INSTITUTE FOR THE
STUDY OF
INTELLECTUAL
BEHAVIOR

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*Program on Cognitive Factors in Human Learning and Memory Report No. 74

Institute for the Study of Intellectual Behavior

University of Colorado

Boulder, Colorado 80309

December, 1977

ABSTRACT

Garner (1976) has identified two main types of dimensional interactions which are likely to affect concept learning; integral and separable dimensions. The present experiment compares rule learning with these two types of stimuli using the conjunctive, disjunctive, conditional and biconditional rules. Results indicate that integral stimuli facilitate acquisition of the conjunctive rule, but that separable stimuli facilitate acquisition of difficult truth-table classes in the conditional and biconditional. Presumably, when a rule requires discrimination of its truth-table class structure then stimuli which enhance the separability of the dimensions facilitate this process. Implications of this work for models of rule difficulty are discussed.

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*This research was supported by NSF Grant GB 34077X.

The authors gratefully acknowledge the work of John E. Morrison and Charles L. Richman as an impetus for the present experiment. Send reprint requests to J. Steven Reznick, Psychology Department, University of Colorado, Boulder, Colorado 80309.

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A logical concept based on a binary operator or rule assigns positive (exemplar) or negative (nonexemplar) status to each of four possible stimulus classes: (TT) both critical features present in the stimulus, (TF) the first present and the second absent (FT) the first absent and the second present, and (FF) both absent. For a variety of reasons, research has focused on four logical rules: the conjunctive rule in which each example of the concept must contain both features; the disjunctive rule in which examples of the concept have both features or either feature; the conditional in which if a stimulus has the first feature, it must also have the second to be an example of the concept; and the biconditional in which stimuli belonging to the concept have both or neither features.

These rules are not of equal difficulty to learn or use. When subjects are told the relevant features and must acquire the rule defining the concept, conjunctive learning is more rapid than disjunctive, dinjunctive more rapid than conditional, and conditional more rapid than biconditional (Bourne & Guy, 1968; Bourne, 1970, Salatas & Bourne, 1974). In some experiments two clusters emerge with the conjunctive-disjunctive cluster learned more rapidly than the conditional-biconditional cluster (Bourne, 1967; Bourne & O'Banion, 1971; and Reznick & Richman, 1976).

Most literature to date has focused on the nature of the rule itself. The main thrust of this approach is "what is it about the rule that makes it more or less difficult to learn?" To this end, theorists have proposed and explored numerous potential causes of differential rule difficulty such as the number

of positive instances to be learned, the relative size of the positive and negative categories, and the complexity of the logical operations (See Bourne 1970 and 1974 for a review of these approaches). Recently, our understanding of this problem has been improved by focusing on rule difficulty as an interaction between initial response tendencies of the person learning the rule and the rule to be learned. For example, Sawyer and Johnson (Note 1), Salatas and Bourne (1974) and Reznick and Richman (1976) have developed models in which rule difficulty results from differences between the response assignments which a person expects and those which are required by the rule.

The present experiment investigates an additional factor which may be involved in this subject-rule interaction; namely, the perceptual characteristics of the stimuli which manifest the rule. Using a wide range of experimental paradigms, Garner (1974) has demonstrated that stimulus dimensions may interact perceptually in various ways. Of particular relevance to concept learning is the distinction between separable and integral (or unitary) dimensions. In a stimulus composed of features from two separable dimensions, the features are perceived as isolated, unrelated events. With integral dimensions, the features interact to produce a new, emergent relation.

Garner (1976) suggests that dimensional integrity should be necessary in learning logical rules hence stimuli which enhance dimensional separability should be facilitative for rule learning in general. Because unitary stimuli tend to destroy or mask the identity of individual dimensions, these stimuli should retard rule acquisition. Garner reviews several concept learning experiments in which dimensional separability is investigated and finds that to the contrary, unitary stimuli are generally facilitative in concept experiments. Since separable dimensions which enhance the logical nature of the concept fail to facilitate learning, Garner notes the possibility that people learn these by

learning responses to the individual stimuli rather than by acquiring logically defined dimensional rules.

The present experiment was designed to investigate the stimulus dimensionality effect reported by Garner. People learned conjunctive, disjunctive, conditional, or biconditional concepts with either unitary or separable stimuli. Unitary stimuli were the geometric shapes traditionally used in rule-learning experimentation. Separable stimuli were formed by spatially separating the dimensions.

METHOD

Subjects. Subjects were 144 University of Colorado Introductory Psychology students who participated in this experiment as part of their course requirements. There was approximately equal representation by sex in each condition.

Apparatus. The stimuli were presented on slides. Each slide contained one value on each of three dimensions. The dimensions and their values were color-blue, red, or yellow; size-large, medium, or small; and shape-square, triangular, or circular. In unitary stimuli all values were represented in a single figure centered in a slide; for example, a large blue square. In separated stimuli, each dimension was represented separately. The upper left corner of the slide contained the black outline of a medium-sized square, triangle, or circle. The upper-right corner contained the black outline of a large, medium, or small trapezoid. The bottom-left corner contained a medium trapezoid either blue, red, or yellow.

A console in front of the subject contained two lamps - one labeled "correct" and one labeled "incorrect" and two buttons - one labeled "+" and one labeled "-". Automated equipment recorded responses, determined and delivered feedback, and advanced the slide projector. After each response, the slide remained in

view while the subject received a 3-sec feedback signal. The slide projector then advanced immediately and the next trial began. The slide projector tray was recycled, if necessary, after each 32-trial run.

Procedure. Subjects were told that they would be seeing a series of stimuli to which they would respond either positive or negative. Each response would be correct or incorrect and their task was to give all correct responses. The domain of possible stimuli was described and demonstrated. They were told that the rule for determining correct responses would be based on the absence or presence of two particular values on two different dimensions and a card naming the values was left in the subject's view for the entire experiment. The experimenter explained how focusing on two values would yield four types of stimuli with both, just one, just the other, or neither attribute. To insure the subject's understanding of this distinction, he was asked to describe the first four stimuli of the experiment verbally in these terms. Subjects were allowed to respond at their own pace. After every 32 trials the experimenter briefly reviewed the instructions. Criterion was 10 consecutive correct responses.

Each subject solved a problem based on one of four rules (conjunction, disjunction, conditional, or biconditional) with either unitary or separated stimuli. Within each cell of the 2 x 4 design were counterbalanced three pairs of relevant attributes (large and circular, triangular and blue, or small and red) and two stimulus orders. One order began TT, TF, FT, FF and the other began TT, FF, TF, FT. In both orders, representation from truth-table classes was equated in each block of eight stimuli.

RESULTS

A probability level of .05 defined the rejection region for all statistical tests. Since analysis of both trials and errors to criterion yielded comparable results, only error to criterion data will be reported. Table 1 contains the mean

Table 1

Mean errors to criterion

Rule	Stimuli	
	Unitary	Separated
Conjunctive	1.889	4.278
Disjunctive	3.056	3.389
Conditional	13.667	11.278
Biconditional	13.444	10.833

errors to criterion for each cell. A pre-ANOVA data check revealed significant inequality of variance which could be rectified by a Log_{10} (X + 1) transformation. In a 4 (rules) x 2 (stimulus conditions) ANOVA done on the transformed error scores there was a significant rule effect, $F(3,136)=41.37$ and a significant Rule x Stimulus interaction, $F(3,136)=2.67$, $MSe=.087$. A Duncan New Multiple Range Test on rules indicated a conjunctive-disjunctive cluster easier than a conditional-biconditional cluster with all between cluster differences significant and all within cluster differences not significant. A Duncan Test on the Rule x Stimulus groups indicated that beyond the cluster differences, the only additional significant difference occurred between the conjunctive-unitary group and both the disjunctive-separated and conjunctive-separated groups, the former being easier.

To determine whether the stimulus manipulation was differentially affecting truth-table classes, trial to last error on a class was computed. Tests on these differences revealed that the TF class took fewer trials to learn with separated compared to unitary stimuli $\underline{t}(34)=2.65$ for the conditional rule and that learning the FF class was facilitated by separated stimuli in both the conditional $\underline{t}(34)=4.10$ and the biconditional $\underline{t}(34)=2.26$ rules.

DISCUSSION

These results suggest that the effect of stimulus dimensionality is rule specific rather than general. We find, as does Garner, that unitary stimuli can be facilitative however the effect appears only with the conjunctive rule. With the disjunctive rule there is apparently no dimensionality effect and with the conditional and biconditional rules separated stimuli appear to facilitate acquisition. This suggests three main questions: First, how to explain this pattern of results; second, how to integrate this experiment with those reviewed by Garner; and third, how to integrate this experiment with existing literature on rule difficulty.

How does stimulus dimensionality affect the subject? From Garner's work we can surmise the perceptual nature of separable and unitary dimensional interactions. Presumably, with unitary stimuli relevant attributes fuse into a unit. A person seeing unitary stimuli should tend to see a slide as, for example, a blue square or not a blue square. If the attributes are separable, a person should be more likely to see dimensional structure; that is, a TT stimulus as being composed of both blue and square, a TF as blue and not square, etc.

In a conjunction, TT is positive and all other classes are negative. Since unitary stimuli would be expected to generate this very distinction, unitary

stimuli should be facilitative for conjunctive concepts. For the other rules, a simple TT versus not-TT approach does not solve the problem. In these rules it is necessary to make other distinctions. In disjunction the distinction is again relatively simple. It is different, however, from the distinction inherent in unitary stimuli. In disjunction TT, TF, and FT are grouped together and are distinct from FF. As expected, unitary stimuli promote no significant facilitation. Since dimensional structure is important in disjunction we might have expected unitary stimuli to facilitate acquisition; however, as Reznick and Richman (1976) observed, many people naturally take a disjunctive approach to all rules. For these people disjunction is learned without their necessarily learning dimensional structure hence separable stimuli would have less of a facilitative effect.

In the conditional and biconditional rules, understanding of truth-table structure is crucial. In the biconditional, TT and FF responses totally differ from TF and FT responses and in the conditional they partially differ. Past research has shown that for these rules, certain truth-table classes are particularly difficult to learn. In the conditional TF and FF are hardest and in the biconditional FF is hardest (Bourne & Guy, 1968; Reznick & Richman, 1976). For these rules we would expect that separable stimuli, by heightening dimensional salience should facilitate acquisition of these difficult responses.

In retrospect, one aspect of our procedure may have worked against finding a large improvement in complex rule acquisition with separated stimuli. We expected separated stimuli to facilitate use of an approach whereby people coded the stimuli into a logical, truth-table description. It should be noted that all subjects were informed about the nature of truth-table classes and actually practiced describing the stimuli in truth-table terms. We did this because our experience has been that complex rule-learning problems are quite difficult and

that without adequate instructions subjects will often fail to solve them. By giving training, we promote this tendency to code the stimuli in truth-table form in both stimulus conditions and therefore reduce the differences we were expecting.

In answer to the second question, the present experiment is compatable with those reviewed by Garner. Siegel (1969) found that unitary stimuli facilitate concept attainment. The only concept which she tested, however, was the conjunctive. Bourne and Parker (1964) used a concept identification task and found concept attainment easier with unitary stimuli. They also tested only a conjunctive concept. It is questionable whether Garner's other two pieces of evidence, Shepard, Hovland, and Jenkins (1961) and Wallach (1962) are comparable to the type of concept learning discussed here. In these experiments, unitary stimuli facilitated acquisition of a biconditional concept. In both of these experiments there were three dimensions, each containing two attributes. This yields a population of only eight stimuli which must be classified. Reznick and Richman (1976) investigated the effects of varying the number of alternative attributes in the relevant dimensions. They suggested that when the number of alternatives was reduced to two, people tended to learn responses to particular stimuli rather than responses to truth-table classes. Since the two experiments cited by Garner require that the subject learn responses to only eight different stimuli, it seems quite plausible that in these experiments subjects learn stimulus-response associations by rote rather than by truth-table classification. Following Garner, if the concept is learned via individual stimuli, then unitary stimuli could be facilitative. If as in the present experiment, problems are sufficiently complex to necessitate truth-table classification, then separated stimuli can facilitate their acquisition.

We propose a pre-experimental bias model of rule difficulty (Sawyer & Johnson, Note 1; Salatas & Bourne, 1974; Reznick & Richman, 1976). The basic tenet of this model is that a person approaches a rule with certain preconceived assumptions about how the stimuli will be assigned. Rule difficulty can be predicted as a function of the difference between the assignments expected and the assignments encountered. This theory has afforded the best predictions of rule difficulty to date. The work of Garner and the present experiment, however, suggest further factors which must be considered.

The bias model fails to address the question of how a person, faced with a rule-learning task, subdivides the population of stimuli into more manageable chunks. Our work suggests that properties of the stimulus tend to evoke different chunking strategies and may in some cases enhance the tendency to code the stimuli into logically defined truth-table classes. Since rule learning depends upon making response assignments on this truth-table class basis, a more comprehensive model of rule learning processes would include stimulus properties as a component affecting rule difficulty.

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Reference Note

1. Sawyer, C. R., & Johnson, P. J. A concept learning model. Paper presented at the meeting of the Rocky Mountain Psychological Association. 1970.