S+ and S- control in *Macaca fascicularis* using a discriminative switching procedure*

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Monkeys were trained using a discriminative switching procedure in which S+ and S- were never presented simultaneously, but in which the S could switch back and forth between the two before making a choice response. S+ and S- substitution tests were conducted following problems in which a relatively large number of training trials were given. Results indicated that S- control was sufficient to maintain discriminative performance at the level attained during training and that S+ control was considerably weaker. Contrasting results from previous experiments using the simultaneous procedure and fewer training trials were discussed in terms of observing behavior.

One concern about discrimination learning by monkeys and other species is the relative strengths of stimulus control by the rewarded (S+) and nonrewarded (S-) stimuli and, in particular, how such control might change during the later trials of a discrimination problem. One way of assessing stimulus control is through the use of substitution tests. This method involves discrimination training (usually two-choice simultaneous) for *n* trials, followed by substitution of another stimulus (usually novel) for either S+ or S-. Errors following S+ or S- substitutions are indicative of S+ and S- control, respectively. While different methods for assessing stimulus control might well give different results, the substitution method seems to be at least as useful as other current methods (Rees, 1970) and is widely used.

With the substitution method, previous work suggests that S- control becomes relatively weaker during the later trials of a problem, for both monkeys (Behar, 1962a, b) and rats (Biederman, 1967). Also using the substitution procedure, Mandler (1968) found greater S+ control using overtrained but not mastery-trained rats. Using a somewhat different procedure with pigeons, Biederman (1968) found that a more trained S- was preferred to a less trained S+. A possible explanation for these effects is that S- comes to exercise relatively less control because choice responses to S- tend to become less frequent (D'Amato & Jagoda, 1961). Perhaps if some other kind of response to S- could be maintained throughout

training, then S- control might remain relatively strong. In the discriminative switching procedure (Rees & Schrier, 1967), such a response is necessarily maintained when discriminative performance is high. With this procedure, only one stimulus (S+ or S-) is present at any one time, but the opportunity to switch from one to the other is available before a final choice response need be made. When S- is presented, the S must perform a switching response to present S+ before a rewarded choice response can be made. According to Wyckoff's (1952) definition, the switching response serves the function of an observing response.

Substitution tests were used to study stimulus control in the present experiment, but, in contrast to previous experiments (Behar, 1962a, b; Biederman, 1967), the discriminative switching procedure was used and many more training trials were given on each problem prior to substitution tests. Despite the large number of training trials, S- control was expected to remain relatively strong due to the frequent occurrence of switching responses from S- to S+.

SUBJECTS

Four male Philippine cynomolgus monkeys (*Macaca fascicularis*; formerly *M. irus*), about 7 years old, were maintained on a diet of commercial monkey chow that allowed steady weight gain but was considerably less than a free-feeding diet. All had previously been used in a study of double-alternation behavior using the same automatic discrimination apparatus, and two of the four had been used in a Wisconsin General Test Apparatus, also in a study of double alternation.

APPARATUS AND PROCEDURE

The apparatus and training procedure used for the discriminative switching task were described by Rees & Schrier (1967). Briefly, 35-mm color transparencies of junk objects

were projected onto a 3 x 3 in. rear projection screen which served as the choice-response key. A 1-in.-diam transilluminated disk positioned near the left edge of the choice key served as the switching key. Thus, two types of responses were available on every trial. A response to the choice key during presentation of S+ produced a 45-mg Noyes sucrose pellet coincident with the beginning of a 5-sec intertrial interval during which both response keys were dark and nonfunctional. A choice response during S- produced only the intertrial interval. During presentation of either S+ or S-, a response to the switching key caused the other stimulus to be presented instead: S+ followed by a switching response produced S- and removed S+, and S- followed by a switching response produced S+ and removed S-. There was no limit to the number of switching responses that could be made during any trial. At the end of intertrial intervals, either S+ or S- (as determined by a Gellermann series) was projected onto the choice key and a white light was projected onto the switching key, both keys becoming functional.

Training consisted of at least two 100-trial sessions on a single discrimination problem, while testing consisted of a subsequent session in which either the S+ or the S- was replaced by a novel stimulus. After a test session, both stimuli were replaced by novel stimuli to begin another series of training and test sessions. Each S received either six or seven of both S+ and S- substitution tests (designated the S+ SUB and S- SUB conditions), depending on the available time. In addition, three other conditions were defined. In order to test whether or not the training problems for S+ and S- substitutions were initially equally difficult, performance during the first sessions of training series that preceded S+ substitutions (PRE S+) was compared with performance during first sessions of training series that preceded S- substitutions (PRE S-). Performance during the second session of each training series (designated the TRAIN condition) was taken as the baseline against which to compare performance on the substitution tests. The main statistical analysis was an analysis of variance in which the main effects were: conditions (TRAIN, S+ SUB, and S- SUB), trial blocks (five blocks of 20 trials within sessions), and Ss.

RESULTS

The mean frequency of errors for each of the conditions of the experiment is shown in Fig. 1. Comparing the error data in the PRE S+ and PRE S- conditions revealed no significant difference

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($t = 1.13$, $df = 3$). In the analysis of variance, conditions and trial blocks were both significant ($F = 21.58$, $df = 2/6$, $p < .005$; $F = 74.92$, $df = 4/12$, $p < .001$), as was their interaction ($F = 13.98$, $df = 8/24$, $p < .001$). The interaction reflects the fact that the differences among conditions were greater in the early trial blocks.

Tests for the simple main effects based on the significant interaction showed that the conditions effect was significant only in the first trial block ($F = 34.73$, $df = 2/6$, $p < .01$). Newman Keuls paired comparisons (Winer, 1962) conducted on conditions for the first trial block indicated that there were more errors in the S- SUB condition than in either of the other two conditions ($p < .01$ in both cases), while the latter did not differ.

DISCUSSION

Since the number of errors made in the PRE S+ and PRE S- training sessions did not differ, it can be assumed that the random assignment of training problems for the S+ and S- substitution tests was adequate. In considering the error data from test sessions, several aspects are important to the questions of S+ and S- control. The fact that S+ substitutions caused no more errors than occurred in the second training sessions suggests that S- was sufficient to maintain the discriminative performance at the level attained in training, and the fact that S- substitutions caused more errors than occurred in second sessions suggests that S+ was not sufficient. Most important, however, the fact that S- substitutions were more difficult than S+ substitutions indicates that S- control was relatively greater. This outcome, when viewed in contrast to the finding of Behar (1962a, b) and Biederman (1967, 1968), supports the suggestion that the relative strengths of S+ and S- control after a large number of training trials might depend on response requirements. More specifically, the difference could be due to whether or not another observing response is required during a trial in which S- was the last exposed stimulus. In the switching procedure,

Fig. 1. Mean number of errors for all monkeys in each trial block for each condition. PRE S+ and PRE S- refer to first training sessions preceding S+ and S- substitutions, respectively; TRAIN refers to second training sessions; and S+ SUB and S- SUB refer to S+ and S- substitution test sessions, respectively.

if the last stimulus presentation were S-, then a switching response exposing S+ must be made before a rewarded choice response can be made; however, in the simultaneous procedure, if S- were the last stimulus to be observed, no further observing responses are required.

A more thorough consideration of the observing responses in the two procedures suggests that they also differ in terms of type, number, and perhaps difficulty. With the simultaneous procedure, head and eye orientations are needed to expose S+ and S- successively on a given trial (assuming the two stimuli are sufficiently far apart to preclude simultaneous fixation), while with discriminative switching, both head and eye orientations and a switching response are needed. Thus, it could be that the relative strengths of S+ and S- control in the later trials of a problem depend on the nature of the observing responses per se. If this hypothesis is correct, then differences in the relative strengths of S+ and S- control should be found within either procedure (providing the nature of the

observing response requirement was properly manipulated), as well as between procedures. For example, using only a simultaneous procedure, the distance between stimuli could be varied in order to require greater or lesser head and eye movements for the successive exposure of S+ and S- on a single trial. Similarly, using only the discriminative switching procedure, the difficulty of the switching response could be manipulated. In either case, it would be predicted that the more difficult observing response would lead to relatively greater S- control in the later trials of a problem. Other aspects of the observing response might also affect the relative strengths of S+ and S- control, e.g., whether the response is ocular or manual.

REFERENCES

- BEHAR, I. Evaluation of cues in learning set formation in mangabey. *Psychological Reports*, 1962a, 11, 479-485.
- BEHAR, I. Evaluation of the significance of positive and negative cues in discrimination learning. *Journal of Comparative & Physiological Psychology*, 1962b, 55, 502-504.
- BIEDERMAN, G. B. The overlearning reversal effect: A function of the nonmonotonicity of the negativity of S- during discriminative training. *Psychonomic Science*, 1967, 7, 385-386.
- BIEDERMAN, G. B. Stimulus function in simultaneous discrimination. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 459-463.
- D'AMATO, M. R., & JAGODA, H. Analysis of the role of overlearning in discrimination reversal. *Journal of Experimental Psychology*, 1961, 61, 45-50.
- MANDLER, J. M. Overtraining and the use of positive and negative stimuli in reversal and transfer. *Journal of Comparative & Physiological Psychology*, 1968, 66, 110-115.
- REES, E. R. Studies of stimulus control, discrimination reversal, and observing behavior in monkeys. Unpublished doctoral dissertation, Brown University, 1970.
- REES, R., & SCHRIER, A. M. Discrimination learning by *Macaca mulatta* with option to switch between S+ and S-. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 367-372.
- WINER, B. J. *Statistical principles in experimental design*. New York: McGraw-Hill, 1962.
- WYCKOFF, L. B., JR. The role of observing responses in discrimination learning: Part I. *Psychological Review*, 1952, 59, 431-442.