Stimulus information and primate pattern discrimination: Simultaneous changes in positive and negative cue information¹

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The present research studied the effects for two-choice, discrete-trial, pattern-discrimination learning of changes in the stimulus-information content of both the positive and negative stimulus cues. The major findings suggest that, with experienced primates, there exists a relation between equal increments in positive and negative stimulus information and discrimination learning that is strikingly similar to the classical psychophysical relationship between stimulus intensity and JNDs.

If stimulus information can, in part, be operationally defined in the simple terms of cue complexity, it is intuitively obvious and easily demonstrable (Polidora & Thompson, 1964) that discrimination learning in the two-choice, discrete-trial situation is directly related to perceived increases in stimulus information when these increases are associated with only one of the discriminanda. It is, however, not as intuitively obvious what the effects would be of increasing stimulus information if the increases equally involved the complexity of both cues and did not change what might be called the "information ratio"³ of the two stimulus patterns of the discrimination problem.

According to Polidora & Thompson (1964), ease of discrimination is related only to changes in information that shift the information ratio by favoring one of the stimulus cues, as opposed to any stimulus change that maintains the same ratio of information between the two cues. However, the patterns used to establish this relation were constructed from a population of stimulus elements which, when combined to make up the discriminative cues, lost much of their independence and contributed to the informational content of the discrimination more in terms of area and luminance than in terms of pattern complexity. If it is reasonable to assume that the major effects of area and complexity would be realized when changes in these variables involved either the positive or the negative cue, but not both, then the relation between stimulus-information and

pattern-discrimination learning, as described by Polidora & Thompson (1964), is quite limited in its applicability. For this reason, and because of the obvious importance of stimulus information to discrimination learning, it would seem worthwhile to assess nondifferential increases in informational content (or cue complexity) when the stimulus changes (added increments of information) can be considered as discrete units, even when in combination with one another.

SUBJECTS

The Ss for this experiment were seven adolescent male Rhesus monkeys, all of which had had previous experience with color discrimination in the automated testing procedures described below. None of the animals, however, had had any previous pattern-discrimination training. All Ss were housed two to a cage throughout the experimental procedure.

APPARATUS

The apparatus used for this experiment was the automated primate discrimination apparatus, APDA, that has been described in detail by LeVere & Bartus (1969). Basically, the apparatus is a discontinuous stimulus-response two-choice situation that requires the animal to observe the stimulus cues through a slanting window for a predetermined time before initiating its choice response by pulling a lever associated with the chosen stimulus display. Correct responses are rewarded by dropping 96 mg of banana pellets directly onto the horizontally oriented stimulus display, where they bounce about and roll from the display into a receptacle within reach of the S.

The stimuli used in this experiment were derived from two 4 by 4 matrices of ¼-in. light bulbs. To obtain the desired independence of stimulus elements, each of these light bulbs was separated from all adjacent bulbs and/or the edge of the stimulus display by a distance of ½ in. center-to-center. With these dimensions, the outside perimeter of each matrix measured 2 in. on a side and was mounted within APDA, with a 4-in. center-to-center separation from the other display. A stimulus set, the positive and negative cue, for a particular treatment condition was constructed by the random selection of a given number of stimulus elements, under the constraints that (1) no particular pattern could be used more than once,

Fig. 1. Mean percentage correct during the first replication as calculated for all seven animals over 40-trial blocks. To calculate these percentage scores, the individual animals that attained criterion performance or better were given scores of 100% until the remaining animals had attained criterion.

(2) the elements comprising any given pattern must be adjacent, and (3) the positive and negative cues of any given set could share no more than one stimulus element in common. Eight sets of such stimuli were constructed and used in two replications of four treatment conditions each.

PROCEDURE

The four experimental conditions used in each replication were: (1) Both patterns must contain three elements and no angles (3/0); (2) both patterns must contain four elements and no angles (4/0); (3) both patterns must contain three elements and one angle (3/1); and (4) both patterns must contain four elements and one angle (4/1). These experimental conditions were administered in accordance with a balanced experimental design derived from Williams (1949) at the rate of 40 rerun correctional trials per day. A criterion of 90% correct performance on a day's run was required before the animal was allowed to progress to the subsequent experimental conditions. Within each trial, the animal was required to maintain an observing response, defined by the interruption of a photocell beam across the stimulus-observation window, for a period of 1 sec, before being able to initiate its choice. Choice responses were required to occur within a 1-sec choice-response interval immediately subsequent to this pre-response period. Maximum allowable post-response stimulus observation was set at 1 sec, and the intertrial interval had a minimum duration of 3 sec, except for a 10-sec timeout period that followed incorrect choice responses.

Immediately after training, each animal was given his daily food ration, with the quantity being dependent upon the speed

Fig. 2. Mean percentage correct performance on the second replication as calculated over 40-trial blocks. Individual percentage points have been calculated as those of Fig. 1.

and accuracy of that particular day's testing.

RESULTS

The results of this experimental procedure were initially analyzed in accordance with an Elements by Angles by Replications analysis of variance, with repeated measures on Ss. This analysis indicated that all simple effects, with the exception of replications ($F = 111.4$, $df = 1/6$, $p < .005$), and all interactions were nonsignificant. The significant replications effect and the fact that the described procedures represented the Ss' initial experience with pattern discrimination indicated that it would be appropriate to analyze the replications separately in order to determine whether the treatments were effective after the primates had acquired some familiarity with the pattern discriminations used during the first replication.

The Elements by Angles analysis of variance, with repeated measures on Ss, applied to Replication 1 indicated, as was predicted, that all main effects and all interactions, save the Elements by Angles interaction ($F = 7.67$, $df = 1/6$, $p < .05$), were nonsignificant according to conventional standards (Fig. 1). However, when the same analysis was applied to the second replication (see Fig. 2), the main effects of elements and angles were both highly significant ($F = 19.01$, $df = 1/6$, $p < .005$ and $F = 34.37$, $df = 1/6$, $p < .005$, respectively), while the subjects' main effect remained nonsignificant. All interactions, except the Elements by Angles ($F = 9.96$, $df = 1/1$, $p < .025$), were nonsignificant. The nature of the E by A interaction is illustrated in Fig. 3, which shows, in the left portion, the effects of adding an element when the stimulus displays have either zero

or one angle and, in the right portion, the effects of adding an angle when there are either three or four elements in each pattern. Tests of significance directed at this interaction (t test for related samples, two-tailed) indicated that the effects of either variable were significant (elements: $t = 4.239$, $df = 6$, $p < .01$; angles: $t = 4.69$, $df = 6$, $p < .01$) only when the other variable was at its minimum value. There was no significant difference, however, in the relative benefit of the addition of an element vs an angle when the other variable was at its minimum value.

DISCUSSION

The major results of this experimental procedure are interpreted as supporting the notion that once a S has gained some experience with a particular type of discrimination or, in more contemporary terms, switched in the appropriate stimulus analyzer (Sutherland, 1964; Mackintosh, 1965), learning is facilitated by increasing the amount of available stimulus information. This increase in stimulus information may be associated with only one of the discriminative cues and, thus, may serve to increase what has been called the information ratio of the discrimination problem or, as indicated by the present research, the increase in stimulus information may be equally associated with both discriminanda and have no effect on the information ratio. While the first variety of informational increase would appear to be linearly related to discrimination proficiency (Polidora & Thompson, 1964), the second variety, which produces no change in the information ratio, would appear to have a more complex relation to the learning process. As shown in Fig. 3, the effects of increasing available information, when these changes do not affect the information ratio, are quite dependent upon the stimulus information already available to the S. And, as such, the relationship between equal increments in stimulus information and discrimination proficiency is strikingly congruent with the classical psychophysical relationships that exist between stimulus intensity and JNDs.

While the differences between the Polidora & Thompson (1964) results concerning equal positive and negative increments in stimulus information and those obtained with the present procedures will remain somewhat speculative until further research is completed, two factors are nonetheless worthy of comment since they bear directly upon the psychophysical interpretation given the present results. First, as has been previously noted, there are the differences between the stimulus displays used in the two experiments. The Polidora and Thompson patterns could be

Fig. 3. Graphic representation of the E by A interaction, illustrating the effects of adding an additional element to the positive and negative cues when these cues contained either zero or one angle and the effect of arranging the positive and negative stimulus elements into patterns containing zero or one angle when the patterns were composed of either three or four elements.

considered as essentially "entities" and described as completed figures superimposed upon a more neutral ground, while the patterns used in the present research are more aptly described as discrete bits of information contained within the perimeter of the total display. In accord with this, it could be argued that the present patterns would be more sensitive to informational manipulations as accomplished by the addition or subtraction of stimulus elements as opposed to the Polidora and Thompson situation where the addition or subtraction of stimulus elements was primarily related to total changes in cue area and luminance. Additionally, and related to this point, it should be noted that the testing situation used by Polidora & Thompson (1964) was a spatially contiguous stimulus-response apparatus, where discrimination learning can be influenced by a number of sampling variables related to the location of the S's choice response (Meyer, Treichler, & Meyer, 1965). The present apparatus, on the other hand, was a spatially discontinuous stimulus-response situation that is more insensitive to response-induced sampling biases (LeVere, 1968) and, hence, could conceivably provide a more precise estimate of stimulus-information manipulations since there is greater certainty that the S is actually exposed to any changes in the stimulus display.

An alternative explanation, and one that is completely compatible and predictable from the present results, is that the negative effects observed by Polidora & Thompson (1964) were due to the fact that the number of stimulus elements used in the basic pattern may have created a stimulus display of such a complexity that the informational increments used by these authors were quantitatively insufficient to affect discrimination proficiency.

Following this psychophysical line of reasoning, it would be predicted that, using the Polidora and Thompson patterns, one would observe changes in discrimination acquisition if (1) the patterns initially contained fewer elements, or (2) greater increments of information were added, assuming, of course, that the basic pattern design is sensitive to these types of informational changes. At any rate, the present results are not to be interpreted as contradictory to any previous analyses, but should rather be viewed as supplemental to these findings and descriptive of a further dimension involving stimulus information and discrimination learning.

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NOTES

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2. The authors wish to express thanks to C. A. LeVer for her help in the preparation of this report.
3. Information ratio is used here as a quantitative variable and describes the relationship between the amounts of information contained within the positive and negative stimulus displays.

Deprivation and the role of taste in food intake¹

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Rats were given single-stimulus feeding tests after varying degrees of food deprivation. Isocaloric diets containing different levels of quinine sulfate were used. Intake was measured after 30, 60, and 120 min of eating. At all deprivation levels and at all intervals, intake was negatively related to QSO₄ concentration. While deprivation level increased intake of all diets, it did not influence relative intake among diets. These results do not support the view that the effects of taste on food intake change as a function of deprivation level.

It has been argued that the importance of taste is either attenuated or potentiated by deprivation. According to the hypothesis of attenuation, hunger is assumed to widen the range of acceptable food substances, increase the motivation to eat, and diminish the role of oral factors (Miller, 1962; Epstein, 1967). The hypothesis of potentiation suggests that the hungry animal is more, rather than less, discriminating. The importance of oral factors relative to caloric or metabolic

signals is increased. This position predicts that, under conditions of deprivation, negative food substances diminish intake and positive substances increase it (Jacobs, 1966; Jacobs & Sharma, in press).

Previous experiments relating to this topic have not been consistent in their use of criteria for defining attenuation or potentiation effects. Methods adopted have varied considerably and have not been amenable to direct comparison. Thus, one finds situations involving single foodcup tests in which a comparison between diets differing in taste quality is not made, direct choice-preference tests that may provide an entirely different situation to the organism, situations not directly involving food ingestion, and nonsystematic variations in deprivation measures (cf. Epstein, 1967; Jacobs & Sharma, in press).

The present experiment attempts to assess the role of taste in intake behavior under conditions of single foodcup feeding using diets differing only in the quantity and quality of nonnutritive flavor substances used. Deprivation conditions were varied in a systematic fashion, comparisons between different test diets were carried out, and possible differences were evaluated.

METHOD

The Ss were 36 male Holtzman albino

rats, ranging in age from 90-120 days. Ss were individually housed in 7 x 7 x 10 in. stainless-steel cages, with wire-mesh floors and fronts. Water was available ad lib throughout all experiments. Food pellets (Wayne Lab Blox) were continuously available except during conditions of deprivation and testing. Conditions of temperature were controlled to 72 deg F $\pm$ 2 deg F.

The Ss were randomly divided into subgroups so that order of presentation of test diets and degree of deprivation could be counterbalanced.

The deprivation conditions used were 4, 8, 24, and 48 h of food deprivation.

Test diets consisted of a wet mash base (Wayne Lab Meal), which was 50% tap water and, in addition, 0.1% quinine sulfate, N.F. (QSO₄).² One diet (H₂O) contained no additive. Thus, the diets were equated for calories but assumed different in taste quality. All diets were presented in spill-proof metal cups.

The actual procedure adopted involved dividing each subgroup into H₂O and QSO₄ sections and administering single foodcup feeding tests. Intake measures were taken after 30, 60, and 120 min of feeding, at which point the tests were terminated. One hour later, food pellets were provided ad lib to all Ss, and they were allowed a 2-day recovery period. Following this, the procedure was repeated with test diet or deprivation condition varied until Ss were measured under all experimental treatment conditions. Thus, order of presentation of test diets, order of deprivation degree, and daily variations in intake were assumed to be controlled for.

After this period of testing, the groups were given feeding tests with an additional diet consisting of the base diet with the addition of 0.2% QSO₄, using the same experimental procedure.

RESULTS AND DISCUSSION

Amounts of test diet eaten for each deprivation condition over the three time periods measured are depicted in Fig. 1. Deprivation level up to and including 24 h increased intake of all diets, while the 48-h groups did not significantly alter their intake of any diet relative to the 24-h intake. Such results are in accord with previous investigations (Miller, 1955; Dufort & Wright, 1962; Dufort & Lawler, 1968). At all deprivation levels and at all intervals, intake was negatively related to QSO₄ concentration.

The shapes of the intake functions generated by the test diets over deprivation levels for all intervals are remarkably similar, pointing to the conclusion that the effects of taste are not altered by deprivation.

There are actually many criteria one might use in evaluating the effects of