JOURNAL OF VERBAL LEARNING AND VERBAL BEHAVIOR 2, 195-202 (1963)

Concept Learning as a Function of Form of Internal Structure[1]

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Garner (1962) distinguished between internal structure as the relations between variables making up a specified set of stimuli, and external structure as the relations between the stimuli and some external variable such as a differential response. He also argued that factors involved in external structure are most closely related to psychological processes of discrimination, or learning tasks such as paired associates which involve learning a differential response to each stimulus. Internal structure, on the other hand, is most closely related to free-recall learning. Whitman and Garner (1962), for example, have shown that the form of internal structure has a very great effect on free-recall learning of visual figures; specifically, that form of internal structure which involves simple contingencies between pairs of variables defining the stimuli facilitates free-recall learning.

Concept learning involves both internal and external structure, since *S* in such an experiment is required to learn which stimuli belong in a specified subset of the total number of possible stimuli, but is also required to differentiate this subset from the other stimuli which do not constitute the concept. He must, in other words, learn to differentiate the positive from the negative instances of the concept. Usually, however, concept problems require only two differential responses, although occasionally more have been used. Thus we would expect that factors involving external structure would be less important than those involving internal structure, since the task of learning which stimuli go together in a group is generally much more of the problem than learning to differentiate these from the negative group. The extent to which a concept-attainment task is affected by internal structure would depend on how closely the concept task resembles the free-recall task.

Free-recall learning requires *S* to learn what constitutes a specified subset of stimuli. Suppose in a concept task we present *S* with just the positive instances of the concept, and then ask him either to reproduce them, or to select them from a larger set of stimuli containing both the positive and negative instances. In such a task, there is only the slightest difference between free-recall and concept learning, if in fact they are not identical.

Suppose, alternatively, that we present *S*

[1] The authors wish to thank the staff of the Medical Illustration Service, Veterans Administration Hospital, Perry Point, Maryland, for their assistance in the preparation of the charts and stimulus material used in this study.

with both the positive and the negative instances, but in such a manner that each type of stimulus is kept intact as a group. We could present the stimuli simultaneously, but in two spatially separate groups. Or we could present all of the positive instances first, followed by all of the negative instances. With this procedure, the task is still primarily one of free-recall, although we may in effect be requiring *S* to learn two separate subsets of stimuli.

Neither of these procedures is typical in concept experiments, however. Rather, stimuli are presented one at a time, and the positive and negative instances are intermixed in either a regular or random order. In this case, *S* must still learn two subsets of stimuli and demonstrate, either by reproduction or differential recognition, that he knows which stimuli belong to each subset. Insofar as the form of the internal structure within each subset can facilitate free-recall learning, however, this procedure should make learning more difficult because it would make difficult *S*'s perception of the relations between the variables defining the stimuli, the very relations which facilitate the learning in the first place.

Thus we would expect concept learning to be affected by the form of internal structure in the same way that free-recall learning is, as long as the method of stimulus presentation is such as to allow *S* to perceive the relations between the variables within one or both of the subsets of stimuli. The specific purpose of this experiment is to show that concept learning is facilitated by that form of internal structure which involves simple contingencies between variables, but that this facilitation is lost when the stimuli are presented in a mixed and random order.

Method

The Concepts

In this experiment we used a total set of 16 visual figures generated from all possible combinations of four variables with two levels each (see Fig. 1). The four variables and their levels are: (1) shape, a circle or triangle; (2) location of space, left or right; (3) center lines, one or two; and (4) location of dot, above or below. From this total set of stimuli, two different subsets of eight each were chosen to define two different concepts.

Correlated Variables. One subset of stimuli constituted the positive instances of concept A, and these eight stimuli are so labelled in Fig. 1. These eight stimuli show both levels of all four variables equally often, but their important characteristic is that two variables (shape and location of space) are perfectly correlated. In uncertainty terms, this subset has 1 bit of internal structure, all of which is in the form of a simple contingency.

Uncorrelated Variables. The other subset constituted the positive instances of concept J, and these eight stimuli are also labelled in Fig. 1. These eight stimuli also show both levels of all four variables equally often, but no pair of variables is correlated. In uncertainty terms, this subset has 1 bit of internal structure, but all of it is in the form of a four-variable interaction.

Thus these two subsets are identical in that each has 1 bit of internal structure, and in that each shows both levels of all variables equally often. They differ only in the form of the internal structure. In addition, four of the actual stimuli are the same in each subset.

Methods of Presenting Concept

The two different concepts formed one of the experimental variables. The other experimental variable was the method of presenting the stimuli for concept learning. The three methods used differed in the extent to which positive and negative instances were intermixed in presentation.

Positive Instances Alone. With this method a single trial consisted of the presentation of just the positive instances, and no negative instances were shown. Each stimulus from concept A (or J) was shown on an 8.5×11 inch card by *E*, with the letter A (or J) in the upper left-hand corner of the card. The stimuli were as shown in Fig. 1, with the height of the circle or triangle being 6 inches. The stimuli were shown one at a time for 5 sec. with one stimulus card immediately following another. Immediately after the last card was presented, *S* picked up a shuffled deck of $2\frac{3}{4} \times 3\frac{3}{4}$ inch cards containing all 16 figures, and was required to select exactly 8 cards which he thought were the positive instances. He was allowed 2 min. (3 min. on the first trial) to do this. He then turned his

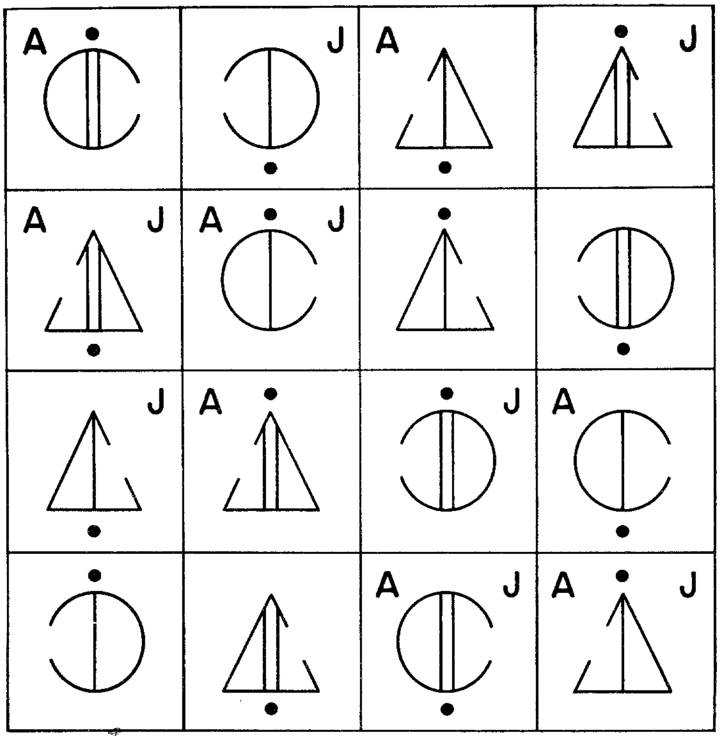

Fig. 1. The total set of figures used in the experiment. The figures labelled "A" formed the positive instances of the correlated concept, and the remaining eight figures were "B." The figures labelled "J" formed the positive instances of the uncorrelated concept, and the remaining eight figures were "K."

selected cards over and wrote on an answer sheet code numbers which were on the backs of the cards. The answer sheet was immediately collected by *E* while *S* reshuffled the cards for the next trial, which began at once.

Positive Instances Grouped. With this method a trial consisted of the presentation of all the positive and the negative instances, but all positive instances were presented first as above, followed after a 10-sec. interval by the presentation of the 8 negative instances, which were labelled B (or K). The *S* then selected the A (or J) figures from the deck of cards, and the test procedure was the same in all respects as above.

Positive Instances Mixed. With this method both positive and negative instances were presented on a single trial, but they were intermixed. As above, each stimulus was presented for 5 sec., but with a 10-sec. interval after the eighth stimulus. The test procedure was the same as above.

The stimulus sequences for all three methods were based on the sequences for the mixed stimuli. With this method each trial consisted of a different order of presentation, although the same for each *S*. The orders were predetermined so that each successive block of 4 stimuli contained 2 positive and 2 negative instances, and also contained each level of each stimulus variable twice. These requirements were satisfied by taking permutations of rows or columns from Fig. 1, in either direction. These permutations were randomly selected, with the further restriction that on successive trials duplicate subsequences and orders were avoided.

The stimulus sequences for the methods involving positive instances alone or grouped were made to match exactly the subsequences of just the positive stimuli in the sequences used with the mixed stimuli.

Subjects

There were 67 *S*s, all of whom were associated with a large V. A. hospital and had volunteered for an experiment in learning. Of these, 31 were high school students working for the summer, and 36 were staff members. They ranged in age from 15 to 52 years. The *S*s were randomly assigned to one of the six conditions, usually in groups of five, but smaller when necessary due to availability of

Ss and the restriction that within each condition an equal number of students and staff be assigned in so far as possible. Each S was used for just one condition.

Preliminary Training

Before actual training began in any condition, Ss were given preliminary training to ensure that they knew what stimuli were possible, and how the stimuli were generated. First they were shown the stimuli as in Fig. 1 (but without the labels), and after 2 min. of study were required to reproduce them. Then they were required to generate the figures by successive addition of variables, to study them, and again to reproduce them.

Before and during this preliminary training, E explained to S that he would be required to learn a concept or classification, that practice would continue until he had correctly selected the 8 stimuli on 2 successive trials, and that he would not know after each trial how many of his choices were correct until he had met the criterion. Instructions for recording responses were then explained.

RESULTS

Two performance scores were obtained from this experiment: (1) the number of correct selections per trial during training, which allow us to obtain group learning curves. Since 8 stimuli were selected from the full set of 16, chance performance with this measure is 50%. (2) the number of trials required by each S to reach criterion, which was recorded as the first trial on which all were correct provided that all were correct on the next trial as well.

Learning Curves

The learning curves for the six different experimental conditions are shown in Fig. 2, which shows that two of the conditions (A alone or grouped) are learned much faster than are the other four conditions. Of particular importance is the fact that the A concept,

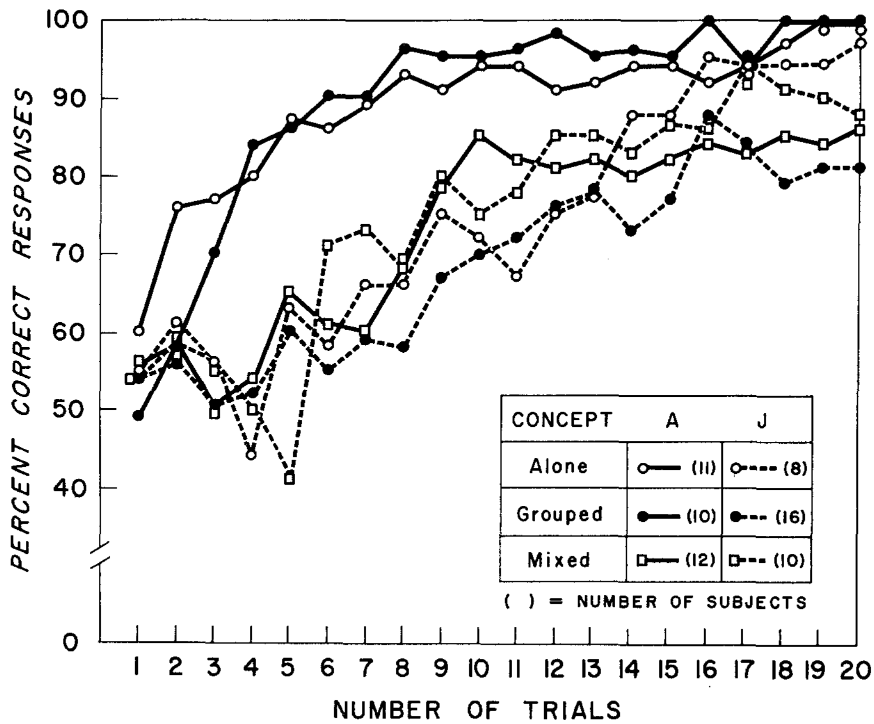

FIG. 2. Learning curves for the two concepts and the three methods of presenting positive and negative instances, as indicated in the insert. Each plotted point is the mean for all Ss in that condition and assumes perfect performance for each S after criterion is met.

with its correlated variables, is just as difficult to learn as the J concept when the positive and negative instances of the concept are intermixed.

To determine more precisely the differences between the six conditions, a mean per cent of correct selections per *S* over all trials (assuming perfect performance after criterion was met, to obtain a measure for all 20 trials for each *S*) was computed; the mean of these values is shown in Table 1. An over-all analysis of variance showed that differences between conditions were highly significant ($F = 5.16$, $df = 5/61$; error variance is 0.0174 and homogenous across groups).

TABLE 1
MEAN PER CENT OF CORRECT RESPONSES PER TRIAL DURING PRACTICE FOR THE SIX CONDITIONS OF THE EXPERIMENT[a]

Method of presentation	Concept learned	
	A	J
Alone	89.2	74.1
	89.4	*74.4*
Grouped	89.4	68.7
	89.4	*69.1*
Mixed	73.6	74.6
	73.1	*75.5*
Average		72.5
		73.0

[a] Italicized percentages are for the four stimuli in the two concepts which were identical.

A further analysis was carried out to determine whether the four poorer conditions and the two better conditions had significant differences among themselves. For this purpose, Kramer's modification of Duncan's multiple range test (Kramer, 1956) was used, and this showed that the only significant differences were between the two groups of conditions so clearly separated in Fig. 2. Because this test showed that none of the methods of stimulus presentation made any difference with the uncorrelated J concept, a mean for these three conditions was computed and is shown in Table 1. The closeness of the value obtained for mixed A stimuli to this mean is apparent.

It will be recalled that four of the stimuli were the same for the A and the J concepts, and separate tabulations were made for these particular stimuli. The mean percentages of correct responses are shown as the italicized values in Table 1. It is quite evident that the results obtained depend on the subset of stimuli to be learned and not on the characteristics of the individual stimuli. This result confirms the previous finding of Whitman and Garner (1962) with respect to free-recall learning.

The point of major interest from this analysis concerns the importance of method of presentation with the A concept. Our previous research had shown that internal structure with simple contingencies provides easy free-recall learning. Thus the results with positive instances presented alone or grouped confirm this previous finding and suggest that concept learning is not fundamentally different from free-recall learning. Whatever psychological processes facilitate free-recall and concept learning with a good form of internal structure are destroyed when positive and negative instances are intermixed. It seems apparent that the subset of stimuli must be perceived as a group for the advantages of the good form of structure to be obtained.

On the other hand, the uncorrelated J concept has a form of internal structure which is difficult to learn presumably because *S* has trouble perceiving the relations within the subset. Thus a method of presenting the stimuli which also prevents the perception of relations within the subset has no further deleterious effect.

Trials to Criterion

The data obtained from our measure of trials to criterion can be discussed briefly because they simply confirm the conclusions obtained from analysis of correct selections. For the A concept, median trials to criterion were 4.0, 4.3, and 9.5 for alone, grouped, and mixed methods, respectively. For the J concept, median trials were 14.5 16.0, and 11.5 for the same respective conditions. A Mann-Whitney *U*-Test was used with these data, and it confirmed the previous result that the A alone and grouped conditions are significantly different from the other four, but neither of these subgroups of conditions has significant differences within them. It is of some interest to note, however, that with this measure the A concept provides better learning than the J concept with all methods of stimulus presentation.

Discussion

There are two major points which we feel this experiment makes. The first is to show that a concept problem is, in many essential respects, not basically different from a free-recall problem. The difficulty of concept learning will, therefore, be affected by the same factors as affect free-recall learning. In particular, we have shown that the form of internal structure of the subset of positive instances affects concept learning in the same way as we have previously shown it affects free-recall learning.

When an experiment in concept learning is carried out in which only the positive instances of the concept are presented to *S*, and *S* is required to reproduce or selectively recognize the positive instances, there is effectively no operational difference between the two types of problem. More commonly, however, in a concept problem, both positive and negative instances of the concept are presented during the learning trials, an operational difference which makes the concept problem seem more like a discrimination-learning task and less like a free-recall task.

The second major point of this experiment is in showing that the presentation of negative instances can have a deleterious effect on concept learning. We are not arguing that negative instances have only a deleterious effect, but only that they will have such an effect if they destroy the perception of the relations within the positive set, which is the essence of free-recall learning.

A Concept as a Subset. The interplay between the role of negative instances and concept learning as free-recall learning can be seen better by considering the nature of a concept problem. Most psychological writers (e.g., Leeper, 1951, p. 740; Woodworth and Schlosberg, 1954, p. 609) have defined a concept problem as one requiring both the establishment of generality and discrimination, and in a strictly operational sense this definition is adequate because *S* in such an experiment is required to demonstrate that he can give the same response to more than one stimulus but can also give different responses to different stimuli. This definition does not, however, necessarily connote the true nature of the psychological process involved.

The essence of a concept problem lies in the selection of a subset of stimuli from a larger set which contains the subset itself. For example, the concept *horse* is not provided by discrimination from the concept *cow*, but rather is provided by its perception as a subset of objects from a larger set of objects called *animal.* In learning a concept, *S* must learn both the subset which specifically defines the concept, and also the larger set from which the concept derives. If he has learned both of these, of course, he is then able to give a discriminative response to the negative instances, i.e., those stimuli from the larger set which are not contained within the specific subset. But the fact that *S* does give such a discriminative response does not mean that his perception of the concept is primarily a contrast phenomenon rather than an inclusion phenomenon.

The Role of Negative Instances. Hovland (1952) has carried out a detailed analysis of the role of negative instances from an information point of view, and Hovland and

Weiss (1953) showed that negative instances are less useful to *S* in a concept problem even when they carry the same amount of information, and information here refers to the discriminative value of the item.

From our point of view, the role of negative instances is two fold, one of the roles being necessary and useful under some circumstances, the other being deleterious. The first role is to define the total set of stimuli from which the particular subset is selected, since perception of just the subset itself does not always define the total set. For example, where a concept involves a single value of one variable (other variables being irrelevant to the concept), then the presentation of just that value, say black, cannot alone define the total set of stimuli. If white is an alternative, then *S* must see at least one white stimulus before he can infer the total set of possible stimuli.

Suppose, however, that the nature of a concept is correlative, as in our concept A. In such a case, all values of all variables can occur, so that the subset also defines the total set, and there should be no need of the negative instances to define the total set. In our actual experiment, the correlated concept did show all values of all variables, but in addition we trained *S*s on the total set prior to learning to ensure that this factor did not enter into the experiment.

The other role of negative instances is to interfere with the perception of properties of the positive subset itself, since the negative stimuli intermixed with the positive stimuli make perception of the positive stimuli as a subset with specified characteristics more difficult. In other words, the use of negative instances interferes with the free-recall process. Such interference will, as our experiment has shown, be of little consequence if the subset has no internal structure which is easily perceived by *S*. But it can have serious consequences if the subset has easily perceived relations between variables.[2]

One last comment concerns some data of Shepard, Hovland and Jenkins (1961) which relate to ours. These authors used eight stimuli formed from three dichotomous variables, and required learning of various dichotomous classifications. Two of their classification systems corresponded approximately to ours, and they found that the classification system which led to simple contingencies between variables was learned more easily. Since they used randomly intermixed stimuli, we should have found a difference with our intermixed procedure. Our data for correct responses show no significant differences, nor do the data for median trials to criterion, although in this latter case there was a difference in the expected direction. We cannot feel sure that this lack of difference is general, and it could well be that our use of four variables, and the larger number of stimuli, are responsible for the discrepancy.

This discrepancy, however, has little effect on the main conclusion of this experiment, namely, that a good form of internal structure will facilitate concept learning just as it facilitates free-recall learning, but that this facilitation can be greatly reduced if the positive and negative stimuli are intermixed so as to make perception of the properties of the positive subset difficult.

SUMMARY

A concept-attainment experiment was run, using 16 stimuli formed from 4 dichotomous variables, and in which *S*s were required to learn a concept (subset of stimuli) of 8 of the 16. Two kinds of subsets of stimuli were used, one with a favorable form of internal structure involving a simple contingency between variables, and one with an inter-

[2] The interference effect of intermixed negative instances with simple concepts has also recently been shown by Peterson (1962).

action between variables. Three methods of presenting stimuli were used: the positive instances alone, both positive and negative instances with each kind grouped together, and both positive and negative instances intermixed.

The results showed that the good form of internal structure strongly facilitated concept attainment except when the stimuli were intermixed. This result is interpreted to mean that the intermixing prevents perception of the characteristics of the subsets of stimuli. We have further argued that a primary function of presentation of negative instances in concept learning is to define the larger set of stimuli from which the particular subset is selected; and that if the subset itself defines the larger set, then negative instances can do no good and may make the problem more difficult.

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(Received December 3, 1962)