APDA: A discontinuous S-R automated primate discrimination apparatus¹

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The present paper describes a discontinuous S-R automated primate discrimination apparatus (APDA) designed to eliminate the stimulus sampling biases associated with previous manual and automated testing procedures and at the same time to provide greater specification of the S's intratrial discrimination behavior. Data from two simultaneous color discrimination problems are summarized as an evaluation of the current design.

As detailed by Meyer, Treichler, & Meyer (1965), the formboard, originally used by Spence (1937) and later modified and standardized by Harlow and Bromer (1938) as the Wisconsin General Test Apparatus (WGTA), has become an indigenous feature of the behavioral primate laboratory. However, this extremely simple and most reliable apparatus is not without limitations. These not only restrict the application of the WGTA, but, more seriously, can produce misleading conclusions concerning variables affecting the discrimination process (LeVere, 1968). Many of the more serious limitations grow out of the inherent spatial contiguity between the stimulus and choice response which, because of the monkey's propensity to restrict severely its visual sampling to the physical location of the choice response, produces stimulus sampling gradients that are unequally distributed over the stimulus display area (Schuck, 1960). The obvious solution of this problem is to isolate visually the monkey's hands during the discrimination trial. However, the construction of such a device, that also enables the primate to master discrimination problems effectively, is quite a difficult matter (Otteson et al, 1962; Meyer et al, 1965) and most discontinuous S-R arrangements have fallen well below the efficiency standards set by the WGTA.

From these data, it would appear that the control of visual sampling exerted by the primate's hands in discrimination learning extends beyond that suggested by Schuck (1960), and is of such a magnitude that the animal may experience great difficulty in isolating the relevant aspects of the testing situation when the choice response and stimulus cue are not collocated. Thus, if the benefits of the discontinuous S-R arrangement are to be enjoyed, a method is needed to control the S's visual sampling that is independent of the physical choice response. LeVere (1967, 1968a, b) has suggested that the initial appearance of a reward following correct responses could provide such unbiased control. This paper describes such an apparatus that is automated and modified to yield precise specifications of the S's intratrial choice response behavior.

Subjects

Eight naive adolescent male rhesus monkeys served as Ss and were housed in pairs throughout the experimental procedures.

Apparatus

Figures 1-3 show the modified automated primate discrimination apparatus (APDA). Figure 1 shows the plastic animal-restraining compartment and the discrimination portion of the device. The line drawings (Figs. 2 and 3) indicate the exterior relationship of the stimulus observation window, response levers, and reward-retrieval wells. Figure 3 provides a cut-away view

Fig. 1. Photograph of APDA inside a sound-attenuated enclosure.

Fig. 2. Line drawing of APDA showing the physical relationships of the stimulus observation window (S obs. window), response levers (R lever), reward-retrieval well (REW. ret. well), and the manipulum locks (man. locks).

Fig. 3. Line drawing similar to Fig. 2 with a cut-away portion to show the location of the right stimulus display area (S disp. area).

showing the location of the discriminative displays as they correspond to the components illustrated in the preceding figure.

The actual dimensions of the apparatus are relatively unimportant provided the relations illustrated in the preceding figures are maintained. We have found, however, that an observation window measuring $3\frac{3}{4}$ in. wide by $3\frac{1}{2}$ in. in height and elevated some $3\frac{3}{4}$ and 5 in. from the response levers and reward-retrieval wells, respectively, is appropriate for both adolescent and adult rhesus and nemestrina macaques. It is, however, essential that the inwardly projecting frame of the observation window be set at such an angle that the monkey cannot concurrently visually sample both its hands and the stimulus displays.

The stimulus display areas measure 2 in. square and are set into the apparatus housing at a slight angle sloping toward the animal compartment. The two stimulus areas are separated by a 2-in.-W, $3\frac{1}{2}$ -in.-H divider. For the research reported here, the discriminative cues were colors provided with Industrial Electrical Engineer (IEE) rear-projection readout displays. We have also used 4 by 4 matrices of light bulbs to provide patterned displays. The apparatus could easily be adapted to front-surface or rear-surface screens for slide projection.

The monkey's visual sampling of the stimulus display areas is promoted by first requiring that the animal look through the stimulus-observation window to initiate stimulus presentation. Secondly, correct responses are rewarded by dropping banana pellets (P. J. Noyes Co.) directly onto the stimulus display area where they initially bounce and then roll down the inclined display area into the reward-retrieval well to be picked up by the monkey. This arrangement not only requires, as have some previous automated procedures (see Meyer et al, 1965), that the animal orient toward the stimulus cues in order to initiate and maintain stimulus presentation, but additionally that visual sampling of the discriminative cues be continued if optimal knowledge of results is to be obtained.

Specification of choice-response behavior is obtained under these constraints by partitioning the discrimination trial into three periods: (1) preresponse stimulus observation, (2) choice response, and (3) postresponse. The preresponse period is defined as the minimum time for which the animal must maintain an

observing response (as defined below) before the response levers are unlocked and the S can indicate a choice. The choice-response period immediately follows and represents the time during which the response levers remain unlocked and the animal has an opportunity to respond by pulling one of the levers. A completed choice response mechanically locks the opposite lever for that particular trial. This initiates the postresponse period that has a duration dependent upon the animal's postresponse observation of the stimulus cues, up to some maximum duration preset by the E. If no choice response occurs, the end of the choice-response period terminates the trial and stimulus presentation, independent of the S's observing response. The sequencing of these intratrial periods was initially designed to be programmed by a Digital Equipment Corporation Line computer³ existing within the department at North Carolina State University. But time demands placed upon the machine necessitated an alternate programming tack utilizing electromechanical plug-in timer and relay panels.⁴ While the latter method represented some sacrifice in precision (e.g., measurements in milliseconds as opposed to microseconds), the plug-in panels offer a cost advantage and permit a greater flexibility in scheduling animal test periods. With either method, the minimum preresponse stimulus-observation period and the maximum durations of the choice- and the postresponse periods, as well as the intertrial interval (ITI), are set and controlled by the E.

The animal's discriminative behavior within the above-described categories is segregated into three major response components: (1) observing, (2) anticipatory, and (3) choice, with the latter two categories each having right-position and left-position subdivisions. Observing responses (R_O) are operationally defined as the interruption of a photocell beam that is directed across the stimulus observation window parallel to the floor of the apparatus. Stimulus presentation and all other trial periods are dependent upon the monkey's initiation and maintenance of an R_O with any break in an R_O shifting the apparatus immediately into an ITI. Anticipatory responses (R_A), left and/or right, are defined as any approach toward a response lever during the preresponsive period and are recorded by two photocells mounted individually under the clear plastic floor of each food-retrieval well. These responses, however, have no effect on trial programming. Choice responses (R_C) are indicated by microswitches, activated by lever pulls of approximately $\frac{1}{4}$ in. In the present situation, not only the occurrence of a response in any of these categories, but also the time of its occurrence (or duration in the case of R_O) is recorded. This is done by having the R_O activate a pulse stream generator (10pps) and recording the number of pulses between the initiation of an R_O and the occurrence of the response event in question on all trials that contained a correct choice response. Since the discrimination procedures reported here were primarily designed to evaluate the testing methods, the above variables were not recorded for incorrect trials.

Procedure for APDA Evaluation

Following initial adaptation and shaping, the monkeys were trained on two whole-cue color problems. The first was a red-white discrimination with red serving as the positive cue for one-half of the Ss. Each S received 40 trials per day under correctional procedures. Following a criterion of 90% correct for 2 successive days, the S was switched to the second color discrimination. The second discrimination was a green-yellow problem balanced so that one-half of the red-positive Ss of Problem 1 were trained with green positive and the remaining half trained with yellow positive. The original white-positive Ss were similarly treated.

During these problems, the minimum preresponse

Fig. 4. Performance of the monkeys on the two initial color discriminations trained in APDA. The top portion represents the mean performance of seven of the eight monkeys, while the lower portion shows the performance of the monkey that required reshaping (dashed portion of the curve) during the first discrimination problem.

stimulus-observation period and the maximum postresponse period durations were set at 1 sec. Because the color problems represented the animals' initial experience with any formal discrimination training, the choice-response period was left unbounded. This eliminated the maximum limit associated with the prereponse stimulus-observation period and the stimuli remained "on" as long as the S maintained an R_0 , or until an R_c . The minimum ITI was 3 sec.

Immediately after each day's testing, the animals were fed daily food rations with the quantity dependent upon the speed and accuracy with which the individual S completed a set of 40 training trials.

Results and Discussion

Figure 4 shows the mean per cent first-choice correct responses over blocks of 40 trials for seven of the eight animals. Monkey No. 2 developed an inappropriate response mode early in the first discrimination problem that necessitated reshaping and will be considered separately. Figure 5 presents the mean times associated with each of the measured intratrial events as calculated over each discrimination problem for both first-choice-correct trials and correctional trials. The total R_0 duration has, however, been reduced to time-to-a-choice-response (R_c) and postresponse stimulus-observing duration (R_{p0}) in order to present more clearly the S's stimulus-observing behavior; in this situation, R_0 duration = (R_{p0} duration + time to R_c).

The results from Monkey No. 2 are shown in the lower portion of Fig. 4. The broken line represents several remedial shaping procedures designed to reestablish the observing response and insure that the animal responded correctly when the opportunity occurred. The significant feature of this portion of the figure is that once the appropriate choice behavior was established and the animal gained the response coordination demanded by the apparatus, learning progressed rather rapidly and the discrimination was mastered with little additional difficulty. Furthermore, the performance of this monkey on the subsequent color discrimination (similar to the seven animals not receiving remedial shaping) indicates that the difficulties experienced

Fig. 5. Bar graph illustrating the time of occurrence (or duration in the case of RPO) of the intratrial-response events that can be measured with APDA. The upper panel represents these events for Problem 1, while the lower panel presents the data obtained from the second discrimination problem. The number above each pair of bars is the probability that the difference between first-choice-correct trials (solid bars) and correctional trials (open bars) could occur by chance as determined by the Mann-Whitney U statistic. Abbreviations: ALL = anticipatory responses to the left when the correct stimulus was on the left, ALR = anticipatory responses to the left when the correct stimulus was on the right, ARL = anticipatory responses to the right when the correct stimulus was on the left, ARR = anticipatory responses to the right when the correct stimulus was on the right, RC = choice response, and RPO = postresponse stimulus observation.

during the early stages of the initial color discrimination were not inherent to either the animal or the automated apparatus. It also serves to emphasize the capacities of the rhesus when motor- and observing-response requirements are arranged in a manner suitable to the monkey.

It appears, therefore, that the APDA not only relieves the E of the drudgery of testing animals, but more importantly provides a flexible and easily manipulable method of presenting various discrimination problems without the potential S-R contiguity difficulties associated with the usual manual and automated testing procedures. The data obtained supplements the usual binary, correct-incorrect choice information by providing precise timing of the occurrence and/or duration of the following: (1) pre- and postresponse stimulus observations, both of which have their roles in the discrimination process (Dickerson & Ellis, 1965; Meyer et al, 1965; Sheridan et al, 1962), (2) approaches to the response manipulandum independent of actual choice response that may be related to intratrial decision processes, and (3) choice responses as they are related to stimulus observation.

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NOTES

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2. The authors wish to express thanks to C. A. LeVere for her help in analysis and preparation of this report.
3. Flow diagrams and preliminary software for the Linc computer are available on request from the authors.
4. Due to the flexibility of electromechanical relay and timer panels, detailed wiring diagrams are not presented. The authors' arrangement is available upon request.

The effect of pressurized air in establishing discriminative response suppression in stump-tailed macaques¹

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Pressurized air was repeatedly associated with one of two frequencies of flashing light during performance of a VI 30-sec positive reinforcement schedule by stump-tailed monkeys. As revealed by the relative suppression of bar presses to each of the two visual stimuli, the Ss learned to discriminate between the different flicker frequencies. However, they also showed signs of adapting to the airblast during the course of training, and its location had to be changed in order to maintain discriminative suppression.

Pressurized air (PA) has been shown to be an effective aversive stimulus in modifying the behavior of rats (Kaplan, 1968; Ray, 1966a, b), cats (Ray, 1966c), and squirrel monkeys (Polidora & Boyer, 1967). In the few experiments in which PA was used as an aversive stimulus, its effect was measured mainly in "active" avoidance tasks. Polidora and Boyer (1967) found that acquisition and extinction of shuttle-avoidance behavior by squirrel monkeys were more rapid with PA than with electric foot shock. They concluded that PA facilitated avoidance learning because it produced less disruptive effects than shock did early in training. However, the fact that the extinction of the response to PA was also more rapid suggests that PA was actually less aversive than foot shock and that it did not produce as strong a conditioned emotional response. Therefore, it might be expected that Ss would adapt to the repeated presentation of unavoidable PA, indicating that PA would not be an effective aversive stimulus in learning paradigms that involve repeated association of conditioned and unconditioned stimuli, e.g., conditioned suppression paradigm. In the present experiment, PA was repeatedly associated with one of two visual stimuli, and the acquisition and extinction of discrimination performance was determined by the relative suppression of responses in the presence of each stimulus.

METHOD

Two experimentally naive, adult, female stump-tailed macaques (*Macaca speciosa*), weighing 6-7 kg, were trained to bar-press for 0.5 cc of grape juice on a VI 30-sec reinforcement schedule while restrained in a primate chair. After their response rates stabilized, a strobe light, driven by a Grass Model PS-2 photostimulator, was used to present 10-sec trials at either 15 flashes/sec (CS-15) or 60 flashes/sec (CS-60). Ten trials at each frequency were randomly ordered and presented during each daily session, with an average intertrial interval of 2 min. After the Ss habituated to the visual stimuli (determined by the lack of suppression of bar presses during visual stimulation), a 1-sec period of PA at 50 lb/in.² immediately followed each CS-15 trial. The 1-sec airblast was delivered through a 15-ga hypodermic needle located 1 in. to the side of the S's head and aimed at the area behind the right ear. As the Ss adapted to the PA during the course of discrimination training, the hypodermic needle was moved to a different location 2 in. in front of the S and aimed at the nose. The relative amount of discrimination between CS-15 and CS-60 was measured by comparing the average number of bar presses during these trials with the number of presses during the 10-sec interval immediately preceding the onset of CS (pre-CS). Since bar-pressing rates during the pre-CS-15 and pre-CS-60 intervals were not different, the average number of pre-CS bar presses was obtained by combining both pre-CS conditions. Discrimination training was terminated when the number of bar presses during CS-60 reached 90% of those made during the pre-CS interval in three successive sessions. Four extinction sessions were then presented in which the airblast was removed from the CS-15 trials. CS trials, intertrial intervals, positive reinforcement, and airblasts were controlled automatically with appropriate timers, solenoids, and pulse generators. A Grass Model 5 polygraph was used to record bar presses and pre-CS and CS intervals during each session.

RESULTS AND DISCUSSION

Both Ss learned to discriminate between the 15/sec flashing