DISCRIMINATORY ABILITY OF PATTERN IN THE CAT: THE EFFECT OF ORIENTATION-FREE PRESENTATION^{1,2}

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The ability of kittens in discriminating length-breadth ratio of geometrical figures was examined with a tracking method. In Experiment I, kittens were trained to discriminate a rectangle from a square, both in free orientation and fixed orientation tasks. In the former task, the spatial orientations of the stimulus figures presented were varied randomly from trial to trial, and in the latter, the orientation of the figures was fixed. The results showed that kittens could discriminate the rectangle with the length-breadth ratio of 1.2: 1 (R 1.2) from the square, but failed to discriminate R 1.1 with both orientation tasks. In Experiment II, an ellipse and a circle were used as stimuli, and the area of the circle was varied in three steps in a random order as an irrelevant cue in addition to changing the orientation of the ellipse in the free orientation task. The kittens showed the same discriminatory ability with the free orientation task as with the fixed orientation task. However, the level of discrimination achieved in Experiment II was much lower than that achieved in Experiment I, and possible causes of the difference were discussed.

Pattern, unlike the size or distance, is considered to be multidimensional. Examination of the discriminatory ability for each dimension, therefore, should be varied for one specific dimension under consideration, with the other dimensions kept constant.

Such a procedure itself, however, cannot ensure that the animal responded to the patterns by discriminating that dimension. Suppose that a rectangle is presented in pairing with a square. The both stimuli differ only in the "length-breadth ratio". In this case, the animal may discriminate correctly by responding to the specific part (local feature), when the patterns are al-

ways presented in a fixed orientation (e.g., upright position).

Many investigators have checked such possibilities by administering the subsequent "generalization test" in which a specific part or parts were presented to see whether the animal responded to such a local feature. This procedure, however, cannot be desirable from the following reasons.

Firstly, it fails to determine whether the animal had responded to the specific partial feature or he generalized the response on the basis of similarity of the patterns. Secondly, when the result shows that the animal responded to a partial feature, it cannot add any information to the study of pattern discrimination because the animal had not responded to the specific dimension included in the total pattern.

One way to eliminate such possibilities would be to randomize the orientation of patterns from the start of training in order to make operationally any partial feature ineffective. Very few studies, however,

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have used this procedure (e.g., Fields, 1932).

In the present study, the authors presented a pair of stimulus patterns, the orientation of which were changed randomly from trial to trial. Following this procedure, the present experiments trained the cat to discriminate the stimulus pair according to the length-breadth ratio of the freely oriented patterns.

The so-called tracking method was used to determine the discriminatory ability. After the animal had reached the learning criterion for a stimulus pair, the length-breadth ratio in one of the pair was approximated stepwise to another in the next training session until he could not attain the correct discrimination in the training. In this article, the discriminatory ability could be defined as the minimum difference in the ratio correctly discriminated by the animal.

The discriminatory ability for fixed orientation pattern was then compared with that for free orientation pattern.

EXPERIMENT I

Purpose

This experiment was performed to determine each kitten's discriminatory ability of rectangle in both free orientation task and fixed orientation task.

Animals

Five kittens of outbred lines (two males and three females) were used. They had been reared without restriction in the animal laboratory at the Psychology Department of Nagoya University, and were two months of age at the beginning of this experiment. None of them had experienced previous learning sessions.

Apparatus

A ground plan of the apparatus was represented in Fig. 1. Floor and side walls were painted black. The transparent plexiglass top was partially covered with black shade to direct the animal's attention to the front screen.

Stimulus Figures

A rectangle was presented side by side in pairing with a square of $4\text{ cm} \times 4\text{ cm}$ (6° in the visual angle). The training started with a rectangle whose length-breadth ratio was 4:1 (henceforth referred to as R 4.0 in this article). After the animal successfully reached the criterion in this pair, the length-breadth ratio of the rectangle was reduced to 3:1, and he was trained to discriminate it from the square until he reached the criterion again. Likewise, R 2.0, R 1.5, . . . were successively presented one after another to determine the limit of discrimination³ (Fig. 2).

Each animal was trained both in free orientation task and in fixed orientation task. In the training of the free orientation task, a square and a rectangle were presented in one of the six orientation differently assigned, i.e., 0° (upright), 15° , 30° , 45° , 60° , and 75° (rotated clockwise) for the square, and 0° (upright, longer edges being vertical), 30° , 60° , 90° , 120° , and 150° (rotated clockwise) for the rectangle in each trial. Combination of orientation, therefore, were 36 in the total number.

Forty trials of a day were constructed by

FIG. 1. Ground plan of the apparatus.

FIG. 2. The stimulus pair used for the discrimination in Experiment I.

³ In all of the pairs used in the experiment, the area of the stimulus figure was kept constant.

ordering at random those 36 plus four combinations in a series. The order of the presentation was kept constant through the training.

In the training of the fixed orientation task, both a square and a rectangle were presented in the orientation of 0° .

Stimulus figures were exposed by the slide-projector, and they were presented in a black solid patterns against white background, with the exception of R 1.2 and R 1.1 for which white solid patterns were used against black background. The light-dark relations in the last two pairs were reversed because this procedure might help to reduce the possible effect of the screen frames.

Throughout the experiment, the positive figure was the rectangle, but the spatial relation in presenting the correct figure was randomized.

Procedure

Habituation. Before the start of the discrimination training, the animal was habituated to the apparatus and laboratory settings for 20 min per day for two days. The animal was then trained to run the goal-box from the start-box in eight trials for one day.

Brightness discrimination training. From the next day, the animal was trained in the brightness discrimination, whose purpose was to confirm the normality of visual function as well as of learning ability. In this training, when he chose the brighter plane (34 lx, 18×15 cm), the animal was rewarded with food pellet of 1.6 g per trial and was released from the goal-box. When he ran to the darker plane (7 lx), on the other hand, the animal was punished with the confinement in the goal-box for 30 sec (so-called "non-correction procedure").

The luminance of the darker plane was set at the same level as the background in the sessions from R 4.0 to R 1.5 and the figure in R 1.2 and R 1.1 sessions. The animal was run 40 trials a day and the criterion of discrimination was set at 18 correct responses per block of 20 trials. When an animal reached the criterion, training of pattern discrimination began from the next day.

Pattern discrimination training. Two kinds of training, free orientation task and fixed orientation task, were included in the pattern discrimination training. First, each animal received free orientation task, in which he was exposed to a pair of figures (rectangle with given length-breadth ratio versus square) with variable combination of orientation. The procedure of the pattern discrimination training was the same as that of the brightness discrimination mentioned above.

If an animal reached the criterion, he was then trained on a discrimination between a pair of less different stimuli from the next training session. But if he failed to reach the criterion after he ran 200 trials (10 blocks) except for the first session, the session was discontinued because the failure could be attributed to his inability of discrimination.

Fixed orientation task was administered after the free orientation task. With this order the animal would respond firmly to length-breadth ratio in the fixed orientation task. The procedures in the fixed orientation task were the same as those in free orientation task, except for the stimulus presentation mentioned above.

Results

The individual curves of free orientation discrimination learning for R 4.0 and R 1.5 are shown in Figs. 3a and 3b respectively. All animals successfully discriminated those rectangles from the square within 280 trials, although the rate of learning differed among animals. They had succeeded in the discrimination tasks of R 3.0 and R 2.0, and the data were not shown here.

Figure 4 shows the mean percentage of correct responses with R 4.0 for each animal⁴ plotted as a function of trial order throughout training, the ordinal number of trials means a specific combination. Although there seemed slight differences in percentage of correct responses for each animal, these differences did not result any

⁴ Animals S_4 and S_6 were eliminated in the data analysis because of their extremely rapid attainment to the criterion.

remarkable tendency consistent with all animals. The stimulus orientation, therefore, caused no effects upon discrimination.

Figures 5a and 5b show the individual curves of discrimination under free orientation for R 1.2 and R 1.1 respectively. While all the animals successfully discriminated R 1.2 from square, they all failed to reach the criterion in the task R 1.1 after 200 trials. As the increasing tendency of percentage of correct responses was not found in the task R 1.1, the difference in this pair was considered to exceed the discriminatory ability in kittens.

FIG. 3a. The percentage of correct responses as a function of trials with R 4.0.

FIG. 3b. The percentage of correct responses as a function of trials with R 1.5.

FIG. 4. The mean percentage of correct responses with R 4.0 plotted as a function of trial order.

The reversal of light-dark relations in these two series seems to have made little influence, since all animals succeeded in the discrimination with R 1.2 in relatively small number of trials.

In the fixed orientation task, all the animals showed the same level of performance as in the free orientation task. While they discriminated R 1.2 from square, none of them discriminated the R 1.1 task.

EXPERIMENT II

Purpose

The authors' concern were with comparing the findings of Experiment I with another kind of stimulus figure to examine the generality of the discriminatory ability in kittens.

This experiment was conducted to determine the discriminatory ability of ellipse from circle. The experiment also examined the effect of varying the stimulus size as an irrelevant cue.

Animals

Two female animals were used. At the beginning of experiment, one (S_1) was one-year-

FIG. 5a. The percentage of correct responses as a function of trials with R 1.2.

FIG. 5b. The percentage of correct responses as a function of trials with R 1.1.

old and had been trained in Experiment I, and the other (S_6) was naive subject aged three months.

Apparatus

The same apparatus as in Experiment I was used.

Stimulus Figures

An ellipse with a particular length-breadth ratio was paired with a circle. Training started with an ellipse with 2.3:1 ratio (henceforth referred to as E 2.3). After the animal successfully reached the criterion in this pair, the length-breadth ratio of ellipse was reduced to 1.7:1 from the next session and he was trained to discriminate it from the circle. Likewise, E 1.35, E 1.2, . . . were presented successively in the training session until the animal failed to reach the criterion after the limited number of trials.

Throughout training, the circle was presented with radius randomly chosen from variables of the following three: 24, 27, and 30 mm, while the ellipse was kept at constant size of approximately 23 cm².

The animal was trained at first with the free orientation task and then fixed orientation task. In the free orientation task, the ellipse was presented in one of the six spatial orientations: 0° (longer axis being vertical), 30°, 60°, 90°, 120°, and 150° (rotated clockwise). Thus the combinations of stimulus figures were 18 in number (size (3) × orientation (6)), and these 18 combinations were used as a series.

In the fixed orientation task, on the other hand, the ellipse was presented in a fixed 0° orientation.

Illustrations of the stimulus figures were represented in Fig. 6. The correct figure was

FIG. 6. The stimulus pair used for the discrimination in Experiment II.

fixed to the ellipse throughout the experiment.

Procedure

The same procedure as Experiment I was used with slight modification. In the training, the animal was run in two series (36 trials) per day. When he made more than 17 correct responses in a series (a block), he was regarded as having succeeded in discrimination and was permitted to proceed to the pair with less amount of difference in the next session.

If the animal failed to reach the criterion after 252 trials (14 blocks), the session was discontinued because the result could be attributed to his inability of discrimination.

Results

Animals succeeded in free orientation task of discriminating E 2.3 from circle in 40 and 160 trials respectively. Although S_6 took more trials to reach the criterion than S_1 , the difference in number of trials could be attributed to the difference in the previous experience with discrimination.

While both animals successfully discriminated E 1.7 from circle (Fig. 7a), they

FIG. 7a. The percentage of correct responses as a function of trials with E 1.7.

FIG. 7b. The percentage of correct responses as a function of trials with E 1.35.

failed to discriminate E 1.35 after 252 trials (Fig. 7b). Since the increase in percentage of correct responses was not found as a function of trials with E 1.35, it was concluded that the difference in the pair was smaller than kittens' discriminatory ability.

Figure 8 shows the mean percentage of correct responses with E 1.35 for each animal plotted as a function of orientation of ellipse. Although there seemed slight difference in percentage of correct responses for each animal, these differences did not show any consistent tendency. The stimulus orientation, therefore, caused no significant effects upon the discrimination.

As for the fixed orientation task, neither of the animals attained the criterion in the task of E 1.35.

DISCUSSION

Comparison of the Results between Experiment I and II

Since both Experiment I and II examined the kittens' discriminatory ability on length-breadth ratio, the same level of discrimination would be expected in both experiments. The kittens, however, failed in discriminating the circle from the ellipse with 1:1.35 length-breadth ratio, while they succeeded in discriminating the square from the rectangle with 1:1.2 length-breadth ratio.

The possible causes of this difference would be found in the difference of experi-

mental conditions, especially those of stimulus figures and/or the procedure of stimulus presentation.

The stimulus figures used in Experiment I were composed of straight edges, while those in Experiment II were composed of curved edges. In this connection, Casper (1950) reported that the discrimination threshold was higher with ellipse than with rectangle in human subjects. On the other hand, many neurophysiologists examined the selective responses of receptive fields which were caused by straight lines or edges (e.g., Hubel & Wiesel, 1962, 1963, 1965), but few reported the information processing with curved line in kittens.

Another possibility would be found in the dimension of irrelevant cue. In Experiment II the size of circle was taken as an irrelevant cue for discrimination in addition to the orientation of ellipse, which might have an effect on discrimination. As Mackintosh (1963) reported, rats took more trials to reach the criterion as the number of the dimensions of irrelevant cue increased. Then, it might be that the kittens' discrimination was disturbed with the salient feature added as an irrelevant cue.

A third possibility lies in the constancy phenomenon. When human subjects observed a pair of stimulus figures in Experiment II, some of them reported the ellipse as an apparent slant of the circle. If the same phenomenon occurred in kittens, it seemed to make discrimination more difficult.

To clarify the factors underlying the data, further investigations should be conducted.

Some Remarks on the Study of Pattern Discrimination in Animals

Bingham (1914) distinguished the concept of "shape" from that of "form", defining the former as the specific distribution of light in the visual field and the latter as the infinite number of variations produced by rotating the shape. In other

FIG. 8. The mean percentage of correct responses with E 1.35 plotted as a function of stimulus orientation.

words, the shape is an orientation-bound pattern, while the form is an orientation-free pattern.

It is hard in the study of animal's pattern discrimination to determine whether the animal makes the concept of "shape" or "form" in the same meaning as Bingham's definition. But if the discrimination of orientation-bound pattern is defined as "shape discrimination" and that of orientation-free pattern as "form discrimination", most of the studies have so far concerned with the former. Several studies reported the form discrimination, but most of them examined whether the animal could transfer the discriminatory response from a certain stimulus pair to another pair produced by rotating one of the pair (e.g., Lashley, 1938). These experiments, however, could not eliminate the possibility that the animal might have responded to the partial cue in a specific location of the pattern, as was mentioned earlier. Therefore, they could not conclude that the animal was unable to discriminate the form, even if they showed no transfer responses.

The procedure of the stimulus presentation in the present experiments would avoid such a problem. In these experiments, the animal could not have responded to any partial cue because it was not presented in a constant location through session. The animal, therefore, had to discriminate the stimulus pair on the basis of only one dimension operated in the experiments.

Several models have been proposed on the pattern discrimination processes in animals. For example, Sutherland (1963) and Dodwell (1970) proposed the models in which the orientation of pattern is one of the most important characteristics for discrimination. In other words, those are the models explaining the shape discrimination. For the form discrimination, some of them assume a higher process like "thinking" which is underlain by the shape discrimination process.

Those models, however, would fail to explain the results of present experiments. According to the prediction from those models, the animals would have failed in discrimination, since the procedure made the orientation inefficient as the discriminating cue from the beginning of the free orientation task.

Deutsch (1962) devised his model so that the same form in the different orientations would produce a constant output. It may be called a model for the form discrimination in a sense. The model, however, is inadequate in explaining the other aspect of the experimental evidences; animal can discriminate the patterns differing only in their orientation (e.g., Warren, 1969).

Therefore, any model which successfully deals with both form and shape discrimination have to be proposed in the near future.

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