

THE EFFECT OF NUMBER OF RELEVANT ATTRIBUTES  
ON DISJUNCTIVE CONCEPT FORMATION

by

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ACKNOWLEDGEMENTS

To . . .

Robert C. Haygood, who gave me invaluable advice, assistance and encouragement

and

My mother, who helped me make stimulus cards

. . . this thesis is dedicated.

## TABLE OF CONTENTS

ACKNOWLEDGEMENTS . . . . .	ii
LIST OF TABLES . . . . .	iv
LIST OF FIGURES . . . . .	v
CHAPTER	
1 INTRODUCTION . . . . .	1
2 METHOD . . . . .	4
3 RESULTS AND DISCUSSION . . . . .	7
REFERENCES . . . . .	14
APPENDIX . . . . .	16

## LIST OF TABLES

## Table

1. Summary of Analysis of Variance of Trials to Last Error . . . . . 8

LIST OF FIGURES

Figure	Page
1. Mean trials to last error as a function of NR for two different rule conditions. . . . .	9
2. Mean trials to last error as a function of NR for three different instructional conditions. . . . .	10

## CHAPTER 1

### INTRODUCTION

The increase in difficulty of learning a concept as the concept becomes more complex has been well documented. One important variable governing concept complexity is the number of relevant attributes (NR) in the concept. Walker and Bourne (1961), utilizing visually presented designs, found an accelerating increase in problem difficulty with increases in NR.<sup>1</sup> Similarly, Bulgarella and Archer (1962), using abstract auditory signals as stimuli, found an increase in problem difficulty with increases in NR, though in this case, the increase was linear. NR has also been used as a control variable in a variety of other studies (e.g., Bourne and Haygood, 1959), with essentially the same results.

The above studies have all used simple affirmation (e.g., "red") for problems with one relevant dimension, and conjunction (e.g., "red and square") for problems with two or more relevant dimensions. The only study of the effects of NR with other than a conjunctive rule was done by Kepros and Bourne (1966), using a biconditional (e.g., "red if and only if square") rule with two, three and four relevant dimensions. They reported a linear increase in biconditional problem difficulty with increased NR. However, they used only the biconditional rule, and thus the relative effects of NR in biconditional and conjunctive problems could not be assessed. For practical purposes, then,

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<sup>1</sup>It is not generally recognized that the Walker and Bourne study confounded increased number of relevant dimensions with increased response complexity. This was done by providing a separate response for every combination of levels on the relevant dimensions; thus, for one, two and three relevant dimensions, the number of response categories was two, four and eight, respectively. This very likely accounts for the non-linear effect of NR in their experiments.

the relative effects of increased NR in nonconjunctive problems are unknown.

Previous studies (e.g., Haygood and Bourne, 1965; Neisser and Weene, 1962) have shown that nonconjunctive rules such as inclusive disjunction (i.e., red or square or both red and square) are more difficult than conjunction. This difference in difficulty has been attributed in part to Ss's unfamiliarity with, and their consequent lack of an effective strategy for, disjunctive problems (see e.g., Bruner, Goodnow, and Austin, 1956; Hunt and Hovland, 1960). The difference is enhanced by S's evident preference for conjunctive solutions (Wells, 1963).

The common and generally effective strategies for conjunctive problems, such as conservative focussing, focus gambling, and hypothesis testing, appear to be increasingly less effective for inclusive disjunction at higher levels of NR. Indeed, all strategies which depend on the existence of attributes common to all examples of the concept (positive instances) should become less effective with increased NR in inclusive disjunction, since the proportion of positive instances having any two or more relevant attributes in common decreases. Thus, on the basis of rule familiarity and strategy effectiveness alone, an interaction of NR and conceptual rule can be predicted; increasing NR ought to degrade performance in inclusive disjunction more than in conjunction.

All previous studies of NR appear to have used instructions characterized by Haygood and Bourne (1965) as attribute identification (AI). In AI, S receives thorough instruction on the correct rule for the problem, and his task is to learn the correct attributes. Two other instructional conditions have been studied experimentally. In rule learning (RL), S is told the relevant attributes, and must discover the rule of combination. In complete

learning (OL), S is told neither the rule nor the attributes, and must learn both. Haygood and Bourne (1965) found CL to be the most difficult, AI the intermediate, and RL the easiest in a typical concept identification problem; this order of difficulty was confirmed in a subsequent study (Haygood and Stevenson, 1967). The effects of NR under RL and OL instructional conditions have not been studied experimentally. It seems likely that NR will have more effect in AI and OL than in RL, because in RL, S is told the relevant attributes at the outset and does not need to discover them. In OL, on the other hand, S does not know the rule, and hence has no effective method at the outset for identifying attributes. This may operate to increase the detrimental effect of NR. Thus a clear prediction of an interaction between NR and instructional condition may be generated.

The effects of NR, type of conceptual rule, and instructional condition are, in themselves, predictable from previous studies. The purpose of the present study was to compare the effects of NR under different types of rules and instructional conditions, and thus to determine the generality of NR effects known to exist for the conjunctive rule and AI instructions.



## CHAPTER 2

## METHOD

Subjects and Design

One hundred-eight student volunteers from introductory psychology classes participated as Ss and were assigned to one of 36 treatments. Three additional Ss were dropped because they were unable to solve the problem in the allotted time (one hour); three others were dropped for other reasons (e.g., failure to follow instructions). All six Ss were subsequently replaced.

The experimental design was a 3 x 3 x 2 x 2 complete factorial with three Ss in each treatment combination and one score per S. The main effects were NR (two, three and four relevant dimensions), conceptual rules (conjunction and inclusive disjunction), instructions (RL, AI and CL), and two different sets of relevant attributes at each level of NR. One irrelevant dimension was utilized in all problems.

Materials and Apparatus

The materials consisted of geometric designs mounted on 4 x 6-inch stimulus cards. Five stimulus dimensions were represented on the cards: color, size, shape, number and background. These dimensions were subdivided into three attributes each. The dimension of color was represented by the attribute of red, yellow or blue; size was represented by the attribute of large, medium or small; shape, by triangle, hexagon or square; number by one, two or three figures on a single card; and background by plain, stripes or dots. Only one attribute from each dimension was present on a given card (i.e., only one color, only one size, etc. on a given card). From the total

set of 243 different cards, a subset was selected so that the proportion of positive instances was approximately 0.50 for each problem. If S failed to solve the problem during the first presentation of the deck, the cards were reshuffled and presented again, until S met solution criterion.

A display card was available for all Ss during the sorting. On it were presented all possible combinations of colors, sizes, and shapes of figures. A sample of each background was also displayed.

In the AI instructional condition, rule cards showing Venn diagrams of the rule were presented to Ss. These consisted of two, three or four overlapping circles with appropriate areas shaded in to represent the rule with which S was to deal. For the RL conditions, attribute cards were constructed that stated the specific relevant attributes with which S would be dealing for that particular condition.

A two compartment box was placed in front of S; one compartment was labeled X and the other NOT-X. Thus S could see the last card in each category.

#### Task and Procedure

The task and procedure were essentially the same as those described by Haygood and Bourne (1965). At the outset, all Ss were given information concerning the nature of the task and of the stimulus dimensions and attributes. Additional information specific to S's rule and instructional condition was also presented (Appendix 1).

The S was required to learn to sort the cards into categories labeled X and NOT-X, representing examples and non-examples of the concept, respectively. Cards were shown to one S at a time. If S's response was correct, the card was placed in the appropriate box and nothing was said. If his response

was incorrect, he was informed of his error before placing the card in the right box. When S had sorted 25 cards in a row correctly, the problem was considered solved.

Because of the possibility that Ss in the 4-dimensional disjunctive problems could meet this criterion without having identified all the relevant attributes, an additional criterion was employed in this situation. Four cards, each of which contained only one of the relevant attributes, were selected such that all four relevant attributes could be presented in this manner; another four cards, each representing three out of the four possible relevant attributes were similarly chosen. In addition, four negative examples were included in this criterion set of cards. When S had met the first criterion of 25 consecutive correct responses, he was shown the set of cards just described. If S failed to classify all of this set correctly, the problem was continued until S again met the consecutive trials criterion. The criterion set of cards was again presented. This procedure was repeated until S had correctly sorted all criterion cards in the course of a single presentation.

## CHAPTER 3

## RESULTS AND DISCUSSION

A summary of the analysis of variance of trials to last error is shown in Table 1. As anticipated from previous research, three of the main effects in this experiment were significant. Problem difficulty increased as NR increased,  $F(2,72) = 18.49$ ,  $p < .01$ ; disjunctive problems were harder than conjunctive,  $F(1,72) = 92.54$ ,  $p < .01$ ; and the three instructional conditions differed in difficulty, with RL being the easiest, AI next in difficulty, and CL the most difficult,  $F(2,72) = 24.69$ ,  $p < .01$ . No significant difference was found between the two sets of relevant attributes.

One of the chief points of investigation in this study was the relative effect of NR on disjunctive and conjunctive problems, shown in Fig. 1. The prediction that Rules interact with NR was confirmed,  $F(2,72) = 16.51$ ,  $p < .01$ . Little change in difficulty was noted in conjunction, compared to the pronounced increase in inclusive disjunction. The second major point of this study was the NR by Instructions interaction, which also proved to be significant,  $F(4,72) = 5.71$ ,  $p < .01$ . This interaction is shown in Fig. 2. The effect of NR, linear in all cases, was least with RL, intermediate in AI, and greatest in CL.

The dip in the curve of NR for conjunction at 3 relevant dimensions was caused by unexpectedly superior performance of the AI and CL groups, and generated a significant NR x Rules x Instructions interaction,  $F(4,72) = 4.47$ ,  $p < .01$ . Although it is possible that some peculiarity of construction of the 3-relevant stimulus sequence facilitated conjunctive AI and CL, this finding probably represents sampling error. A new set of 12 Ss was run for these

Table 1  
 Summary of Analysis of Variance of Trials to Last Error.

Source	df	Mean Square	F Ratio
Attribute sets (A)	1	416.14	----
NR	2	92901.86	18.49*
Instructions (I)	2	124047.86	24.69*
Rules (R)	1	465182.81	92.54*
A x NR	2	262.12	----
A x I	2	5075.40	----
A x R	1	2151.50	----
NR x I	4	18619.01	3.71*
NR x R	2	82948.90	16.51*
I x R	2	89026.68	17.72*
A x NR x I	4	4669.24	----
A x NR x R	2	5091.71	----
A x I x R	2	8205.54	----
NR x I x R	4	22447.21	4.47*
A x NR x I x R	4	7105.34	----
Residual	72	361797.42	

\* Significant beyond the .01 level.

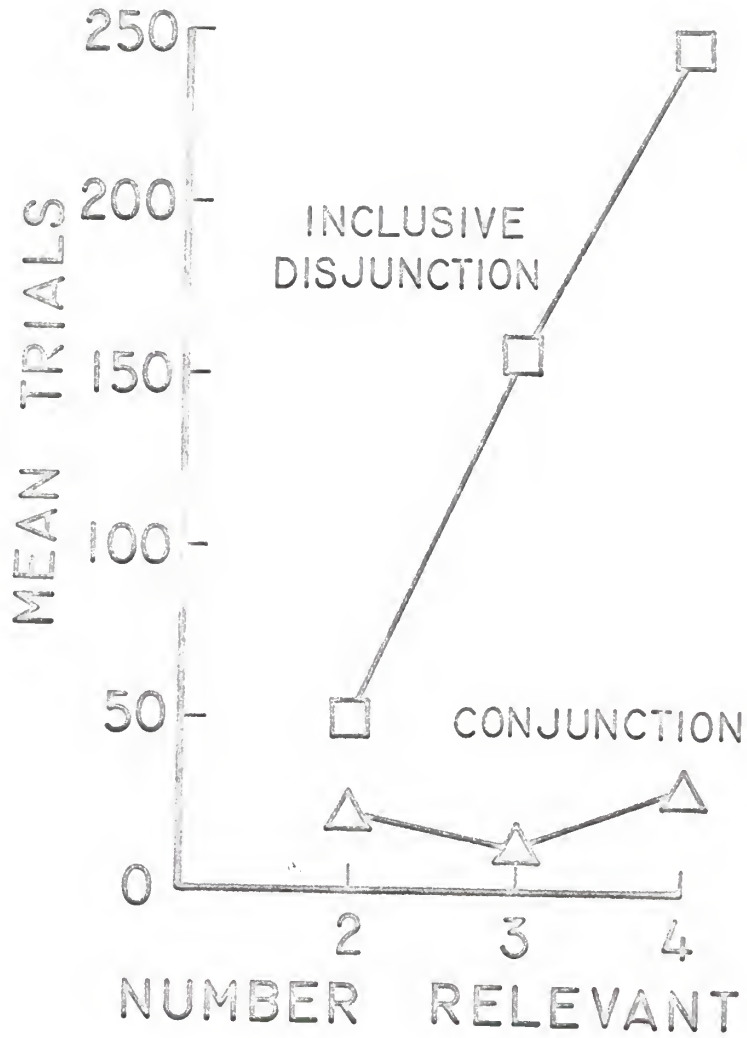


Fig. 1. Mean trials to last error as a function of NR for two different rule conditions.

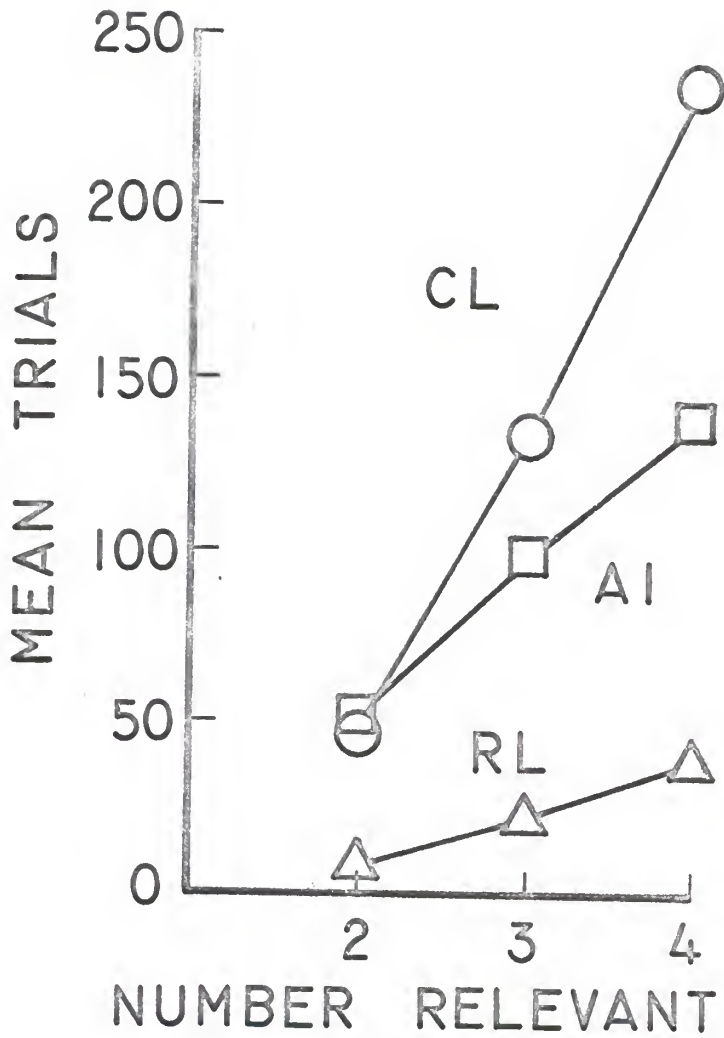


Fig. 2. Mean trials to last error as a function of NR for three different instructional conditions.

conditions, and for these  $S_s$ , both the dip in the curve and the three-way interaction vanish.

As in previous studies, the interaction of rules and instructions was significant,  $F(2,72) = 17.72$ ,  $p < .01$ . There was little difference in conjunctive rule performance over instructional conditions, reflecting in part the irregularity of the curves for conjunction, and suggesting that the experiment is not sufficiently sensitive to demonstrate the smaller differences in conjunction. A similar result for number of irrelevant dimensions was noted by Haygood and Stevenson (1967). None of the other interactions was significant. Analyses of errors yielded essentially the same results.

The results of this study confirm previous findings that NR, rules, and instructions are important determiners of problem difficulty in concept formation. In addition, the results indicate that the effect of NR with inclusive disjunction is much the same as that found with conjunction and biconditional rules, a linear decrement in performance. The rate of decrement, however, clearly depends on the difficulty of the rule, increasing as rule difficulty increases. This result is probably closely tied to relative changes in complexity of the positive categories for the two rules. In conjunction, only one combination of relevant attributes is ever placed in the positive category, regardless of the level of NR. It is conceivable, though there is no evidence to support the speculation, that addition of a highly salient attribute (e.g., red) might actually operate to facilitate integration of the conjunctive stimulus complex. Under inclusive disjunction, by contrast, a minimum of three different complexes of relevant attributes are regarded as positive instances. As NR increases beyond two, the number of possible combinations of relevant attributes increases geometrically, reach-



ing 15 at the level of four relevant attributes. Thus the memory load, already greater than that for conjunction at two relevant attributes, increases differentially for every increase in NR. As noted previously, it would appear that no matter what strategy S might employ, it is doomed to become progressively less efficient as NR increases in inclusive disjunction.

In the same way, the more difficult the instructional condition, the greater the decrement from increased NR. The effect in RL is minimal, as would be expected from the fact that in RL, Ss are told the relevant attributes at the outset; there is no problem of identifying and remembering which are the important characteristics of the pattern. AI instructions are less effective than RL, because S is not told the relevant attributes, and must search for them from an increasing number of attributes as NR increases. The instructions for AI yield faster solution than CL, because in AI S has been furnished a pattern of sorting against which to compare the categorization of various attribute combinations; whatever hypotheses S may be entertaining can thus be more readily confirmed or rejected. It is clear that the advantages conveyed by knowledge of the correct rule increase as rule complexity (NR) increases.

From the results of this study, it appears that the effects of NR, previously established under limited conditions, are quite general. However, the exact increase in problem difficulty with increases in NR is highly dependent on the exact nature of the conceptual problem; the more difficult the problem is in other respects, the greater the effect of NR. Furthermore, it is becoming increasingly evident not only from the results of this study, but from those of Haygood and Bourne (1965), Haygood and Stevenson (1967), Kepros and Bourne (1966), etc., that essentially all informational variables

interact in concept-learning tasks. Because of typically disproportionately smaller variances, some interaction terms may fail to reach the traditional levels of significance; however, it is beginning to seem practicable to demonstrate almost any interaction by designing a properly sensitive experiment.

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APPENDIX

## APPENDIX 1

## INSTRUCTIONS FOR ALL CONDITIONS

This is an experiment in concept formation. I'm going to present the cards in this deck to you one at a time. You can see from this display, the deck consists of cards representing five dimensions: color, shape, size, number and background. These dimensions are subdivided into what we shall call attributes. For example, the dimension of color may be represented by the attribute of red, yellow or blue. The dimension of shape may be represented by the attribute of triangle, hexagon or square, the dimension of size by large, medium or small, the dimension of number by one, two or three figures on a single card, and the dimension of background by plain, stripes or dots. If there is more than one figure on the card, all the figures on the card will have the same size, shape and color.

I'm going to ask you to solve a problem in which you have to learn a concept. Your task is to sort this deck of cards into two possible categories, examples and non-examples of the concept. This is indicated on the boxes in front of you as X and NOT-X. Actually it's as if I gave you a deck of playing cards and asked you to sort them into two piles, face cards and number cards. The difference in this case is that I'm not going to tell you the correct way to sort these cards; you'll have to discover this yourself.

The best way to sort these patterns is to learn the general principle by which the patterns are classified. In the example of the playing cards you would pay attention to only one thing: Does the card have a face or not? If we had a similar concept with these patterns, and if color was the important characteristic, then red patterns might be the concept. If that was the case, then whenever you saw a card with a red pattern you would tell me to put the card in the box marked X, and whenever you saw yellow or blue patterns you'd tell me to put them in the NOT-X box. Today the problem for you to solve is not going to be that easy.

At this point special instructions, presented later in this appendix, were given to S, according to the instructional condition to which he was assigned. Following the special instructions, the following instructions were given to all Ss.

I'm going to present the cards in this deck to you one at a time. I want you to tell me if you think the card should go in box X or NOT-X. If your choice is incorrect I will tell you so and put the card in the right box. When you have placed 25 cards in a row correctly we will consider the problem solved. You may refer to the display card and to the top card of either stack at any time during the sorting. In other words, you will not be allowed to see in which category the cards were previously sorted. (\*SPECIAL INSERT FOR AI AND RL CONDITIONS). At first you'll just be guessing, but as you continue to find out which patterns are X and which are NOT-X,

you'll be able to figure out what the important characteristics of the patterns are. Take as much time as you like to decide where the cards should go. Do you have any questions?

#### SPECIAL INSTRUCTIONS, RL

You will be sorting the cards into two categories: X and NOT-X. You will be sorting on the basis of one attribute from each of (2) (3) (4) dimensions from now on. For example, I may tell you that (RED AND HEXAGON) (MEDIUM AND RED AND HEXAGON) (STRIPES AND MEDIUM AND RED AND HEXAGON) are the attributes to look for. I will not tell you the rule for sorting the cards, however. You will learn this in the process of sorting.

#### SPECIAL INSTRUCTIONS, CL

In the problem you are going to have, there will be (2) (3) (4) important characteristics to watch closely. You will be sorting these cards on the basis of (2) (3) (4) attributes, one attribute from each of (2) (3) (4) dimensions from now on. These (2) (3) (4) dimensions will be related by a special rule. I am going to give you an example of what I have described, which deals with two attributes. Pay attention to what I say, but don't try to memorize the rule, as you will not be using this particular rule in your problem.

For example, if red and hexagon were the two important attributes, the solution might be that all red patterns are examples of the concept except the hexagons. In other words, the rule would be "all except", and you would have to look at both characteristics, red and hexagon.

If the rule is the "all except" rule, and the characteristics are red and hexagon, then cards with red patterns except cards with hexagon patterns would go into the X category. Because the rule is "all red patterns except red hexagons", red hexagons and those patterns that are not red would be NOT-X examples. Your problem today will not be this combination of attributes or the "all except" rule.

#### SPECIAL INSTRUCTIONS, 2 AI

In the problem you are going to have there will be two important characteristics to watch closely. You will be sorting the cards on the basis of one attribute from each of two dimensions from now on. The possible dimensions are color, size, shape, number and background. You will have one problem to solve.

### Either-Or Rule Instructions

For an example of the rule you will be using to sort the cards, let's say that the two important characteristics are color and shape. If that is the case, you might find that any pattern that is either red or hexagon or both red and hexagon goes in the X category. In other words, if the concept is either red or hexagon or both, then all red patterns, all hexagon patterns and all red hexagons go into the X category. Any pattern that is not red or hexagon or both is not an example of the concept, and so would go in the NOT-X category.

This card shows how the rule works. Notice that the red, the hexagon and the red and hexagon areas are marked in. This means that for this particular concept, an example that goes in the X category is a pattern that is either red, or hexagon or both red and hexagon. Your answer to the problem today will not be that particular combination of attributes, but the solution will be some combination of characteristics using the "either-or" rule. You may keep this rule card for reference throughout the experiment.

### And Rule Instructions

For an example of the rule you will be using, let's say that the two important characteristics are color and shape. If that is the case you might find that all patterns that are both red and hexagon would go in the box marked X. In other words, if the correct concept is red and hexagon, then all red hexagons would be examples of the concept. Any card that lacked either one or the other or both of these attributes would not be an example of the concept, and so would go in the NOT-X box.

This card shows how the rule works. Notice that only the area that is both red and hexagon is marked in. This means that these patterns go in the X category. Those patterns that are only red or only hexagon or neither go in the NOT-X category. Your answer today will not be this particular combination of attributes, but the solution will be some combination of characteristics using the "and" rule. You may keep this rule card for reference throughout the experiment.

## SPECIAL INSTRUCTIONS, 3 AI

In the problem you are going to have there will be three important characteristics to watch closely. You will be sorting these cards on the basis of three attributes, one from each of three dimensions from now on. The possible dimensions are color, size, shape, number and background. You will have one problem to solve.

### Either-Or Rule Instructions

For an example of the rule you will be using, let's say that the three

important characteristics are size, color and shape. If that was the case you might find that any pattern that is either medium or red or hexagon or medium red or medium hexagon or red hexagon or medium and red and hexagon goes in the X category. In other words, if the concept is either-or and the relevant attributes are medium and red and hexagon then any pattern having any one of these attributes or any combination of these attributes will go in the X category. Any pattern that has none of these attributes will not be an example of the concept and it will go in the NOT-X category.

This card shows how the rule works. Notice that the medium, the red, the hexagon, the medium and red, the medium and hexagon, the red and hexagon and the medium and red and hexagon areas are marked in. This means that for this particular concept, an example that goes in the X-category is a pattern that is either medium or red or hexagon or any combination of these attributes. Your answer to the problem today will not be this particular combination of attributes, but the solution will be some combination of characteristics using the "either-or" rule. You may keep this rule card for reference throughout the experiment.

#### And Rule Instructions

For an example of the rule you will be using, let's say that the three important characteristics are size, color and shape. If that was the case you might find that all patterns that are medium red hexagons would go in the box marked X. In other words, if the correct concept is medium red hexagon, then all medium red hexagons would be examples of the concept. Anything that lacked any one or two or all of the attributes would not be an example of the concept, and would go in the NOT-X category.

This card shows how the rule works. Notice that only the area that is medium and red and hexagon is marked in. This means that these patterns go in the X category. Those patterns that are only medium or only red or only hexagon or only medium red or only medium hexagon or only red hexagons and those patterns which have none of the attributes go in the NOT-X category. Your answer today will not be this particular combination of attributes, but the solution will be some combination of characteristics, using the "and" rule. You may keep this rule card for reference throughout the experiment.

#### SPECIAL INSTRUCTIONS, 4 AI

In the problem you are going to have there will be four important characteristics to watch closely. You will be sorting these cards on the basis of four attributes, one from each of four dimensions from now on. The possible dimensions are color, size, shape, number and background. You will have one problem to solve.



### Either-Or Rule Instructions

For an example of the rule you will be using let's say that the four important characteristics are background, size, color and shape. If that is the case then you might find that any pattern that is either striped or medium or red or hexagon or striped medium or striped red or striped hexagon or medium red or medium hexagon or red hexagon or striped medium red hexagon goes in the X category. In other words, if the concept is either-or and the relevant attributes are striped and medium and red and hexagon then any pattern having any one of these attributes or any combination of these attributes will go in the X category. Any pattern that has none of these attributes will not be an example of the concept and it will go in the NOT-X category.

This card shows how the rule works. Notice that the stripe, the medium, the red, the hexagon and all areas of overlap are marked in. This means that for this particular concept, an example that goes in the X category is a pattern that is either striped or medium or red or hexagon or any combination of these attributes. Your answer to the problem today will not be this particular combination of attributes, but the solution will be some combination of characteristics using the "either-or" rule. You may keep this rule card for reference throughout the experiment.

### And Rule Instructions

For an example of the rule you will be using, let's say that the four important characteristics are background, size, color and shape. If that is the case, you might find that all patterns that are medium red hexagons on a striped background would go in the box marked X. In other words, if the correct concept is striped, medium red hexagon, then all striped medium red hexagons would be examples of the concept. Anything that lacked any one or two or three or all of the attributes would not be an example of the concept, so would go in the NOT-X category.

This card shows how the rule works. Notice that only the area that is striped and medium and red and hexagon is marked in. This means that these go in the X category. Patterns that are not composed of all four attributes go in the NOT-X category. Your answer today will not be this particular combination of attributes, but the solution will be some combination of characteristics using the "and" rule. You may keep this rule card for reference throughout the experiment.

### \*SPECIAL INSERT FOR RL CONDITIONS

In your problem the relevant attributes you will be dealing with are (BLUE AND TRIANGLE) (LARGE AND BLUE AND TRIANGLE) ( ONE AND LARGE AND BLUE AND TRIANGLE).

or,

In your problem the relevant attributes you will be dealing with are TWO AND SQUARE) (TWO AND YELLOW AND SQUARE) (TWO AND SMALL AND YELLOW AND SQUARE).

\*SPECIAL INSERT FOR AI CONDITIONS

In your problem you will use the (AND) (EITHER-OR) rule.

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1967

## ABSTRACT

The purpose of this study was to determine the relative effects of increasing the number of relevant stimulus dimensions in a concept for different conceptual rules and instructional conditions. The results indicated that the effect with inclusive disjunction is similar to that previously found for conjunction, a linear decrement in performance. However, the rate of decrement is greater for disjunctive than for conjunctive problems. Similar results were obtained in a comparison of instructional conditions. Although the linear decrement with increases in number of relevant dimensions thus appears to be quite general, the rate of decrement depends highly on the exact conditions of the conceptual problem.