DISCRIMINATION LEARNING BY MACACA MULATTA WITH OPTION TO SWITCH BETWEEN S+ AND S-¹

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Three rhesus monkeys were trained to press either of two response keys. A response on the reinforcement key during presentation of the reinforced stimulus produced a sucrose pellet followed by an intertrial interval, but during presentation of the unreinforced stimulus produced only the intertrial interval. A response on the switching key changed the discriminative stimulus from reinforced to unreinforced or from unreinforced to reinforced. The reinforced stimulus was presented automatically on half the trials, but could be produced only by a switching response on the other half. Switching tended to occur in three distinct stages during acquisition of discriminative behavior. The first stage was identified as "nondiscriminative switching"; the second as "nonswitching"; and the third as "discriminative switching".

A switching response results in a change in stimulus conditions. Findley (1958), for example, trained pigeons to switch between two concurrently programmed schedules of reinforcement. Control of switching behavior was viewed as a function of the differential aversiveness of the two schedules. By a similar method, several investigators (Azrin, 1961; Thompson, 1964; Zimmerman and Ferster, 1964) allowed switching between a time-out condition and a condition in which food was produced on a fixed-ratio schedule. Although the results were not always in agreement, it seems that in general some degree of control over switching behavior was gained by manipulating the size of the fixed ratio.

Following a different line of investigation, Zeigler and Wyckoff (1961) and D'Amato and Fazzaro (1966) used procedures in which a response produced discriminative stimuli. In the former case, pigeons were successfully trained to emit an "observing" response (pedal press) that resulted in simultaneous presentation of the rewarded (S+) and unrewarded (S-) stimuli of a two-choice discrimination task. If no observing response was made on a particular trial, the probability of a reinforced response on that trial was 0.5, since no information

about S+ and S- was available. D'Amato and Fazzaro (1966) trained capuchin monkeys (*Cebus apella*) to emit "cue-producing" responses that resulted in additional relevant cues being superimposed over the S+ and S- of a simultaneous discrimination problem. A cue-producing response, in effect, switched a less-discriminable problem to a more-discriminable one.

The first objective of the present study was to develop a method of bringing switching behavior under stimulus control. This was accomplished by making changes between stimulus conditions contingent upon a switching response. The procedure is similar to the methods which allow switching between food and no-food conditions (Azrin, 1961; Thompson, 1964; Zimmerman and Ferster, 1964), but is also akin to the studies by Zeigler and Wyckoff (1961) and D'Amato and Fazzaro (1966) in its emphasis on discriminative control of the switching response. The second objective was to study the acquisition of discriminative behavior in terms of the development of stimulus control over switching behavior.

METHOD

Subjects and Apparatus

Three young adult, male rhesus monkeys (*Macaca mulatta*) about 6 yr old were maintained on a diet of commercial monkey chow which, although considerably less than a free-feeding diet, allowed steady weight gain. All

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had a similar history of color-discrimination problems in a Wisconsin General Test Apparatus.

Stimuli were projected onto a 3-in. by 3-in. rear-projection screen by a Kodak Carousel slide projector (AV-580). The projection screen also served as the reinforcement key. The switching key was a 1-in. diameter translucent disc positioned 1.5 in. from the left edge of the reinforcement key. When operative it was illuminated from the rear by a 1.1-w lamp. Solid state logic units and punched tape equipment were used for programming and recording. Reinforcers were 45-mg Noyes sucrose pellets delivered into a food cup positioned 2 in. below the switching key. Five discrimination problems were used. The first was a brightness-discrimination problem in which the reinforcement key was lighted for S+ and dark for S-. The second was a color-discrimination problem in which the key was blue for S+ and red for S-. To humans, S- appeared brighter than S+. The final series of three discrimination problems consisted of stimuli which were multi-colored photographs of several complex forms which varied in color, brightness, and pattern. These photographs were intended to serve as two-dimensional analogs of the "junk" objects traditionally used as discriminative stimuli in the Wisconsin General Test Apparatus.

Procedure

The subjects were pretrained on a successive brightness-discrimination problem for which only the reinforcement key was operative. An intertrial interval of 5 sec, during which all responses were ineffective, and all response keys were dark, was followed by projection of S+ onto the reinforcement key. A response on that key during projection of S+ delivered a sucrose pellet and produced another intertrial interval. An "observation" interval of 0.5 sec following onset of the S+ was gradually introduced in increments of 0.1 sec. Responses on the reinforcement key were ineffective during this interval.

In the second stage of pretraining, the intertrial interval was followed by projection of S-, instead of S+, and by the onset of the switching-key light. An observation interval of 0.5 sec followed onset of the S-. A response on the reinforcement key immediately ended the trial without reinforcement. A single response

on the switching key, however, produced an 0.8-sec blackout period while the projector changed slides, followed by projection of S+ onto the reinforcement key. A second switching response reversed the projector and produced S- again. Any number of switching responses could be made and each would reverse the projector, but if a response was made on the reinforcement key while S+ was being projected, a sucrose pellet was delivered and the trial was terminated. Two different responses were therefore required for reinforcement: first, a switching response to change from S- to S+, and, second, a response on the reinforcement key during S+. An observation interval of 0.5 sec was gradually introduced after each switch from S+ to S- or from S- to S+.

After the two-stage pretraining, the complete testing procedure was introduced. An intertrial interval was followed half the time by S+ and half the time by S-, programmed in random order. When S- was presented, both a switching response during S- and a response on the reinforcement key during S+ were required for reinforcement. A response on the reinforcement key during S- always ended the trial without reinforcement. The 0.5-sec observation interval was employed after the onset of a discriminative stimulus for each trial, and after each switch from one discriminative stimulus to the other. After about 20 sessions of brightness-discrimination training using this procedure, the color-discrimination problem and the three multi-colored-photograph discrimination problems were presented. One monkey (Neal) did not receive the color-discrimination problem. Sessions consisted of 100 trials and were usually scheduled Monday through Friday.

RESULTS

Pretraining and Brightness Discrimination

Two monkeys (Van and Neal, respectively) switched 80% and 92% of the trials to S+ during Session 2 of the second stage of pretraining; S+ and S- trials were presented in random order thereafter. One monkey (Will) was given random presentation of S+ and S- after only a few exposures to S- and correctly switched only 17% of the S- trials to S+. The second stage of pretraining was reinstated so that the intertrial interval was again always

followed by S-. Over the next seven sessions the percentage of S- trials which were switched to S+ increased to 90%; S+ and S- were randomly presented thereafter.

Results for the first 17 sessions of brightness discrimination after pretraining for each subject are summarized in Fig. 1. The percentage of S- trials switched to S+ increased with practice and almost no S+ trials were switched and left in S-. Van and Neal, however,

switched back and forth between S+ and S- before making a reinforcement response.

Color and Multicolored-Photograph Discriminations

The acquisition of discriminative behavior within problems occurred in three distinct stages which were differentiated by switching frequency and by the percentage of trials in which a response on the reinforcement key was made during S+ (percentage of trials reinforced), as shown in Fig. 2 and 3. The criterion for demarcating the first, or nondiscriminative-switching, stage of behavior was the occurrence of a series of trials during which switches to and from S+ occurred with about equal frequency. In all discrimination problems for Van and Neal, and in three of the four problems for Will, the criterion for nondiscriminative switching was met. Although the discriminative performance of Van on Problems 1 and 2 appeared high during the nondiscriminative-switching stage, in both cases the stage was very short (four and three trials, respectively). It is thus quite possible that the outcomes occurred by chance.

The criterion for demarcating the second, or nonswitching, stage of behavior was the occurrence of a series of trials containing not more than one switching response and followed by an abrupt increase both in switching to S+ and in responding on the reinforcement key during S+. In all discrimination problems for Will and Neal, and in all but Problem 1 for Van, the criterion for nonswitching was met. Even in the case of Problem 1 for Van there is a clear suggestion from the cumulative switching-response curve (Fig. 2) that a period of relatively few switching responses followed the nondiscriminative-switching stage.

In all discrimination problems, except Problem 1 for Van, an abrupt increase in switches to S+ and reinforcement responses during S+ demarcated the start of the third, or discriminative-switching, stage of behavior. With two exceptions (Problems 1 and 2 for Neal) the number of trials reinforced was greater than 90% throughout the discriminative-switching stage.

Discriminative-switching behavior was usually acquired more rapidly with each succeeding discrimination problem (Will-3 and Neal-2 were exceptions). In general, there appeared to be a tendency for the stage of nondiscrimi-

Fig. 1. Percentage of trials reinforced as a function of training sessions on the brightness problem. S+ and S- trials are shown separately.

Fig. 2. Cumulative switching responses (left ordinate) made by Van on Problem 1 and Neal on Problems 1 and 2 as a function of training trials. Percentage of trials reinforced (right ordinate) during separate stages of switching behavior is shown in the form of a histogram superimposed on the cumulative response curves.

native switching to become progressively shorter. It seemed quite possible that with additional discrimination problems the non-discriminative-switching stage would disappear completely, as it did for Will on Problem 4.

DISCUSSION

To account for some of the aspects of the three-stage acquisition, it is convenient to specify the sequence of events, starting with the presentation of an established $S-$, as a chain in which presentation of the $S-$ was a discriminative stimulus for switching, and the resultant $S+$ was a conditioned reinforcer for the previous switching response. This is not unlike Wyckoff's (1952) account of the maintenance of observing responses: given the proper sequence of events (observing response, $S+$, effective response, reinforcement), an $S+$ can serve both as a discriminative stimulus for the effective response and as a conditioned reinforcer for the observing response. Similarly, Catania (1966, pp. 224-227), in discussing the role of the "changeover" response in concur-

rent scheduling, points out that the maintenance of changeover responses "may be attributed to the establishment of the respective schedule stimuli as conditioned reinforcers" (p. 226). Both the switching response and the changeover response effect a switch between discriminative stimuli which are associated with particular reinforcement schedules.

During the first, or nondiscriminative-switching stage, both of the novel stimuli of each new discrimination problem exhibited a discriminative function similar to that of an established $S-$. In other words, each novel stimulus acted as a discriminative stimulus for switching. It is not clear why they should function more like an $S-$ than an $S+$. In any case, the subsequent nonswitching and discriminative switching stages can be explained in terms of conditioned reinforcement. Since neither of the novel stimuli had the necessary discriminative properties of a conditioned reinforcer, the initial nondiscriminative-switching behavior was not maintained, resulting in the nonswitching stage. Later, when the novel $S+$ acquired the discriminative properties nec-

Fig. 3. Cumulative switching responses (left ordinate) made by Van on Problems 2, 3, and 4; Neal on Problem 3; and Will on Problems 1, 2, 3, and 4 as a function of training trials. Percentage of trials reinforced (right ordinate) during separate stages of switching behavior is shown in the form of a histogram superimposed on the cumulative response curves.

essary to establish it as a conditioned reinforcer, the discriminative-switching stage began.

Another account of the development of the three stages of switching behavior stems from studies of investigative behavior (Butler, 1965). Assume that the switching response was at least partially maintained by the stimulus changes which occurred each time the projector changed slides after a switching response. If these stimulus changes were most strongly reinforcing when novel stimuli were presented, then a stage of nondiscriminative switching should have resulted. A nonswitching stage could then follow if the novel stimu-

lus changes lost reinforcing strength before the discrimination between S+ and S- was established. It should be noted that the stimulus-change and conditioned-reinforcement accounts of the three stages of switching behavior are not necessarily mutually exclusive and probably do not exhaust all possible explanations.

It is evident that both objectives of the present study have been satisfied. First, stimulus control over switching behavior was achieved; second, the acquisition of discriminative behavior was analyzed in terms of the development of this stimulus control. Within discrimination problems, frequency and type

of switching changed over trials in three distinct stages, the final stage being identified by the sudden onset of discriminative behavior.

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