THE EFFECT OF REDUNDANCY ON DISJUNCTIVE CONCEPT IDENTIFICATION

by

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To . . .

Dr. Haygood, without whom this work would have been impossible

My parents, for starting me off in college

My friends at K.S.U., who made these years in Manhattan tolerable

. . . this thesis is gratefully dedicated.

TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

CHAPTER 1

Introduction

In the common language, redundancy is a quality or state of being excess or superfluous, exceeding what is natural, usual, or necessary. Among experimental psychologists, several more precise and technical definitions have arisen; although stated differently, these definitions can be shown to be equivalent.

One definition is that redundancy exists when there is transmission of more information than is minimally necessary for the solution of a problem or the comprehension of a stimulus. The dollar bill is an example of this. It contains the numeral 1, a picture of George Washington, and the words "one dollar" spelled out. Any one of these characteristics would be sufficient to know that it is a one dollar bill, and the others do not add any new information.

Another definition of redundancy is that it exists whenever it is possible to predict accurately one part of the stimulus from another part. The English language is clearly redundant. For example, the letter U always follows the letter Q; since one can predict with perfect accuracy that Q will be followed by U, no new information is provided by the U and it is informationally superfluous. Similarly one can predict the color of playing cards from the suit because of redundancy, spades and clubs being always black, hearts and diamonds always red. This type of definition obviously can be applied to the dollar bill example.

Garner (1962) presented still another definition of redundancy. He said that redundancy occurs when "fewer than the total possible number of stimuli are actually presented to the subject (p. 321)". Garner's definition requires some explanation, however. The "total possible number of stimuli" represents all the stimuli that can be generated with a given number of stimulus dimensions. If the problem contained two ternary irrelevant dimensions and one ternary relevant dimension, then there would be 27 possible stimuli. If some of the possible stimuli are not presented to S, as in the case where S reaches solution early in the sequence of stimuli, this would not generally be considered redundancy as Garner's definition would imply. On the other hand, if all squares were red and all triangles green, fewer than the total possible stimuli would be used because green squares and red triangles would be left out; this would generate the redundancy Garner was defining.

Many experiments have been performed to study the effects of redundancy on communication of information (Chapanis, 1954; Miller, 1958; Shannon, 1951). In general, increasing redundancy aids communication, and thus aids performance, depending upon the task and the type of redundancy. If the redundancy occurs among the relevant characteristics, it increases the number of cues S can use to identify a set of stimuli correctly. This can also provide a means for overcoming the disruption ordinarily brought on by irrelevant information or noise. Rappaport (1957) showed that relevant stimulus redundancy facilitated rapid discrimination of visual forms in the presence of background visual noise (irrelevant information) but it had an inhibitory effect in a noise-free situation. Redundancy can also hinder communication by making the stimulus patterns more complex and thus more difficult to examine (Bricker, 1955). Concept-identification tasks represent a kind of communication situation in problem solving;

experiments are typically concerned with determining how much, what kind, how, and how long information must be presented before S is able to solve the problem. Therefore it is reasonable to expect that redundancy would have an effect on such tasks.

Bricker (1955) was the first to study the effects of stimulus redundancy in a concept-identification task. He showed different arrangements of neon glow tubes to Ss and required them to learn to identify the patterns with monosyllable responses. He varied stimulus redundancy by adding elements to the minimum number of elements necessary to identify each stimulus. This increased the complexity of the stimulus but also added alternative ways of identifying each pattern. Bricker found that stimulus redundancy retarded learning and slightly increased reaction time.

Haygood and Bourne (1959, 1961) found results contrary to those of Bricker in a different type of concept-identification experiment. They varied the levels of both redundant relevant and irrelevant information and found that increases in redundant relevant information improved performance at all levels of irrelevant information. This effect was attributed primarily to the fact that increasing the number of relevant redundant dimensions increases the number and proportion of cues that S can use to identify a set of stimuli correctly. The beneficial effect of relevant redundancy with no irrelevant dimensions contradicted the earlier results of Rappaport (1957).

Redundancy can take many forms in a concept identification task. The simplest occurs when there is perfect correlation between the levels of the redundant dimensions. Haygood and Bourne (1964) called this Form A redundancy, in contrast to Form B redundancy, in which no single relevant dimension correlates with the redundant dimension.[1] In an experiment to compare these two forms, Haygood & Bourne found that the facilitative effect of Form B redundancy was reliable, but that it was less easily perceived and utilized by S than Form A. This experiment resolved in part the contradiction between the Bricker (1955) and Bourne and Haygood (1959) results, since the decrement reported by Bricker was found with Form B redundancy.

All of these studies of stimulus redundancy in concept learning have used concepts based on simple affirmation (e.g., "red") or conjunctive (e.g., "red and square") rules. Bruner (1956) described still another concept-identification rule, inclusive disjunction; a typical example of an inclusive disjunctive concept would be "either red or square or both". With such a concept, red squares, green squares, and red triangles would all be examples (positive instances) of the concept.

In recent years there have been numerous studies comparing various conceptual rules. Neisser and Weene (1962) had Ss learn two sets of 10 problems, of which each problem represented a different one of 10 unidimensional and bidimensional rules. They found that inclusive disjunctive concepts are substantially harder to learn than conjunctive concepts. Haygood and Bourne (1965), using a different type of stimulus materials (geometric designs instead of clusters of letters) also found inclusive disjunction to be a more difficult rule; the superiority of conjunction held up across a variety of instructional conditions. These results were subsequently confirmed by Looney and Haygood (1967) and Haygood and Stevenson (1967).

The Looney and Haygood (1967) and Haygood and Stevenson (1967) studies also showed that the effects of some variables are different for different rules. Looney and Haygood compared the effects of number of relevant dimensions (i.e., concept complexity) on conjunctive and disjunctive concept learning. They found that the deleterious effect of increasing the number of relevant dimensions was greater with disjunction than with conjunction. A similar interaction was found by Haygood and Stevenson between conceptual rule and number of irrelevant dimensions.

Thus, not only are inclusive disjunctive concepts harder to learn than conjunctive concepts, but also the effect of other variables depends on which conceptual rule is used. The effects of increasing the number of irrelevant and relevant dimensions is greater as rule difficulty increases, with inclusive disjunction showing a larger effect than conjunction. The present study was designed to extend this further by comparing the effects of stimulus redundancy on conjunctive and disjunctive concept problems.

Most concept studies in the past, particularly the concept identification experiments, (e.g., Bourne and Haygood, 1959) have used the technique of explaining the rule to S and having him discover or identify the relevant attributes. Haygood and Bourne (1965) called this instructional condition attribute identification (AI). They also pointed out two other possible instructional conditions, rule learning (RL), and complete learning (CL). In the RL condition, S is told the relevant attributes and must discover the rule. In CL, S must discover both the relevant attributes and the rule. Haygood and Bourne found CL to be the most difficult, AI intermediate, and RL the easiest in a typical concept-identification problem. This order difficulty of instructional conditions was confirmed by Haygood and Stevenson (1967) and Looney and Haygood (1967).[2]

In general, it has been found that the instructional condition interacts with other variables in concept-identification problems. In the Haygood and Stevenson (1967) study pronounced linear effects of number of irrelevant dimensions were found with AI and CL, but there was no effect on RL, Ss were told the relevant attributes at the outset; they should not have been concerned with the irrelevant dimensions. Looney and Haygood (1967) found a similar interaction between instructional conditions and number of relevant dimensions. The effect of number of relevant dimensions, linear in all cases, was greatest for CL and least for RL.

Turning to the case of redundancy, added redundant relevant attributes should be of little help in RL because S already knows a usable, satisfactory pair of attributes. On the other hand, redundant relevant attributes should help AI because S will have more usable attributes to choose from to fit the rule. This is the finding already documented by Haygood and Bourne (1964). In CL, Ss will have more usable attributes to choose from, and since CL is much more difficult than AI, the beneficial effect of redundant relevant attributes should be greater.

The above argument leads to a prediction of an interaction of redundancy and instructional conditions; all three conditions should be made easier by redundancy, with CL being helped the most and RL the least. The examination of this interaction was another major purpose of the present experiment.

CHAPTER 2

Method

Subjects and Design

The Ss were 108 Introductory Psychology students who participated in the experiment for class credit. All Ss were naive in that they had not previously been in a concept-identification experiment. The Ss were run in sets of three, which were randomly assigned to one of 36 treatment conditions. If three Ss could not participate at one time the group was filled in later with the additional Ss needed.

Five Ss were dropped for failure to follow instructions and nine Ss were dropped for failure to solve the problem within the 200 trial limit. All 14 Ss were subsequently replaced. Several additional Ss were lost because repeated equipment failure kept them from completing the task. These Ss were excluded since they had no effect on the data collected.

The experimental design was a 3 x 3 x 2 x 2 complete factorial with three Ss in each treatment and one score per S. The experimental variables were redundancy (zero, one, and two redundant relevant dimensions), instructions (RL, AI, and CL), conceptual rules (conjunction, and inclusive disjunction), and two different sets of relevant attributes (double-triangle and large-blue).[3]

Materials and Apparatus

The stimulus materials consisted of geometric patterns on color slides. The characteristics of the geometric patterns were allowed to vary along five stimulus dimensions with three levels of each dimension. The dimensions and their levels were: Number (single-double-triple), color (red-yellow-blue), form (triangle-square-hexagon), size (large, medium, small) and background (plain-spotted-striped). A card listing the dimensions and their levels (all possible characteristics) was available for each S throughout the task.

The equipment was designed so all three Ss of each group could work independently at the task at one time. They were separated by screens. Each S was seated in a lecture chair with a two-button box in front of him. The buttons were labled YES and NO and had a green light used for feedback over each. Feedback was controlled with a Western Union Telegraph tape reader, Model 1A.

The stimulus patterns were shown with a Kodak Model RA 950 Random Access Carousel projector on a screen in front of the Ss. The order of the slides was controlled by a Model 119 Orthronics 8-channel tape reader. The S's responses and feedback were recorded by an Esterline Angus Model AW Operations recorder.

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 detailed instructions concerning the nature of the task, the operation of the apparatus, the meaning of the feedback lights, and the possible stimuli. Additional information specific to S's rule and instructional group was also presented, verbatim instructions are included in Appendix A.

The Ss were required to sort or classify a series of visually presented stimuli into two categories labeled YES and NO, representing examples and non-examples of the concept, respectively. Within any problem, a stimulus dimension was considered relevant if it could be used to correctly classify each stimulus pattern. The number of relevant dimensions in any problem depended on the level of redundancy of that problem. When number and form were the relevant dimensions used, size was made redundant with number for the one-level condition. For the two-level redundant condition size and number were redundant, as in the one-level, and color was made redundant with form. In the conditions where size and color were the relevant dimensions form was redundant with size for the one level condition and number redundant with color was added for the two level condition.

There was only one irrelevant stimulus dimension, background, for every problem. In each problem, the stimulus dimensions that were not relevant or irrelevant were held constant and thus were presumed not to exist. However, a certain amount of irrelevant information might have been introduced by instructions indicating that all of the dimensions could vary. The slides used to present the stimulus patterns were constructed in such a way that when any dimension was redundant with any other, the levels within each were perfectly correlated; e.g., if size and form were redundant, triangles were always large, squares medium, and hexagons small.

The stimulus pattern slides were shown to the Ss one at a time. After all three Ss had made responses, a light came on over the correct response button for 1 sec., then a new pattern appeared on the screen. The time between the last response and a new stimulus was held constant at 4 sec. but the time between stimuli could not be controlled for there was no time limit for responding. Accuracy rather than speed was stressed in the instructions. However, there appeared to be some social pressure against long response times when more than one S was working at the task.

When _S_ had sorted 20 stimuli in a row correctly the problem was considered solved. If this criterion was not met by the 200th trial, _S_ was considered to be a non-solver. The task was terminated when all _Ss_ had met criterion.

CHAPTER 3

RESULTS AND DISCUSSION

Since instructions stressed accuracy, number of errors was the main dependent variable. A summary of the analysis of variance of the errors is shown in Table 1. As anticipated from previous research three of the main effects in the present experiment were significant. As relevant redundancy increased, errors decreased, F (2,72) = 3.85, $p < .05$. This supports previous results found by Bourne and Haygood (1959) and Haygood and Bourne (1964). Inclusive disjunctive problems were consistently harder than conjunctive, F (1,72) = 24.90, $p < .01$, as they were in the Looney and Haygood (1967) and Haygood and Stevenson (1967) studies. The three instructional conditions differed in difficulty, F (2,72) = 7.39, $p < .01$, however there was an unexpected change from the usual order (e.g., Looney and Haygood, 1967) with AI being more difficult than CL. This reversal occurred only in the zero redundancy condition, but the effect was sufficient to override the normal order found in the 1- and 2-redundant conditions. No significant difference was found between the two sets of relevant attributes.

One of the chief points of investigation in the present study was the relative effect of relevant redundancy on inclusive disjunctive and conjunctive problems, shown in Fig. 1. Previous studies have shown that the effect of different variables were larger for inclusive disjunctive than for conjunctive problems. In the present experiment, there was no significant difference in the effect of relevant redundancy on the two problems; increasing relevant redundancy resulted in about the same

Table 1

Summary of Analysis of Variance of the Errors

Source	df	Mean Square	F Ratio
Redundancy (Rd)	2	439.11	3.85*
Rules (Rl)	1	2841.82	24.90**
Instructions (I)	2	844.08	7.39**
Attribute Sets (A)	1	7.26	----***
Rd X Rl	2	20.48	----***
Rd X I	4	965.44	8.46**
Rd X A	2	437.37	3.83*
Rl X I	2	414.32	3.63*
Rl X A	1	71.70	----***
I X A	2	43.62	----***
Rd X Rl X I	4	394.76	3.46*
Rd X I X A	4	266.48	2.33
Rd X Rl X A	2	87.37	----***
Rl X I X A	2	51.17	----***
Rd X Rl X I X A	4	125.61	1.10
Error	72	114.12	

*Significant beyond the .05 level
**Significant beyond the .01 level
***F Ratio less than 1.00 not reported

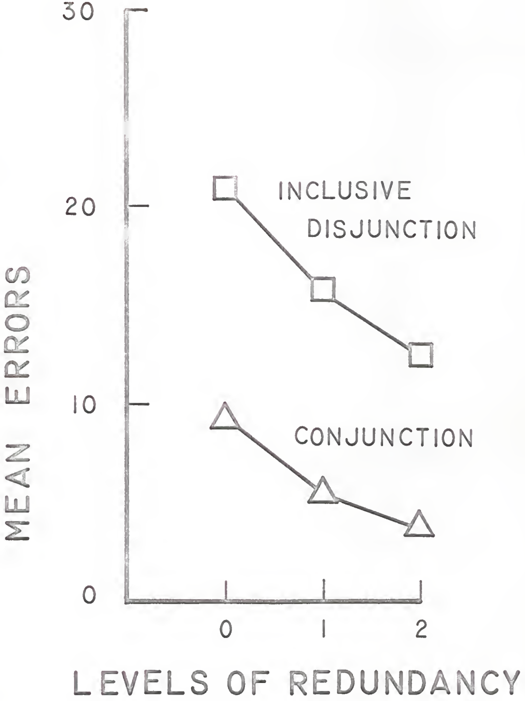

Fig. 1. Mean number of errors to solution as a function of number of relevant redundant dimensions for two different rule conditions. Each plotted point represents the data fron 18 Ss.

improvement in performance in the inclusive disjunctive problems as in the conjunctive problems.

The second major point of this study was the Redundancy by Instructions interaction, which proved to be significant, F (4,72) = 8.46, p < .01. This interaction is shown in Fig. 2. The effect of the interaction was not as expected since there was the reversal of AI and CL difficulty at the zero-redundancy level. However, as expected, the RL condition was not helped by redundancy.

The Redundancy by Attributes interaction was significant, F (2,72) = 3.83, p < .05. This was probably caused by a difference in saliency of the dimensions that were made redundant in each problem. Archer (1962) reported that performance in concept identification tasks is facilitated when the relevant dimension is obvious, but impeded if the relevant information is less obvious.

As was expected, the Rules by Instructions interaction was significant, F (2,72) = 3.63, p < .05. The RL condition was not much harder in the inclusive disjunction than in the conjunctive problems because in both cases; S's task is simply to learn the correct category for each of the four possible relevant attribute combinations. However, the inclusive disjunctive rule was much more difficult in the AI and CL instructional conditions.

The final significant interaction, Redundancy by Rules by Instructions, F (4,72) = 3.46, p < .05 is tied to the reversal of AI and CL difficulty; the complex interaction shown in Fig. 2 was different in magnitude for the two problem sets.

The major conclusion that can be drawn from the present experiment is

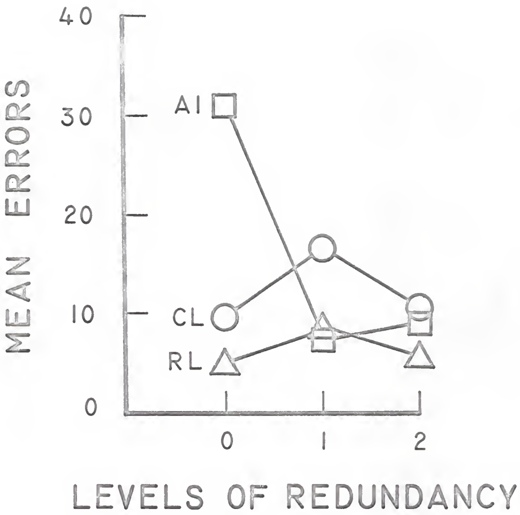

Fig. 2. Mean number of errors to solution as a function of number of redundant relevant dimensions for three different instructional conditions. Each plotted point represents the data from 12 Ss.

that inclusive disjunctive problems are affected by redundancy in the same way conjunctive problems are affected. It was thought that since the inclusive disjunctive problems are more difficult than the conjunctive ones that they should be helped more by redundancy, but apparently this is not the case. Because of the odd reversal of the AI and CL difficulty at the zero-redundancy level, no firm conclusions can be drawn about the interaction of Redundancy and Instructions. It is believed that the main reason for this reversal is sampling error. Rather poor Ss could have been picked for the AI condition and exceptionally good ones for the CL condition. The AI Ss made more errors than would be predicted from previous studies and the CL Ss made only one fourth of the errors predicted. There is also the ever-present possibility that Ss talked about the experiment outside of the laboratory. The AI and CL groups for the zero-redundancy level should be replicated before any final conclusion about effect of redundancy in the different instructional conditions is made.

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FOOTNOTES

1. Haygood and Bourne used a four-choice problem whose categories were defined by the four possible combinations of two binary dimensions--e.g., red triangles, red squares, green triangles, and green squares. Form B redundancy was introduced by adding a third binary dimension distributed so that the categories represented large red triangles, small red squares, small green triangles, and large green squares. The size dimension was completely redundant, since its levels could be predicted perfectly from a combination of the other two relevant dimensions, though not from any one alone. The addition of the Form B redundant relevant dimension created four possible problem solutions: the original solution of color and shape, color and size, shape and size, and all three dimensions taken together. Cases of intermediate correlation between dimensions would also be considered Form B redundancy.

2. This order of difficulty does not hold up in all types of problems. Summers (1967) found that if the problem contains only a single relevant dimension, it makes little difference whether the S must discover the rule, the relevant attribute, or both.

3. Another conceptual rule (biconditional) was included in the original design, but the results will not be reported here because 60% of the Ss failed to solve within the 200 trial limit.

APPENDIX A

Instructions for all Conditions

This is an experiment to see how well you can learn to sort geometric designs into categories. Each design can be classified into one of two groups, which are labled YES and NO on the box in front of you. Your job will be to try to discover what it is that tells the two groups apart. It is very much like asking you to sort a deck of playing cards into two piles, face cards and number cards. This would be an easy job for you. The difference is that I am not going to tell you how to sort these designs. There is a correct way to sort them into YES and NO categories and you have to discover this yourself.

Each time you see a design, decide into which group you think it goes, and push the appropriate button on your control box. After everyone has pushed a button, one of the lights will come on over the correct button. This way you can check to see if you did push the right button. At first you will just be guessing, but as you continue to see which designs go into which group, you will be able to make the correct response every time.

The geometric designs you will be seeing may vary along five different dimensions. All of the possible characteristics are listed on the card on your desk. The designs may be: large, medium, small; red, yellow, blue; square, triangle, hexagon; single, double, triple; and be on a plain, spotted, or striped background.

Here's what you do. You look at the design, decide if it belongs in the YES or the NO category, make your response by pushing the appropriate button (remember you will just be guessing at first), the light will come on and indicate the correct response, and then a new design will appear on the screen. You will repeat the procedure until I tell you to stop.

Speed is not important, accuracy is. So take your time in responding, and don't feel like you have to push a button just because everyone else is pushing buttons. The design will remain on the screen until everyone has responded.

SPECIAL INSTRUCTIONS HERE

Are there any questions? Remember YES and NO are just lables of the categories, they don't mean right and wrong. Your job is to find the correct way to sort the designs into these categories.

Special Instructions

Rule Learning:

Just two of the characteristics are necessary for you to be able to sort these designs. The characteristics for your problem are (Double & Triangle)(Large & Blue). These two characteristics are related by a special rule which determines how the designs are to be sorted. Once you discover this rule, you will be able to sort all the designs correctly.

Attribute Identification, Conjunction:

There are two important characteristics to look for in your problem. These characteristics are related by a special rule AND. This means that both of the characteristics must be present for the design to be an example for the YES category. An example of this is SINGLE and PLAIN. The design would have to be both single and on a plain background for it to belong in the YES category. Any design that didn't have both characteristics would go in the NO category. SINGLE and PLAIN are not the answer to your problem, this is just an example.

Attribute Identification, Inclusive Disjunction:

There are two important characteristics to look for in your problem. These characteristics are related by a special rule EITHER OR BOTH. This means that if either of these two characteristics or both are present in the design, then the design is an example of the YES category. Any design that did not have at least one of the two characteristics present would be an example of the NO category. An example of this is SINGLE and PLAIN. The design could be either a single figure or be on a plain background or be both single and on a plain background to be in the YES category. Any design that was neither single nor on a plain background would go in the NO category. SINGLE and PLAIN are not the answer to your problem, this is just an example.

Complete Learning:

In the problem you are going to have there will be two important characteristics to watch for. They will be two of the ones listed on your card. The two important characteristics will be related by a special rule. Your job is to discover which two characteristics are important and by what rule they are related. Once you discover this you will be able to sort all the designs correctly.

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Previous studies have shown that the effects of many variables are larger for inclusive disjunctive than for conjunctive problems. The present study was designed to extend this further by comparing the effects of stimulus redundancy on conjunctive and disjunctive concept problems. It has been found that the type of instructions interacts with other variables in concept-identification problems; thus a second purpose of this study was to examine the interaction of redundancy and instructional conditions. The results showed that increasing relevant redundancy resulted in about the same improvement in performance in inclusive disjunctive problems as in conjunctive problems; there was no significant difference in the effect of redundancy on the two problems. The Redundancy by Instructions interaction was significant but not as expected since there was a reversal from the expected order of difficulty at the zero-redundancy level. The results were interpreted as showing that the beneficial effects of relevant stimulus redundancy are general conceptual rules.