*CUE-PRODUCING BEHAVIOR IN THE CAPUCHIN
MONKEY DURING REVERSAL, EXTINCTION,
ACQUISITION, AND OVERTRAINING¹*

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In a two-choice discrimination situation, a cue-producing response produced the discriminanda for 0.05 sec. The cue-producing responses beyond those normally necessary to identify the discriminanda thus provided only redundant information. Two of the four Capuchin monkeys studied showed a large increase in cue-producing responses during reversal learning and extinction, and they reversed much faster than the two whose cue-producing responses showed little increase. During acquisition of a difficult discrimination, the cue-producing responses of the first two subjects reached a high level and during overtraining gradually reduced to their initial low level. The results were related to Wyckoff's theory of observing behavior and to the notions of uncertainty, reduction, and lack of information as extensions of the concepts of reinforcement and motivation.

Observing behavior has been investigated in a number of different contexts. In one class of experiments, the observing response, though not associated with differential "primary" reinforcement, produces information (discriminative cues) which may provide the source of reinforcement for the observing behavior. For example, the fact that a pigeon continues to peck a key when the only consequence of this action is to produce a stimulus which provides information concerning the schedule in force on a second key (*e.g.*, Hendry and Dillow, 1966; Kelleher, Riddle, and Cook, 1962), may be interpreted in terms of the conditioned reinforcement arising from the response-produced stimuli. Experiments showing that rats learn to choose the side of an E-maze which provides information concerning the availability of reward, rather than the side on which the reinforcement schedule is precisely the same but without the information cue (*e.g.*, Mitchell, Perkins, and Perkins, 1965; Prokasy, 1956), are also interpretable in terms of conditioned reinforcement. Both sets of results may be accommodated by the assumption that the conditioned reinforcement strength of a stimulus is a positively accelerated function of the (primary) reinforcement frequency with which the latter is correlated (*cf.* Kelleher *et al.*, 1962; Wyckoff, 1959).

The reinforcement for observing behavior in the vigilance situation, a second category of observing response experiments, is even

more direct: detection of the target stimulus depends upon execution of the observing response (*e.g.*, Holland, 1958).

The observing behavior investigated in the present experiment is somewhat similar to that studied in the first class of experiments. The observing response, referred to here as a cue-producing response (CPR), gave the subject a brief glimpse of the discriminanda of a two-choice discrimination problem; this may be considered to comprise the conditioned reinforcement for the cue-producing behavior. However, since on any given trial the information provided by each CPR was identical, additional responses beyond those normally required to identify the discriminanda provided only redundant information. The primary interest was to assess the effects of reversal learning and extinction on cue-producing behavior in this situation. In contrast to previous studies of observing behavior, most of the present investigation occurred in the context of two or more discriminations maintained concurrently.

After much of the present data was collected, a paper describing a similar technique with human subjects was published by Premack and Collier (1966).

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METHOD

Subjects

Three male and one female (Dixie) Capuchin monkeys (*Cebus apella*) with comparable past experimental experience served. Throughout the experiment, deprivation level was maintained by feeding each subject a quantity of Purina monkey chow approximately equal to 4% of its body weight. The ration became available 30 min after each daily session and any food remaining 1 hr later was removed. If a subject failed to work during an experimental session, the feeding period was reduced to 30 min. This schedule maintained the animals at 90 to 95% of their free-feeding weight.

Apparatus

Two Lehigh Valley Electronics monkey boxes (Model 1317) were modified by adding five Industrial Electronic Engineers, Inc. inline stimulus projectors (Series 10,000) arranged in the following pattern:

o o
o o

Each projector was faced with a plastic key (Grason-Stadler, E8670A) which served as the response mechanism. Except for cue-producing responses, which registered immediately, a key-press had to be maintained for a minimum of 0.4 sec to be counted as a response or to be recorded. The latter requirement is desirable because it allows the subjects a brief interval in which to rectify occasional errors due to "hasty" responding. A microswitch, with which the subject could initiate a trial, was centered directly below the five projectors. Reinforcers (CIBA 190-mg banana pellets) were delivered to a small cup situated on the right wall 11 cm from the stimulus panel.

Programming of stimuli was accomplished by a tape block reader described previously (D'Amato, 1965). Except where indicated otherwise the form stimuli appeared as white figures on black backgrounds. All forms but the dot were composed of lines approximately 1.5-mm thick; their overall height (and width) was 17 mm.

Procedure

Preliminary discrimination training. All subjects were first trained on a conditional

discrimination in which color comprised the conditional cue and a circle and an inverted triangle served as the differential stimuli. When the backgrounds of the figures were red, responses to the circle were reinforced (S+) but those to the inverted triangle were not (S-); when the backgrounds were green this relationship was reversed. After reaching a criterion of at least 85% correct responses, subjects were trained on a "simple" discrimination, a small (7-mm) dot of light serving as S+ and a vertical line as S-. Upon reaching criterion on the latter task, subjects were trained on a "complex" discrimination comprised of an S+ formed by superimposing the same vertical line together with an inverted triangle and a square, and an S- formed by superimposing a plus sign on a circle. Twenty trials per day were given during this phase.

To initiate a trial the subject pressed the microswitch on a schedule which reinforced every fifth response (FR 5); when this schedule was completed, the discriminanda appeared on two of the five projectors. Assignment of S+ and S- was balanced over the five projectors. A correct response was reinforced but an incorrect response (responding to S-) resulted in a 60-sec timeout. Pressing an unlit key had no effect.

Shaping of cue-producing behavior. Upon reaching criterion on the complex discrimination the subjects were given all three discriminations concurrently, usually 60 trials a day, 20 on each of the three discriminations randomly interspersed. Completing the FR schedule on the microswitch now resulted in a white light appearing on the center projector. Pressing the center key, which defined a CPR, immediately produced the discriminanda on two of the remaining four keys for a period of 1.0 sec. The subject was free to make any number of CPRs before making the choice response. Location of the discriminanda remained fixed during any given trial. Thus, if S+ was assigned to the upper left key and S- to the upper right, the discriminanda became visible in these locations for 1 sec each time that the subject executed a CPR.

In order for a choice response to register, it was not necessary for the subject to respond during the time that the discriminanda were visible. Indeed, the subject could register a choice without making any CPRs at all,

merely by completing the FR 5 and then pressing the unlit keys until it pressed the key to which either S+ or S- was assigned. Such behavior, which was infrequent (less than 1% of the trials), produced a pellet on 50% of the trials.

All subjects were run with the duration of the response-produced stimuli set at 1.0 sec until they achieved a criterion of at least 85% correct responses on all three discriminations during a single day's trials. Upon reaching this criterion the duration was reduced first to 0.75 sec and then reduced to 0.50 sec as this same criterion was met successively.

At this point the subjects were brought down to the final discriminanda duration, 0.05 sec, in a somewhat different fashion, depending upon their performance. At the shorter durations some subjects were unable to maintain a high level of proficiency on the conditional discrimination, so that with respect to this task the earlier criterion had to be abandoned. By the end of this phase, however, all subjects had reached a criterion of at least 90% correct responses on the simple and complex discriminations. The total number of trials received at the completion of the "shaping" phase was 2400, 1560, 2460, and 2460, for Coco, Dagwood, Dixie, and Peanuts, respectively.

The discriminanda durations are specified in terms of the time intervals during which power was applied to the appropriate light bulbs of the stimulus projectors. Except where indicated otherwise, the 0.05-sec duration, which is the shortest value recommended by the manufacturer, was used during the remainder of the experiment.

Reversal learning. During this phase, one discrimination at a time was reversed; first the simple discrimination, followed by the complex, and finally the conditional discrimination. During reversal of the simple discrimination, trials were given concurrently on the complex and conditional discriminations with reinforcement contingencies, as they were during acquisition. Similarly during reversal of the complex discrimination, the reinforcement contingency for the conditional discrimination remained as it was during acquisition, though, of course, the contingency for the simple discrimination continued to be that of reversal learning. Finally, during re-

versal of the conditional discrimination, the reinforcement contingency for both the simple and the complex discrimination were those of reversal also.

Unfortunately, this plan could be followed only for Coco and Dagwood; the other two subjects failed to master the initial reversal task within a reasonable time. As during the previous phase of the experiment, 60 trials were given in each daily session, 20 on each discrimination problem.

Extinction of the simple and complex discriminations. After the reversal phase was completed, Coco was given 15 sessions of extinction on the simple discrimination during which neither stimulus was reinforced. During this portion, only 40 trials per day were given, 20 on the simple discrimination, and 20 on the complex. The conditional discrimination was dropped because Coco failed to reach a high level of reversal performance on this task. At the end of the 15 sessions, the reinforcement contingency on the simple discrimination was reinstated for three days, as it had been during reversal. On the fourth day, extinction of the complex discrimination commenced and lasted for 12 sessions. Dagwood received much the same training, except that extinction of the complex discrimination occurred first and, since this subject had achieved a high level of performance on reversal of the conditional discrimination, the latter was maintained during all extinction sessions. Thus, this subject received 60 trials per day.

Acquisition and overtraining on a difficult discrimination. Approximately seven weeks after the above phases were completed, Coco and Dagwood were returned to the experimental situation and trained on a discrimination between an upright and an inverted triangle. They received 40 trials per day for a total of 28 days, during which the discriminanda duration produced by a CPR was fixed at 0.10 sec.

RESULTS

Reversal performance. Figure 1 presents the reversal performance of the four subjects on the simple discrimination. On the left side of each of the four graphs the mean number of CPRs per trial is shown separately for the three types of discrimination problems over

three or four prereversal sessions. Note that for Coco and Dagwood the abscissa is marked in terms of single sessions (20 trials per discrimination), while for Dixie and Peanuts, the units are in terms of two days (40 trials per discrimination). Also shown in the figure is the per cent correct responses on the simple discrimination during the prereversal and reversal sessions. Since there was little or no interaction between a subject's choice performance on a discrimination undergoing manipulation, reversal or extinction, and its performance on the remaining discrimination tasks, the latter data are not included in the graphs.

Several aspects of the results stand out clearly. First, despite comparable levels across the four subjects in per cent correct responses and mean numbers of CPRs during the prereversal days, there is a striking difference in both of these measures during the reversal phase. Coco and Dagwood show a precipitate increase in the CPRs which produced the stimuli of the simple discrimination; moreover, this increase is selective in that it generalized little to the CPR behavior shown toward the complex and conditional discrim-

inations. Associated with this rapid increase in CPRs is a relatively steep reversal learning curve. Both of these subjects achieved reversal criterion (90% correct) within five or six days of training.

In contrast, during reversal training Dixie and Peanuts showed only a small and rather gradual increase in the number of CPRs on the simple discrimination, and they failed to achieve reversal criterion by the end of 22 days of training. Because of their poor performance these two subjects were not (except as noted below) included in further phases of the experiment.

In Fig. 2 the same type of data, obtained from Coco and Dagwood, are presented for reversal of the complex discrimination. Again the same general pattern of results is evident, particularly in the case of Dagwood. There is a rapid rise in the number of CPRs made to the discrimination which is undergoing reversal, an increase that is for the most part restricted to that particular task. Coco was placed on this reversal immediately after achieving criterion on the reversal of the simple discrimination; hence, only one prereversal day is available for this subject.

Fig. 1. Choice and CPR behavior during reversal of the simple discrimination. Although the subjects received equal numbers of trials on the complex and conditional discriminations during this phase (20 trials each per day), their choice performance is shown only for the simple discrimination. In the case of Peanuts and Dixie the units of the abscissa are blocks of two days.

Fig. 2. Choice and CPR behavior during reversal of the complex discrimination. Choice behavior is shown only for the latter task although the subjects received equal numbers of trials on the (reversed) simple and conditional discriminations.

In an effort to obtain further reversal learning data from Dixie, the conditional discrimination was dropped from the experiment after 22 training sessions (Fig. 1), and reversal training on the simple discrimination continued. Finally, after 10 additional sessions, this subject reached the reversal criterion and was then given reversal training on the complex discrimination. In spite of the fact that prereversal performance on the complex discrimination was quite high, Dixie failed to show a significant increase in CPRs during reversal. As may be seen by comparing Fig. 3 with Fig. 2, Dixie required much more training than either Coco or Dagwood to acquire this reversal.

Dagwood was the only subject that managed a consistently high level of performance on the conditional discrimination with the 0.5-sec exposure duration. During reversal of the conditional discrimination (Fig. 4) this subject once more showed a rapid and selective increase in the number of CPRs executed

Fig. 3. CPR and choice performance during reversal of the complex discrimination. The conditional discrimination was dropped during this reversal series. The units on the abscissa are blocks of two days. On each day Dixie received 20 trials on the (reversed) simple discrimination and 20 on the complex; choice performance is shown only for the latter.

on conditional discrimination trials; accompanying this increase was a rather steep increase in the percentage of correct responses. Coco, on the other hand, never achieved more than 75% correct responses on the conditional discrimination with the 0.05-sec duration. Still, during reversal of this discrimination Coco's CPRs showed the usual increase and only slowly declined to their prereversal level; performance during reversal also failed to exceed the 75% level.

Performance during extinction. In spite of the marked increase in the numbers of CPRs which occurred during reversal training (Coco and Dagwood) ultimately, as the subject achieved complete or partial mastery of the reversal task, CPR behavior returned to its prereversal level. The question arises as to whether CPR behavior would be maintained at an elevated level if no solution were possible, *i.e.*, if both alternatives (of one discrimination task) were associated with extinction. Figure 5 presents the extinction results for Coco and Dagwood. Included in the figure are the CPRs to each discrimination (the conditional discrimination was dropped for Coco), and, for the discrimination undergo-

Fig. 4. CPR and choice performance during reversal of the conditional discrimination. The choice behavior on the simple and complex discrimination is not shown. During each daily session the subjects received 20 trials on each of the three (reversed) discriminations.

ing extinction, the percentage of choices of the former S+.

Coco was extinguished on the simple discrimination first and on the complex second, while the sequence was reversed for Dagwood. Note from the figure that both animals showed a marked elevation in CPRs during the first extinction series, which persisted over the 15 extinction days. During the second extinction series CPRs again increased, although in this case the elevation was not as long-lasting as during the first extinction series.

Acquisition and overtraining on the difficult discrimination. The purpose of this phase was to investigate the course of CPRs during the development of a rather difficult discrimination and overtraining. This phase was conducted last, since Dagwood and Coco by this time had had extensive experience in performing CPRs; therefore any systematic change in CPR behavior during overtraining was not likely to be a result of their becoming

more efficient in the mechanics of executing a CPR.

Figure 6, which presents the acquisition and overtraining data in blocks of two sessions (80 trials), shows a pattern similar to that observed during reversal. The mean number of CPRs per trial increases rather rapidly during the acquisition phase, reaching a maximum somewhere in the neighborhood of criterion (90% correct). With overtraining, the number of CPRs gradually diminishes to its initial, low level.

DISCUSSION

Turning to the overtraining experiment first, the increase in CPRs during the acquisition phase is in accord with Wyckoff's (1952) hypothesis that observing behavior "will increase (or remain high) under conditions of differential reinforcement." The decrease in CPRs to initial levels brought about by overtraining seems, however, to be at odds with this assumption. The discrepancy may be more apparent than real. In most simultaneous discrimination learning situations, the present one included, there is a contingency operating that discourages superfluous observing responses; namely, reinforcement is directly contingent upon the cessation of observing behavior. If it is assumed that subjects become, with increased training, more efficient at distinguishing between a pair of stimuli, the previous contingency should serve to depress cue-producing behavior to the minimal level consistent with accurate performance. Perhaps it should be pointed out that it is possible to devise simultaneous discrimination tasks in which the contingency between reinforcement and cessation of observing behavior is much attenuated (*e.g.*, Zeigler and Wyckoff, 1961), and it is an interesting question whether under such conditions a similar reduction in observing responses would accompany overtraining.

There are three remaining features of the present data that merit discussion: the sharp differences in CPR behavior displayed by different subjects, in contrast to a fair amount of intrasubject consistency; the association of rapid reversal learning with a pronounced increase in CPR behavior toward the discrimination undergoing reversal; and the question of how to interpret the increases in cue-pro-

Fig. 5. Extinction of the simple and complex discriminations. The number in each panel indicates the order of extinction. A brief reconditioning period on the first-extinguished task intervened between the first and second extinction series. The reinforcement contingencies for the concurrent discriminations not undergoing extinction were those of reversal learning. Choice performance is shown only for the task undergoing extinction.

ducing behavior observed during various phases of the experiment.

Turning to the first point, the considerable intersubject variability in CPR behavior during reversal of the simple discrimination is evident from Fig. 1. Consistency within subjects may be seen for Coco and Dagwood in Fig. 1, 2, 4, 5, and 6. Throughout these different phases, the CPR behavior of both subjects remained sensitive to the experimental conditions. Further evidence for intrasubject consistency in CPR behavior is provided by the data of Fig. 3. During reversal of the complex discrimination, Dixie again showed only a relatively small, and gradual, increase in CPRs. The present data suggest, then, that there are consistent individual differences in the extent to which changes in reinforcement contingencies, and related operations, elicit observing behavior. In the present instance there is nothing in the past experimental history of the subjects to which the individual differences can be attributed.

The correspondence between speed of reversal learning and augmentation of CPRs is

substantial, as shown by Fig. 1, 2, and 3. However, it is not perfect, inasmuch as Coco, whose increment in CPR behavior was generally less than that of Dagwood, showed somewhat faster reversal learning on the simple and complex discrimination tasks. Moreover, Coco achieved criterion on the difficult discrimination a bit faster than Dagwood, though again, the former's CPR behavior was less extensive. From the prereversal data of Fig. 1 it is apparent that Coco and Dagwood required approximately two CPRs on the average to locate and identify, with almost perfect accuracy, the discriminanda of the simple discrimination task. Consequently the additional CPRs executed during reversal of this discrimination (three to five times that of prereversal) could not have provided the subject with relevant information; in other words, the additional CPRs produced only redundant information. In view of this fact it is difficult to fathom the connection between increases in observing behavior and speed of reversal, though obviously the relationship cannot be one of "cause and effect".

Fig. 6. CPR and choice performance during acquisition and overtraining on a difficult discrimination. Each CPR produced the discriminanda for 0.10 sec.

This question takes us to the last point, namely, how one is to account for the increased CPR behavior during reversal and extinction, as well as the selectivity of the augmented cue-producing behavior. The first point to be noted is that the CPR behavior observed during reversal learning is in direct opposition to Wyckoff's (1952) prediction that when a well-established discrimination is reversed the probability of an observing response "will decrease temporarily and then return to a high value" (p. 436). There is no indication of a decrease of CPRs in any of the reversal data (*cf.* Premack and Collier, 1966).

Moreover, in some cases increases in CPRs preceded noticeable improvement in reversal learning (Fig. 1, 2, and 4). Zeigler and Wyckoff (1961), working with pigeons, also obtained the latter relationship during acquisition of a simultaneous discrimination. They provisionally attributed their result to an assumed preference of the subjects for one or the other of the discriminanda, which pre-

sumably served as the reinforcement for the observing behavior. The rather prolonged prereversal experience and the stable prereversal CPR behavior would seem to preclude making such an interpretation for the present data.

The CPR behavior obtained during extinction (Fig. 5) is not in accord with the assumption that the probability of an observing response "will decrease (or remain low) under conditions of non-differential reinforcement" (Wyckoff, 1952, p. 435). In all cases, non-differential reinforcement (extinction) had the effect of elevating CPRs; moreover, this elevation persisted for quite some time.

Inasmuch as the increases in CPRs that occurred during reversal and extinction appear to be the result of the nonreinforcement encountered during these phases, the relevance of frustration theory (*e.g.*, Amsel, 1962) for the present data requires consideration. It does not appear, however, that the theory can accommodate the pattern of obtained results. If the increase in CPR behavior were being generated by the frustration induced by nonreinforcement, the degree of selectivity repeatedly observed would not be expected. Moreover, since frustration should develop *after* completion of a (nonrewarded) reversal or extinction trial, increases in CPRs should be more likely for the discriminations not undergoing reversal (or extinction).

Certain recent developments in perceptual learning theory make use of concepts which are perhaps more in keeping with the present data. There has been increasing interest in recent years in perceptual learning as distinct from "response" or "instrumental" learning. While the theoretical ramifications of this distinction cannot be discussed here (*cf.* Gibson and Gibson, 1955; Gibson, 1966; Tighe and Tighe, 1966), a pivotal issue has concerned the source of reinforcement for perceptual learning, which some feel is quite different from the externally manipulated rewards usually involved in instrumental learning. One view is that perceptual activities are reinforced by uncertainty reduction, *i.e.*, by the information provided by veridical perception of the environment. This kind of interpretation can accommodate the experiments in which an observing response serves to transform a schedule from a less predictable to a more predictable one, for example, from a

mixed to a multiple schedule (*e.g.*, Kelleher *et al.*, 1962) or a tandem to a chain (*e.g.*, Hendry and Dillow, 1966).

However, the present task is to account for the augmentation of CPR behavior rather than its maintenance, and moreover, augmentation that provides only redundant information. In different terms, the problem is one of accounting for the motivation of the observing behavior rather than its reinforcement. Various writers concerned with perception and related activities have assumed that one source of motivation for exploratory perceptual behavior (*e.g.*, observing responses) arises from a lack of information. For example, according to Berlyne (1966), "when an animal is disturbed by a lack of information, and thus left a prey to uncertainty and conflict, it is likely to resort to . . . exploratory responses," which "supply or intensify stimulation from particular sources" (p. 26). Applied to the present case, the increase in CPRs during reversal, extinction, and acquisition would be interpreted as a "search" for information to resolve the uncertainty which non-reinforcement in the first two cases, and inconsistent (to the subject) reinforcement in the last, occasions. This hypothesis accounts for the parallel observation that, during initial reversal training trials, human subjects increased the duration of their viewing of the discriminanda (Premack and Collier, 1966). It can also accommodate the recent finding of Hendry and Coulbourn (1967) that a pigeon pecked a key at a substantial rate to obtain a stimulus which, although it had information value, was neither a discriminative stimulus nor associated closely in time with positive reinforcement.

Although still rather vague and imprecise in their present applications, the notions of uncertainty reduction and lack of information appear to offer promise as extensions of the concepts of reinforcement and motivation respectively.

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