and Dj rules, a positive-focusing strategy usually works best. In learning the Cd rule, however, a negative-focusing strategy may facilitate learning due to the decrease in category homogeneity of positive instances for these rules. Also, as intradimensional variability is increased with the Cd rule, the proportion of negative instances is decreased so that focusing on them would require attention to a smaller number of stimuli.

Haygood and Kiehlbach (1965) found that truth table pretraining seemed to facilitate learning of conceptual rule problems. Truth table pretraining was given to all Ss in this experiment. The reasoning for this procedure in the present study was to expose all Ss to a procedure that might help them in dealing with the problem and in some way bring all Ss to a similar level of functioning before beginning the task of RL. The E could not, however, control whether each S actually utilized the training when dealing with the task. Each S was questioned after the task was completed to determine if he/she had utilized the truth table pretraining in solving the problem. In the writer's opinion this questioning indicated that generally those who used the pretraining solved the problem much more rapidly, efficiently, and logically. This information tends to support the findings of Haygood and Kiehlbach.

Subjects were also questioned after completing the task to determine whether they could verbalize the rule they had "learned" by giving twenty consecutive correct responses. The fact that some Ss had solved the problem but could not verbalize the rule indicated that solution can not be defined only by the actual learning of the rule (twenty successively correct) and that a factor such as memorization of stimulus presentation ordering may have been learned by the S.

The traditional rule ordering of the three rules used in this study from easiest to most difficult, which is Dj, Cd, and Bd has been found by Haygood and Bourne (1965), Guy (1969), Vodarski (1970), and others. Although this study did find the rule condition to be reliable ($p < .01$) it did not find the traditional rule ordering. Rather than Dj, Cd, and Bd, this study found the ordering from easiest to most difficult to be Dj, Bd, and Cd with the exception of level 15 of the Cd and Bd rules where the Bd rule was more difficult. Although the Dj rule was clearly found to be the easiest, the Cd rather than the Bd rule was generally found to be the most difficult. Figure 1 which indicates the mean errors to criterion identifies the Cd rule as most difficult for levels five and twenty-five but not for level fifteen. Figure 2 which illustrates the mean trials to criterion also identifies the Cd rule as most difficult for levels five and twenty-five but not for level fifteen. According to the mean trials to criterion for all levels and mean errors to criterion for all levels, the Cd rule, numerically, was twice as difficult as the Bd rule. A possible explanation of this Cd-Bd problem difficulty inversion is that _S_s tended to adopt a positive-focusing strategy which could make the Cd rule quite difficult to solve due to the large proportion of positive class assignments. Another possible explanation for the inversion is that the _S_s learning the Bd rule understood and utilized the truth table strategy better than the _S_s learning the Cd rule which could explain the quick solution to the problem by the _S_s learning the Bd rule.

Haygood, Harbert, and Omlor (1970) found that as intradimensional variability increased, performance improved with the simple affirmative and conjunctive rules. The results of the present study are inconsistent with those of Haygood et. al., but this could be a function of the different rules used in the two studies. There were no significant differences attributed to levels of intradimensional variability as indicated by Tables 4, 5, 6, and 7. Figures 1 and 2 showed little difference between all three levels concerning the Dj rule. With the Cd rule, level fifteen yielded a higher performance level relative to level twenty-five while level five was more difficult than either level fifteen or twenty-five. For the Bd rule, level twenty-five yielded the best performance but level five performance was slightly better than level fifteen. This indicates that increasing intradimensional variability did not significantly facilitate RL performance involving the Dj, Cd, and Bd rules. This might suggest that variations in the positive-negative ratio is not the crucial factor in determining rule ordering. Since performance did not improve significantly as attribute levels were added, the findings suggest that Ss generally adopted a positive-focusing strategy. If Ss had adopted a negative-focusing strategy, the Cd rule might have yielded improved performance since the ratio of negative to positive instances remains small as attribute levels are increased.

The difficulty of the Cd and Bd rules may be partially explained by the unusual class assignments (see Table 1). When dealing with the Cd rule, Ss tend to treat TF and FT classes the same which results in errors for this rule, whereas it is correct for the Dj and Bd rules. For example, when 5-A are the two relevant attributes, Ss begin by classifying both 5-C (TF) and 10-A (FT) as negative instances. The Cd rule defines TF as a negative instance and FT as a positive instance. Both the Cd and Bd rules are complicated by the positive assignment of both TT and FF classes which requires Ss to place objects in the same category when both relevant features are present or absent. Another explanation for the difficulty of these rules may be their infrequent appearance in everyday life.

Tables 4, 5, 6, and 7 illustrate that only the rule variable was significant. The sex variable, attribute level variable, and all interactions failed to reach significance.

The findings of the experiment are somewhat inconsistent with earlier research. To more thoroughly examine the variables involved, some recommendations for further research are proposed. One recommendation is to develop controls in order to more closely examine the focusing strategy variable since it appears to partially determine the difficulty of conceptual problems. A larger sample size might also be helpful as well as more stringent controls to insure actual rule learning rather than presentation ordering or rote memorization. The controls to insure that the S actually learns the rule may come about by possibly redefining the task for S to perform as well as setting different standards for successful completion of the task.

CHAPTER V

SUMMARY

The present study explored the effects of increasing intradimensional variability (number of attribute levels) on the performance of bidimensional rule learning tasks.

Thirty-six *S*s were randomly assigned to one of the eighteen experimental conditions: three bidimensional rule problems, three levels of intradimensional variability, and males vs. females. The *S*s were required to sort a stimulus card with a number and a letter on it into a positive or negative category of an unknown rule. The rules used were the Disjunctive (Dj), Conditional (Cd), and Biconditional (Bd). The intradimensional levels included five, fifteen, and twenty-five attributes per dimension. The *S*s were told at the beginning of the rule learning task what the two relevant attributes were and that their task was to learn the rule which explained the relationship between them. Twelve *S*s solved problems in each of the three rule conditions, twelve *S*s solved problems in each of the three intradimensional levels, and two females and two males solved problems in each of the nine experimental conditions as defined by rule and level.

It was thought that increasing the number of attribute levels would have an effect on the performance ordering of the various rules and possibly change the traditional rule ordering from easiest to most difficult (i.e., Dj, Cd, and Bd respectively). If such a change was discovered it could be explained by the unequal ratio of positive to negative instances which results from increasing attribute levels among rules. The Cd rule might then be most efficiently solved when the S adopts a negative focusing strategy which allows him to pay attention to a smaller number of stimuli.

The findings of the experiment suggest that Ss may have employed a positive-focusing strategy since the Cd rather than the Bd rule was generally found to be most difficult; hence the traditional rule ordering was not supported. The rule effect of the study was statistically significant ($p < .01$) as well as the Cd-Bd problem difficulty inversion ($p < .05$). Suggestions for further research were made to more closely examine certain aspects of human conceptual rule learning behavior.

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APPENDIX A

APPENDIX A

INSTRUCTIONS

This experiment involves concept rule learning. A concept describes the relationship between two or more objects. Sorting objects according to whether they are red or white exemplifies the learning of a simple concept.

Some conceptual rules involve two classes of objects such as number and alphabetical letter. The conceptual rule explains the relationship between the number and the alphabetical letter. In any example of a problem containing two important features (one from each class, in this case ten from number and Y from letter) there are four patterns into which these features can fall. They are: both present (10 _and_ Y), the first present but not the second (10 but _not_ Y), the second present but not the first (_not_ 10 but Y), or neither important feature present (not 10 and not Y). Using "T" to indicate presence and "F" to indicate absence, the four categories previously mentioned are respectively: TT (indicating both important features present), TF (indicating the first present but not the second), FT (indicating the second present but not the first), and FF (indicating neither important feature present).

The first part of this experiment requires you to separate cards according to the preceding categories. The important features are 10 and Y and you are to place cards on the appropriate square according to the presence or absence of these two features. When you have given ten consecutive correct responses, this phase of the experiment is complete.

The preceding part of the experiment has illustrated that any combination of two important features can be classified into just four categories (TT, TF, FT, or FF). In the next part of the experiment it will be necessary for you to classify objects in this manner and in addition, you are to specify if each pattern is an example or non-example of the concept. If the card I give you is an example of the concept, put it in the slot marked "yes", if it is a non-example, put it in the slot marked "no". I will then tell you if your response is right or wrong. Begin by guessing but paying attention to the presence or absence of the important features which are the number 5, the letter A. Refer to this card with the important features on it to remind you of them throughout the experiment. When you have given 20 consecutive correct responses you have learned the rule and the experiment is over. Do you have any questions?

APPENDIX B

APPENDIX B

RAW DATA

Subject	Rule	Level	Sex	Trials	Errors
1	Bd	15	F	4	1
2	Bd	5	M	9	5
3	Cd	5	F	170	43
4	Dj	25	M	2	1
5	Dj	5	M	0	0
6	Cd	15	F	18	6
7	Cd	25	F	99	33
8	Bd	25	M	43	14
9	Dj	15	F	4	1
10	Dj	5	M	0	0
11	Cd	15	M	44	16
12	Cd	25	M	130	36
13	Dj	25	F	2	1
14	Cd	5	M	101	39
15	Dj	15	M	1	1
16	Bd	5	F	4	1

Subject	Rule	Level	Sex	Trials	Errors
17	Bd	25	F	4	2
18	Bd	15	M	2	1
19	Dj	15	F	2	1
20	Cd	25	F	56	16
21	Bd	5	M	70	30
22	Dj	5	F	7	1
23	Cd	15	F	27	4
24	Bd	15	F	126	31
25	Cd	5	M	181	45
26	Dj	25	F	0	0
27	Bd	25	F	8	4
28	Bd	15	M	135	45
29	Cd	15	M	135	41
30	Bd	25	M	3	2
31	Bd	5	F	133	37
32	Dj	5	F	4	1
33	Cd	25	M	162	38
34	Dj	25	M	7	4
35	Cd	5	F	89	27
36	Dj	15	M	3	1