SOLUTION OF THE INTERMEDIATE SIZE PROBLEM BY PIGEONS¹

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Pigeons learned to respond to the middle-sized member (S^D) of a set of three simultaneously presented stimuli with responses to the S^D reinforced on a VI 1 schedule. They were then tested for several days with other sets of three stimuli. One procedure presented reinforcements on a VI 1 schedule during the test independent of the stimulus chosen when a reinforcement was programmed. The tests were also given under extinction conditions. With the testing carried out with extinction, preference consistently was for the test stimulus most similar in physical size to the S^D . However, when the tests were with reinforcement, random responding resulted. Another effect of testing with reinforcement was an increase in incorrect responding with the training set. Such a test procedure was unsatisfactory for determining the effective aspect of the S^D . The conclusion, based on the data of the extinction series, was that pigeons learned the intermediate size problem on the basis of the discrimination of absolute stimulus properties.

In the intermediate size problem, an organism learns to respond to the middle-sized member of one set of stimuli and is then tested with a different set. The assumption is that stimulus preference in the test is controlled by the nature of the effective stimulus in the original discrimination. This may be the middle-size relationship, the absolute physical size of the S^D , or some contextually determined property (Zeiler, 1963). Since the stimulus responded to in the test would differ depending on which of these properties controlled the discriminative behavior, the essential nature of the stimulus is identified by the test element chosen. The current investigation with pigeons represented the first in which sub-primates learned the intermediate size problem when the stimuli were presented simultaneously. As such, it provided an opportunity to compare the basis of solution of the problem by pigeons and by primates.

The same subjects were tested repeatedly with a number of sets. Whenever there is more than a single test trial, a decision must be made about the reinforcement contingencies to be used.

Historically, the contingencies in the testing phase of transposition studies have been chosen on the basis of some intuitive rationale. In order to determine whether the procedure was an important variable, the current study explored the effects of testing with either reinforcement or extinction conditions.

METHOD

Subjects

Six experimentally naive Carneaux pigeons over one year of age were maintained at 80% of their free-feeding weight.

Apparatus

A ventilated soundproof chest housed a 16 by 10¾ by 12 in. experimental chamber modified from that described by Ferster and Skinner (1957). Three 2½ in. diameter translucent keys, with their centers 8½ in. above the floor, were mounted ¾ in. apart, center-to-center. Behind each key was a digital display unit that could project a white disk in 12 different diameters. Each disk appeared on a black background. Stimulus 1 had a diameter of ⅜ in., and each succeeding disk increased in area by a factor of 1.4. A window centered on the wall opposite to the response keys provided access to grain during a 6-sec magazine cycle. In a time-out (TO) period, the projec-

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tors and a houselight were turned off. A white masking noise was always present. All phases of the experiment were automated.

Procedure

In training, the same set of three stimuli, each of a different size, were presented simultaneously. The three stimuli changed positions after each reinforcement and TO unless there were persistent position preferences. These were eliminated by changing positions only after a reinforcement.

Responses to the middle-sized stimulus (S^D) were reinforced on a VI 1-min schedule. So that a chained response of switching from an incorrect stimulus to the S^D could not be established, a contingency circuit prevented a correct response from producing a reinforcement within $3\frac{1}{2}$ sec of an incorrect response. Similar procedures have been found effective in reducing switching behavior (Findley, 1958; Herrnstein, 1961).

A daily session consisted of 45 1-min stimulus-on periods each separated by a 15-sec TO. Key pecks in a TO period had the same effect as a response to an S^A in a stimulus-on period; that is, they activated the $3\frac{1}{2}$ sec contingency circuit. In order that there be a full minute of response time in each stimulus-on period, the clock that timed the 1-min intervals was stopped during a reinforcement.

The training criterion was two successive days of overall 95% correct responses. A minimum of 900 correct responses on each of these days was required, and the total number of responses on the criterion days had to differ by no more than 10%. The first test day followed the second criterion day.

Pigeons 1, 2, 3, and 5, which were trained with stimuli 2-4-6 (stimulus 4 was the S^D), were tested with sets composed of stimuli 1-3-5, 3-5-7, 4-6-8, 5-7-9, 6-8-10, 7-9-11, and 8-10-12. Pigeons 10 and 12 were trained with stimuli 5-6-7 (stimulus 6 was the S^D) and were tested with sets 1-2-3, 2-3-4, 3-4-5, 4-5-6, 6-7-8, 7-8-9, 8-9-10, and 9-10-11. On each test day, a 1-min presentation of each test set was preceded by either four (Pigeons 10 and 12) or five (Pigeons 1, 2, 3, and 5) 1-min trials with the stimuli used in training. On these training trials of each test day, responses to the middle-sized stimulus were reinforced on a VI 1 schedule. The sequence on a test day was 4-5

training trials, a 1-min probe with a test set, 4-5 training trials, test probe, *etc.* This procedure was continued until each of the test sets was presented once each day. A test series consisted of seven successive days of testing for Pigeons 1, 2, 3, and 5, and eight successive days of testing for Pigeons 10 and 12. The order of presentation of the test sets was randomized daily. As in training, a 15-sec TO followed each 1-min stimulus-on period.

Pigeons 1, 2, 10, and 12 were given the test probes under extinction conditions (extinction series). Pigeons 1 and 2 received a second series in which reinforcement was presented in the test periods on the VI 1 schedule no matter which stimulus was chosen when a reinforcement was due (reinforcement series). However, Pigeon 1 stopped responding on the fourth day of the reinforcement series. None of the data for this bird for the second series were used. Pigeons 3 and 5 were also given two test series, but the first was with reinforcement while the second was an extinction series.

RESULTS

The responses in a test period could be to the stimulus most similar in size to the S^D (absolute choice), to the middle-sized stimulus (transposition), or to the third stimulus of the set. To determine which stimulus was preferred in each of the test sets, two dependent variables were examined: (a) the first element chosen when the set was presented on each test day (first choice measure); (b) the stimulus to which the responses occurred most frequently in each of the 1-min probe periods (frequency measure). Both measures of preference revealed that the stimulus chosen was a function of the reinforcement conditions employed in the test series.

Because of an interest in the number of responses that occurred to the preferred stimulus in the test sets relative to the number of responses to the S^D , the frequency measure was analyzed as follows. On every test day, there were either 32 or 35 1-min training trials for which the mean frequency of responses to the S^D was computed. The number of responses to the preferred stimulus in each of the sets was transformed into a z score relative to this mean frequency.

Figure 1 shows the percentage of the test days on which a stimulus was preferred in each of the test sets for the first series (extinction) for Pigeons 1, 2, 10, and 12. Since the responses in a test interval were confined almost entirely to the preferred stimulus, the frequency (Fig. 1a) and the first choice (Fig. 1b) measures of preference were in close agree-

Fig. 1. Percentage of test days in the first series for Pigeons 1, 2, 10, and 12 on which the large (L), middle-sized (M), and small (S) stimulus was preferred in each test set. Capital letters show the stimulus preferred most frequently in a set; lower case letters show the percentage of days on which other stimuli were preferred. Pigeons 1 and 2 were trained with 2-4-6 (stimulus 4 was the S^D) and Pigeons 10 and 12 were trained with 5-6-7 (stimulus 6 was the S^D).

(a) Preference as measured by the stimulus responded to most frequently in each 1-min test probe.
(b) Preference as measured by the stimulus chosen first on the presentation of each set in each probe period.

ment. The frequent probe periods in which there were no responses resulted in days on which there was no preference with a set. For example, Fig. 1b shows that the preference for Pigeon 1, as measured by the first choice, was for stimulus 3 on three days (43% of the test days) and stimulus 5 on four days with both sets 1-3-5 and 3-5-7. Stimulus 4 of 4-6-8 and stimulus 5 of 5-7-9 were preferred on all seven days. Stimulus 6 of 6-8-10 and stimulus 7 of 7-9-11 were preferred on three days with no responding occurring on the other four days. Stimulus 8 of 8-10-12 was preferred on one day with no responses made to the set on the other six days. When two stimulus letters appear at the same data point, each of these stimuli were preferred on the percentage of days indicated. For example, with set 1-3-5, Pigeon 2 preferred stimulus 3 on two days and stimulus 5 on two days.

In sets 4-6-8, 5-7-9, 6-8-10, 7-9-11, and 8-10-12 for Pigeons 1 and 2, the preferred stimulus was always the smallest element. This was the stimulus of each set that was most similar in physical size to the S^D (stimulus 4 of set 2-4-6). With sets 1-3-5 and 3-5-7, it was not possible to state which of two stimuli, 3 or 5, was the most physically similar to the S^D . However, if relational factors controlled the choices, the birds should have transposed with both sets independent of whether the middle-sized stimulus was stimulus 3 or 5. Transposition with one set (e.g., 1-3-5) and preference for the same physical stimulus in the other set (e.g., stimulus 3 in set 3-5-7) indicated that a specific stimulus (e.g., stimulus 3) controlled behavior. Transposition with both sets on the same day, which would be evidence for relational learning, did not occur. Instead, on each day, the responses were restricted to one of the two stimuli with daily shifts in preference between the two. All of the test sets showed, therefore, that training with set 2-4-6 and testing under extinction conditions resulted in behavior controlled by the specific physical size of the S^D .

For Pigeons 10 and 12, sets 4-5-6 and 6-7-8 directly compared the importance of absolute *vs* relational cues. Stimulus 6 of these sets was the previous middle-sized S^D of the training set (5-6-7) and was now either the largest or smallest set member. That the absolute properties of this stimulus controlled the choice

behavior was revealed unambiguously as stimulus 6 was preferred in both sets by the two birds on all eight test days. With the other sets, transfer was most frequently on the basis of absolute properties. That is, the largest set member was chosen when the test stimuli were smaller than those of the training set, while the smallest stimulus was preferred when the test sets were larger than the training set. Considering both measures of preference, transposition did occur for Pigeon 10 once with 2-3-4, three or four times with 7-8-9, and on one or two days with 8-9-10. Pigeon 12 transposed once with 2-3-4, once or twice with 3-4-5, and once with 7-8-9. However, even in these cases, there were usually an equal or greater number of days on which the preferred stimulus was the element most similar in size to the S^D . There were no test sets for either bird for which both measures of preference concurred in revealing that the most frequent preference was for the middle-sized stimulus. Transposition was probably due to the fact that the stimulus most similar to the S^D in these sets was either an S^A of the training set or was very similar to an S^A .

A reinforcement test as the first series resulted in very few test periods in which Pigeons 3 and 5 failed to respond. The number of responses to the preferred stimulus of each test set is shown separately for each day in Fig. 2. The first choice data (not shown) corroborated those based on the frequency of response. There was mainly absolute transfer on days 1 and 7 for Pigeon 3 and on the first four days for Pigeon 5. On no other days were there systematic preferences for either bird. In some cases, preferences changed often with a given test set. For example, with 7-9-11, Pigeon 3 preferred stimulus 7 on days 3, 5, and 7, stimulus 9 on days 1 and 4, stimulus 11 on day 2, and responded equally often to stimuli 9 and 11 on day 6. With all of the test sets, there were several days on which the responses shifted from stimulus to stimulus so that there were almost equal numbers of responses to two or three stimuli. There was no apparent relationship between the stimuli reinforced during a probe and the subsequent choices.

Figure 3 shows the preferred stimulus on each day for each set in the second series. These data are based on the frequency meas-

ure; again, the frequency and first choice variables were in close agreement. Pigeon 2, now tested with reinforcement, transferred absolutely on days 1, 2, 5, and 6 and showed inconsistent behavior on the other days. The behavior of this bird was similar to that of Pigeons 3 and 5 in their first series (Fig. 2). There was frequent switching from key to key in each of the 1-min test periods. The second series for Pigeons 3 and 5 (extinction) showed extinction of the unstable behavior of the re-

Fig. 2. Frequency of response to the preferred stimulus of each test set for each day of the first series for Pigeons 3 and 5. The letters indicate whether the preferred element was the large (L), the middle-sized (M), or the small (S) stimulus of the set. The training set was 2-4-6, and the S^D was stimulus 4.

inforcement series, and the eventual occurrence of either no responding or systematic absolute choice with every set.

In addition to the different patterns of preference established with the two testing procedures, the extinction and reinforcement series had differential effects on the training trials of each test day. The level of correct

responding never fell below 98% for any bird in an extinction series. However, this level dropped below 95% to as low as 80% in every reinforcement series.

With either the extinction or the reinforcement conditions, the number of responses to the preferred stimulus of each set was usually less than the mean number of responses to the S^D on the training trials ($z < 0.0$). A consistent exception was with sets 4-5-6 and 6-7-8 for Pigeons 10 and 12 where the preferred stimulus was the previous S^D . Pigeon 10 responded to stimulus 6 in these tests more frequently than to that stimulus when it was the S^D in 14 of 16 instances, while Pigeon 12 had 12 of 16 such instances of $z > 0.0$. For both birds, this behavior occurred more frequently than would be expected on the basis of chance, $\chi^2 > 3.84$, $df = 1$, $p < .05$. Although both Pigeons 1 and 2 showed a majority of days of a $z > 0.0$ to stimulus 4 in set 4-6-8, the occurrence of such behavior was not significantly greater than would be expected on the basis of chance. Such accelerated frequencies of responding occurred occasionally for Pigeons 3 and 5 with other sets as well as with 4-6-8.

DISCUSSION

The patterns of stimulus preference were identical whether measured by the first stimulus chosen when a set was presented or by the stimulus responded to most frequently in each of the probe periods. However, the type of test procedure, reinforcement or extinction, was an important variable. When the first test was an extinction series, responding usually was confined to the stimulus of each set most similar to the S^D in absolute terms. Transposition was attributable to either specific stimulus preferences (sets 1-3-5 and 3-5-7) or to the avoidance of a previous S^A . A reinforcement series, as either the first or the second series, produced either absolute transfer or a variable distribution of responses. This behavior carried over to the beginning of a subsequent extinction series, but disappeared rapidly as absolute properties regained control over the test behavior. The extent of this control was indicated by the eventual extinction of responding to the test sets composed of stimuli that were all quite different from the S^D .

Fig. 3. Frequency of response to the preferred stimulus of each test set for each day of the second series for Pigeons 2, 3, and 5. The letters indicate whether the preferred element was the large (L), the middle-sized (M), or the small (S) stimulus of the set. The training set was 2-4-6, and the S^D was stimulus 4. Data points at N (unfilled circles) mean that there were no responses to the set on that day.

The erratic behavior in every reinforcement series implied that under such conditions the behavior with the test sets was not completely determined by the training conditions. A striking example of the independence of the training and the test conditions was the consistent preference of Pigeon 3 for stimulus 1 in set 1-3-5. This element was far more similar to an S^A than to the S^D in either absolute or relational terms. However, the tendency for absolute preferences to persist with the test sets not too different from the training set indicated some effect of the training discrimination on the test performance. In addition, the decrement in correct performance on the training trials suggested that the reinforcement presented during the test disrupted the training discrimination. Since the test with reinforcement established unstable and unpredictable behavior in both the training and the test, such a testing procedure was not as satisfactory as an extinction series for the evaluation of the nature of the S^D .

A recent review of the literature (Zeiler, 1963) revealed that species other than pigeons transposed when the training and the test sets were similar to each other. With the extinction series, the current findings were that pigeons transferred absolutely whether or not the training and the test sets were very similar. The data were quite similar to those of Honig (1962) who found that absolute stimulus properties controlled the behavior of pigeons in the two-stimulus transposition problems. In both the extinction series of the current study and in Honig's experiment, transposition occurred only when a generally preferred specific stimulus happened to have the relationship identical to that of the S^D . These failures to obtain any evidence for the role of relationships supported Spence's (1937, 1942) contention that the specific stimuli of the training set control the stimulus preferences in a test. Pigeons were the first species given the intermediate size problem to behave consistently as predicted by Spence's theory.

A finding that cannot be explained at this time was the large number of responses that

occurred to the preferred member of the test sets that contained the previous S^D . Various conditions of manipulations of other stimuli have been shown to increase the rate of responding to an S^D (Reynolds, 1961; Catania and Gill, 1964). Such behavior, called behavioral contrast by Skinner (1938), also was investigated by Pavlov (1927) who called it positive induction. There was a similarity between the current finding that the accelerated level of responding was more consistent after training with 5-6-7 than after 2-4-6 and Pavlov's report that a decreased difference between an S^D and an S^A stabilized the effect of positive induction. Further research is required to determine if there is a relationship between contrast, which has been studied only with successive discriminations, and the high response frequencies now reported in a simultaneous discrimination.

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