ATTENTION AND CUE-PRODUCING BEHAVIOR IN THE MONKEY[1]

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Explicit cue-producing responses were employed to study attending behavior in the monkey. The subjects learned a discrimination based on compound stimuli, a vertical bar embedded on a red ground *versus* a horizontal bar on a green ground. On some trials only one of the two stimulus components was presented (red *versus* green or vertical *versus* horizontal bar), and the animals had the option of responding on the basis of the component presented or transforming it to the compound discriminanda by means of a cue-producing response. Analysis of the choice and cue-producing response behavior showed that (a) both monkeys acquired the discrimination between the compound cues solely on the basis of the color component, (b) mastery of this discrimination did not confer any "habit loading" (discriminative control) on the bar component, and (c) the monkey may prefer to respond on the basis of one component (color) even though it is capable of using both components equally effectively.

Despite increasing interest in the role of attention in discrimination learning, little direct research has been conducted. This lack may be largely due to the absence of adequate techniques. The present paper describes a method which permits, among other things, continuous monitoring of the components of a compound stimulus to which the subject is responding and, presumably, therefore attending.

The transfer paradigm has been the chief technique used to evaluate the importance achieved by the separate components of a compound stimulus. Given a compound positive stimulus (S+) comprised of say a triangle embedded on a red ground, the contribution of each component to the solution of the problem can be evaluated by presenting each component separately after the discrimination is acquired (*e.g.*, Reynolds, 1961). The chief limitation of this approach and its variations is that the point in time at which the transfer test is made is essentially an arbitrary decision. The development of the saliency or importance of each stimulus component is thus not easily evaluated, except by a costly expenditure of subjects. The present procedure seeks to avoid this difficulty, as well as certain other limitations of the transfer paradigm, by providing from the outset the option of obtaining a missing stimulus component by means of an explicit cue-producing response. Another potential advantage of such a technique is that it might reveal preferences among stimulus dimensions, if these exist.

METHOD

Subjects

Two experimentally naive male Capuchin monkeys (*Cebus apella*), weighing about 1800 g at the start of the study, served.

Apparatus

Two Lehigh Valley Electronics monkey boxes (Model 1317) were modified by adding five Industrial Electronic Engineers, Inc. in-line stimulus projectors (Series 10,000), arranged in the pattern $\begin{smallmatrix}0&&0\\&0&\\0&&0\end{smallmatrix}$. Each projector was faced with a plastic key (Grason-Stadler, E8670A), which served as the response mechanism. Except for cue-producing responses (see below), which registered immediately, a key press had to be maintained for a minimum of 0.4 sec to be counted as a response.[2] A micro-

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[2]Because cue-producing responses tend to be depressed or even abolished when burdened by a 0.4 sec hold-down requirement, such responses were programmed to register immediately.

switch, with which the subject could initiate a trial, was centered directly below the five projectors. The standard dipper mechanism provided with this experimental chamber was located immediately under the microswitch. When required, a Foringer dispenser delivered reward pellets to a small cup situated on the right wall, 11 cm from the intelligence panel.

Programming of stimuli was accomplished by a tape block reader, described elsewhere (D'Amato, 1965).

Procedure

Preliminary discrimination. The subjects were first shaped to initiate a trial by pressing the microswitch on a fixed ratio schedule which reinforced every third response (FR 3). This illuminated (with white light) one of the five projectors; pressing the key on this projector (for a minimum of 0.4 sec) resulted in a water reward of approximately 0.5 cc for one subject (Rudy) and a 190 mgm (CIBA) banana pellet for the other (Lyn). (After an initial period of employing water deprivation as a source of motivation, the procedure was shifted to food deprivation, which seemed to produce a more stable drive state in the animals. This accounts for the different motive-incentive conditions used with the two subjects.) After each experimental session, water and food were made available to Rudy and Lyn, respectively, for a period ranging from 30 to 60 min; food was freely available for Rudy, as was water for Lyn. The subjects began each experimental session 20-24 hr after the previous feeding period.

After shaping was completed, the animals were trained on the preliminary discrimination, later used to develop cue-producing behavior. During this phase, initiating a trial produced the positive 2nd negative stimuli on (any) two of the five projectors. S+ and S— were randomly assigned to the five projectors, subject to the restriction that each stimulus occur on each key equally often. When this discrimination was learned to the criterion of 10 correct choices in succession, establishment of cue-producing responses (CPRs) was begun. (Incorrect responses were always followed by a 1-min time out.)

Initiating a trial now produced both discriminanda (on any two of the five projectors) on only 25% of the trials. On another 25%, activating the microswitch illuminated the center of the five keys with white light; pressing this key—defined to be a cue-producing response—immediately produced S+ and S— on two of the remaining four projectors.

The other 50% of the trials were critical. On half of these, initiating a trial produced S+ and illuminated the center key (cue for a CPR); the subject had the options of responding to S+ (which would be followed by reinforcement) or making a CPR and receiving S— in addition to S+. To describe the latter sequence of events in more detail, immediately upon pressing the center, white-illuminated key the stimuli disappeared from the projectors. About 0.1 sec later, S+ reappeared on the projector it had previously occupied and S— on one of the remaining three projectors. On the other half of these trials, S— and the cue for a CPR were presented together. On such trials, the subject could not possibly be correct unless it performed a CPR, which produced the missing S+. The monkeys were maintained on this program, 40 trials per day usually, until they consistently made a CPR when S— alone was presented but failed to do so when S+ appeared along with the cue for a CPR. Rudy required 195 trials to reach this criterion, and Lyn, 120 trials.

Test discrimination. The test discrimination was between two compound stimuli, S+ being a white vertical bar (17 by 1.5 mm) embedded upon a red ground and S—, a horizontal bar embedded on a green ground. Four types of trials (10 of each) comprised a training block. Initiating a trial (a) produced both compound discriminanda; (b) produced only the cue for a CPR (illumination of the center key) which, when performed, led to the appearance of the compound discriminanda; (c) produced the color component plus the cue for the CPR; or (d) produced the bar component along with the cue for a CPR. On trials of the (c) and (d) variety the subject had the option of responding on the basis of the component presented or performing the CPR and receiving the second stimulus component. One to three blocks of 40 trials were given daily, usually only a single block.

RESULTS

The results from Rudy are shown in Fig. 1. The lower panel gives the percentage of correct responses for each of the three displays the subject could respond to: the compound stimuli, the color component (red *versus* green), and the bar component (vertical versus horizontal). Although the abscissa is labeled in terms of blocks of 80 trials, the numbers of each type of trial depended upon the subject's CPR behavior. For example, on the first block of 80 trials, when confronted with the color component, Rudy made a CPR only 5% of the time (on one out of 20 opportunities). On the other hand, when faced with the bar component Rudy transformed it to compound stimuli on 45% of such trials (nine out of 20). Consequently, during the first block of trials this subject responded to the compound discriminanda on 50 of the 80 trials; responded to the color component on 19 of the 80 trials; and to the bar component on only 11 trials.

Although it is somewhat obscured in Fig. 1, Rudy's performance when responding to the compound stimuli closely paralleled performance to the color component alone. During Trials 61-80, for example, Rudy responded on 13 trials to the compound discriminanda and was correct on 12; during this same period, 7 of 9 responses to the color component were correct. On the other hand, Rudy continued responding at a chance level to the bar component long after mastering the discrimination based on the compound cues. This suggests that (a) mastery of the compound discrimination was based exclusively on the color component, and (b) little, if any, control over behavior ("habit loading") accrued to the bar component by virtue of its comprising part of the compound stimuli.

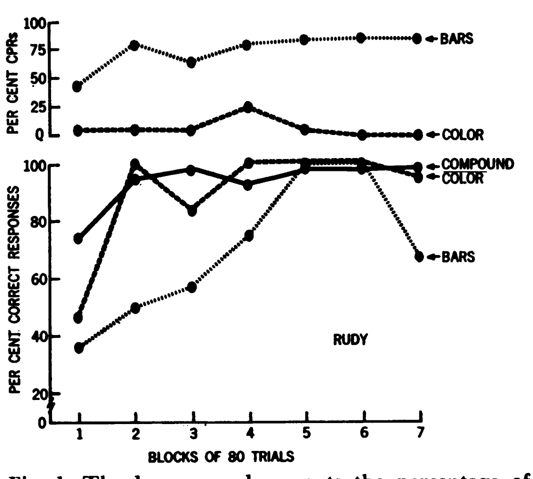

Fig. 1. The lower panel presents the percentage of correct responses for the color component (red *vs.* green), the bar component (horizontal *vs.* vertical bar) and the compound cues (vertical bar on red ground *vs.* horizontal bar on green ground). The upper panel shows the percentage of cue-producing responses (CPRs) to the color and bar components. A CPR transforms the component stimuli to compound stimuli. (See text).

Turning now to the CPR data (Fig. 1, upper panel), Rudy quickly developed a high rate of CPRs to the bar component and maintained it despite the fact that this subject eventually was able to respond correctly to the bar component. Rudy responded to the bar component on nine trials over the last three blocks of 80 trials and was correct on eight of these. Nevertheless, cue-producing behavior in the presence of the bar component remained undiminished at 85%.

The same type of behavior is evident in the results obtained from the second monkey. The lower panel of Fig. 2 shows that on the first block of 40 trials Lyn responded at a chance level to the compound stimuli and to both the color and the bar components; the same rate of CPRs was also maintained in the presence of each of the two components. Shortly thereafter Lyn began responding correctly to the color cues and simultaneously the rate of CPRs in the presence of this component dropped to zero. Behavior toward the bar component was quite different. Only 20% of responses to the bar component were correct on Blocks 2 and 3. At this point Lyn never again responded to the bar component alone, *i.e.*, rate of CPRs in the presence of the bar component leaped to 100% and remained

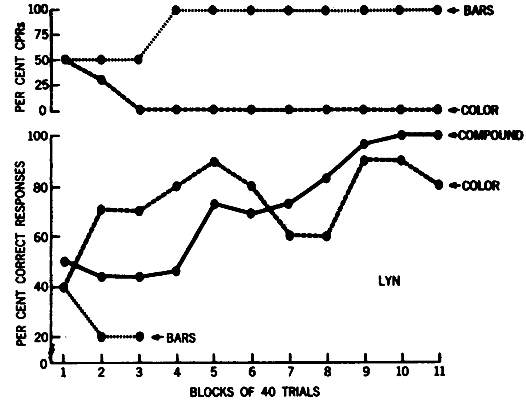

Fig. 2. Cue-producing and choice behavior obtained from Lyn. Legend of Fig. 1 applies.

there throughout this portion of the experiment.

After 440 trials, Lyn was forced to respond to the bar component by denying the option of a CPR on a portion of the trials. This was accomplished by substituting for the 10 color component trials an equal number of trials on which the bar component was presented with no provision for a CPR. Answers to two questions were sought: (1) Did Lyn learn anything about the bar component by virtue of the fact that he responded to the compound discriminanda (and hence to the bar component) on better than 320 trials, eventually mastering that discrimination? Would Lyn, as he began to master the discrimination between the horizontal and vertical bars, reduce the rate of CPRs when the option of cue-producing behavior was open?

Figure 3 shows that the answer to both of these questions was, no. When forced to respond to the bar component Lyn picked up exactly at the level at the end of Block 3 (Fig. 2), namely, at 20% correct responses. As to the second question, despite the fact that Lyn eventually was capable of responding correctly on the basis of the bar component, this subject never failed to make a CPR in the presence of this component when the option was available.

DISCUSSION

A theoretical controversy of long standing is whether the components of a compound S+ develop "habit loadings" (discriminative control) appropriate to each component's contribution to the compound stimulus, or whether the subject selects out or attends to some feature or features of the compound stimulus, ignoring all others. Under the latter hypothesis it is assumed that only those elements to which attention is directed become associated with the instrumental response (gain discriminative control). This is one form taken by the so-called continuity-noncontinuity opposing viewpoints. The present data, especially those obtained from Lyn, are more consonant with a selective attention principle. The operation of such a mechanism has been demonstrated in pigeons (Reynolds, 1961), and in human subjects learning a paired-associates task (Underwood, Ham, and Eckstrand, 1962).

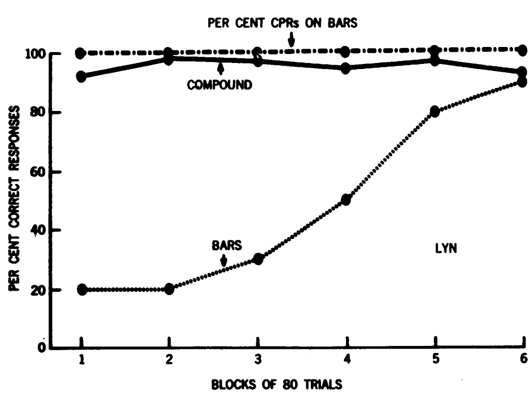

Fig. 3. Cue-producing and choice behavior obtained from Lyn when this subject was forced to respond to the bar component on 20 of each block of 80 trials. (See text).

Present results also suggest that in addition to a principle of selective attention there apparently can operate in the monkey, at least for a time, a preference structure among stimulus components which are equally informative. As already noted (Fig. 3), when the option was available Lyn never failed to perform a CPR in the presence of the bar component, even when as capable of responding correctly on the basis of the bar component as on the basis of the compound discriminanda. Had this phase of the experiment been continued, Lyn would have eventually reduced the rate of CPRs, perhaps to zero. Nevertheless, it is of some interest that this complete preference for the compound discriminanda over the bar component persisted throughout the second phase of the experiment.

The CPR technique described is closely related to the observing-response procedure investigated by Wyckoff (1952) and Kelleher (1962). In both cases the subject performs a response that provides information (in the present case, redundant information) about the reinforcement contingencies in effect. The present procedure was specifically developed for choice situations, and the information provided by a CPR can be redundant, completely reliable, or provide any degree of relevancy between these two extremes. It appears that the technique could serve usefully in a wide range of choice discrimination situations. Probe CPR trials should be of value in monitoring, during establishment of a discrimination, the stimulus elements to which the subject is responding. Such trials may also provide information about animals' preferences for various stimulus dimensions, now a totally ignored aspect of discrimination learning. It is also possible that the technique will be of value for comparative studies of discrimination learning in animals.

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