MAINTENANCE OF BEHAVIOR CONTROLLING THE DURATION OF DISCRIMINATIVE STIMULI¹

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The maintenance of a response controlling the duration of positive and negative discriminative stimuli in a multiple schedule was examined with respect to the possible consequences of the response: none, escape from the negative stimulus, production of the positive stimulus, and initiation of the reinforcement schedule associated with the latter. The last two seemed to be the major factors in producing and maintaining the response. Escape from the negative stimulus maintained it in most subjects, but only at a much lower level.

Key words: discriminative stimuli, concurrent schedules, multiple schedules, change-over responses, pigeons

A number of procedures have been devised in which pigeons can exercise some control over a discrimination program. The subject pecks at a food key to procure primary reinforcement. Two or more reinforcement schedules are available, each correlated with a distinctive stimulus. Responses to a second key permit at least partial control over the schedules on the food key and the stimuli associated with them. Various procedures have differed in detail. Findley (1958) added a "change-over" key, which he called a "switching key", to concurrent schedules. Instead of switching between two different food keys at different locations, the pigeon made an explicit changeover response to alternate between the schedules available on the food key. In this procedure, the effective component was entirely under the subject's control, since no changeovers were arranged in the absence of a switching response. This procedure has been used extensively in the study of the distribution of time and responses among schedules.

Findley (1962) also introduced a "switching key" with a similar function into a multiple-schedule procedure. Fixed-ratio schedules alternated with differential reinforcement for a low rate of responding. The pigeon could switch from one to the other schedule after the first reinforcement was obtained in either com-

ponent, but the schedule switched automatically after a maximum number of reinforcements was obtained in that component.

Honig, Beale, Seraganian, Lander, and Muir (1972) added yet another term and another method with their "advance procedure". This was originally designed to facilitate acquisition of a conceptual discrimination, in which a large number of specific positive and negative stimuli were successively presented by a slide projector. The pigeon was able to advance the projector to the next stimulus, and thus enter into the next trial. Trials were of limited duration, and in the absence of an advance response, the program advanced to the next trial automatically. Positive and negative trials occurred in random order, so that an advance response did not entail a change-over, which occurred on only half the trials.

We use the term "control-key" procedures to describe, in a general and neutral way, these and other related methods (see especially Baum and Rachlin, 1969). Such procedures provide a sensitive method for analyzing preference (Catania, 1966; Herrnstein, 1970), and they facilitate the acquisition of discriminative performance. For example, when a multiple schedule is in effect with variable-interval (VI) and extinction (EXT) components, the addition of the control-key contingency reduces the time spent in EXT and the number of responses to S- (Honig *et al.*, 1972).

Within this context, the control-key response can itself be interpreted as a discriminated operant, as Findley originally recognized. The pigeon learns rapidly to make it primarily in the presence of S-, which produces S+ if the

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components alternate, but not in the presence of S+, which would produce S-. The general conditions that support control-key responding are reasonably well understood. The primary reinforcement contingencies must differ in some significant way for the pigeon, with respect to frequency, amount, or delay of reinforcement, or the response requirements to obtain reinforcement (Honig and Lindsay, 1975). But the specific effects of the control-key response that maintain the behavior are not well understood. Normally, a response emitted appropriately in the presence of S- has a number of confounded consequences: (1) It terminates S-. (2) It initiates S+. (3) It activates the reinforcement schedule associated with S+. (4) It increases the density of reinforcement in the experimental session by reducing time in S-. Finally, it is possible that the response is not maintained by its scheduled consequences, but that it can be classified as a "displacement" or "interim" activity in the absence of reinforcement. Aside from some preliminary studies carried out by Muir and reported in Honig *et al.* (1972), these various consequences have not been sorted out within a common experimental framework. The present experiment sought to do so.

We systematically eliminated several of the possible consequences of the control-key response to determine which was most important in maintaining the behavior. In the absence of such responses, S+ and S-, which alternated on a regular basis, were presented for 1-min trials. Control-key responses did not terminate the trial in which they occurred, but they produced one or more consequences for the remainder of that trial. The consequences are described here with reference to a control-key response in S-, since that is the condition in which the vast majority of such responses occurred.

(1) A response terminated S-, produced S+, and initiated the positive reinforcement schedule. This was the Full Control Procedure (FCP).

(2) A response terminated S-, produced S+, but extinction remained in effect for the balance of the trial. This was the Stimulus Change (SC) condition.

(3) A response darkened the stimulus key (and made it ineffective) for the remainder of the trial. This was the Timeout (TO) condition.

(4) A response had no scheduled consequences. This was the Displacement Activity Control (DAC).

With certain exceptions, noted below, symmetrical consequences were scheduled for control-key responses that occurred in S+. While we could eliminate several consequences of the control responses, we could not manipulate each of them independently. For example, the response could not produce S+ without also removing S-, at least not when these stimuli were presented at the same location on the food key. Furthermore, we could not have the pigeon initiate the positive reinforcement schedule without the stimulus change from S- to S+, since this would have interfered with the discrimination itself, where S- is a reliable cue for extinction.

METHOD

Subjects

Seven experimentally naive, adult, male White Carneaux pigeons were maintained at 80% of their free-feeding weights. Water and grit were continuously available in their individual home cages, which were housed in a room illuminated from 6:00 a.m. to 11:00 p.m. Sessions were conducted during the afternoon.

Apparatus

The experimental chamber was housed in a sound-attenuating box. Two of its three keys were used. The food key, 2.5 cm in diameter, was centered on the front wall, 8.5 cm over the upper opening of the food magazine. The control key was located at the same height, 10 cm to the left of the food key. The keys were illuminated by in-line digital display units, which provided the only illumination in the chamber except during reinforcement, when a light over the magazine was on and both keylights were off. The reinforcement consisted of 4-sec access to mixed grain. An exhaust fan provided some masking noise. Scheduling and recording were carried out automatically by equipment housed in an adjoining room.

Procedure

Following autoshaping of a key peck and gradual introduction of variable-interval (VI) reinforcement using a white stimulus on the center key, all subjects were placed on a multiple schedule. Reinforcement was delivered at varying intervals averaging 1 min (VI 1-min)

in one component, which alternated with extinction in the other. The VI 1-min component was correlated with a vertical white line on a blue (501 nm) ground displayed on the center key (S+). The extinction component was correlated with a white line at 30° to the vertical on a green (555 nm) ground (S-). The stimuli were presented alternately, S+ always being presented in the first period on each session. Each stimulus terminated automatically after 1 min in the absence of a control response. Sessions terminated after the thirtieth reinforcement.

The left key provided the various control functions and was illuminated with white light at all times except during reinforcement. Responses to it had the following consequences in the various conditions: in the Displacement Activity Control (DAC), there were no scheduled consequences. In the timeout (TO) condition, both keys were darkened and ineffective for the remainder of the 1-min period. In the stimulus change (SC) condition, control responses in S- changed the food-key stimulus to S+, but the bird remained in extinction until the end of the period. Responses in S+ changed the food-key stimulus to S- and halted the reinforcement program. Thus, the effects of control responses were not symmetrical in this condition. In the Full Control Procedure (FCP), control responses effectively switched between the components of the multiple schedule. Responses in S- produced S+ and initiated the VI schedule, while responses in S+ produced S- and terminated the VI schedule for the rest of the period. The control key was illuminated under all conditions except the positive component in TO.

Control-key responses did not affect the period timer, so that the effects of such responses were imposed upon the balance of the period in which they were made. If the pigeon made more than one control-key response in the SC condition or the FCP, each reversed the changes brought about by the previous response in that period. However, in the DAC such repetitive responses were ineffective anyway, and in TO, the control key was turned off for the rest of the period after a TO response.

Four groups were studied, primarily to compare the consequent events in TO, SC, and FCP in maintaining control-key responding. The seven subjects had various conditions as follows: Birds 77 and 78 first received 20

sessions in the SC condition, then 32 sessions in the TO condition, and finally 10 sessions with the FCP. Birds 50 and 51 received 28 sessions in the TO condition, followed by 10 sessions in the SC condition. Two further birds, 48 and 49, were studied to examine control-key responding with no scheduled consequences. Bird 48 had six sessions of the DAC procedure, followed by 14 sessions on the FCP. Bird 49 was similar, but with 28 sessions in the DAC condition. Bird 42 had 16 sessions with the FCP only, in order to examine the acquisition of control-key responding in that condition without any preceding treatments.

RESULTS

Control-key behavior is presented in terms of two measures. A discrimination ratio, $DR(T)$, was based on the proportion of total session time spent in the presence of S+, or in the presence of S+ and TO when the TO procedure was in effect. Since the pigeon could not alter the stimuli in the DAC condition, the rate of responding to the control key was also computed to permit a comparison of DAC with the other conditions. This measure is, in effect, the reciprocal latency of the control-key response, since the birds seldom made more than one response in a period. These two measures were closely related and there were no important discrepancies between them. Control-key responses in S+ were minimal at all times and are not presented.

Figure 1 depicts the advance performance of Birds 77 and 78. Three distinct levels of control-key performance can be seen. The FCP produced a high rate in S-. Consequently, much more time was spent in S+ than in S-, with $DR(T)$ s above 0.80. The SC condition produced an intermediate level of advance performance, $DR(T)$ being between 0.65 and 0.85. In the TO condition, Bird 77 did not make a TO response after the sixteenth session, and the $DR(T)$ was 0.50. Bird 78, however, maintained a low level of responding throughout all 30 sessions.

Figure 2 depicts advance performance of Birds 48, 49, and 42. In the DAC condition, Bird 48 at once stopped responding on the control key and was shifted to the FCP after six sessions. Bird 49 maintained a low level of control-key responding for several sessions before meeting the extinction criterion of three con-

Fig. 1. Control-key performance from Birds 77 and 78. Panel *a* shows the discrimination ratio, DR(T), based on the proportion of the total session time spent in S+. Panel *b* shows the rate of control-key responding. SC = Stimulus Change condition. TO = Timeout condition. FCP = Full Control Procedure.

secutive sessions without a response. Both birds rapidly increased their control-key performance when the FCP was introduced, reaching an asymptotic level of about 0.90. The data from Bird 42, which received only the FCP, are

also presented in Figure 2. The results are very similar to those obtained from the other subjects in that condition.

Figure 3 shows advance performance of Birds 50 and 51. They maintained TO behav-

Fig. 2. Control-key performance from Birds 48, 49, and 42. Panel *a* shows the discrimination ratio from the Full Control Procedure (FCP). It is not shown for the Displacement Activity Control (DAC), where it is necessarily 0.50. Panel *b* shows the rate of control-key responding. Bird 42 was studied only in the FCP, with no preceding treatments.

ior at a low but non-zero level for all 28 sessions. When SC was introduced, advance performance increased but never reached the level attained by Birds 77 and 78 when they were in the SC condition.

Table 1 presents stabilized data with respect to control-key responding, averaged over the

last six sessions of each condition except the DAC. The DAC data are not presented because the discrimination ratios were necessarily 0.50, and response rate on the control key was zero when this condition was terminated for both subjects. The values obtained under each condition are generally in good agreement

Fig. 3. Control-key performance from Birds 50 and 51. Panel *a* shows the discrimination ratio, while panel *b* shows the rate of control-key responding. TO = Timeout condition. SC = Stimulus Change condition.

among the various subjects. The main exception is that the SC condition was less effective in maintaining responses after long exposure to the TO condition (Birds 50 and 51) than

when it was presented first (Birds 77 and 78). However, the values from all four subjects fell between those obtained from the TO and the FCP.

Table 1

Performance baselines in terms of discrimination ratio (DR) and control-key response rate (CKR/min) FCP = Full Control Procedure. SC = Stimulus Change condition. TO = Timeout condition.

Condition	Subject						
	77	78	48	49	50	51	42
FCP							
DR	0.90	0.89	0.92	0.91			0.92
CKR/min	10.40	8.52	17.64	18.66			11.38
SC							
DR	0.79	0.82			0.62	0.70	
CKR/min	3.54	4.30			1.00	2.52	
TO							
DR	0.50	0.55			0.52	0.51	
CKR/min	0	0.36			0.10	0.08	

DISCUSSION

The data indicate that all of the postulated reinforcing consequences of responding to the control key can be effective in producing and maintaining this behavior. The DAC condition did not support the same behavior, however, and we can conclude that there were no intrinsically reinforcing features in the emission of this response. Behavior in the TO condition, while maintained by three of four birds, was emitted at a low level. Response rates decreased for all subjects after this procedure was introduced, in contrast to the other procedures, where it was maintained or increased. These results agree with those obtained by Rilling, Askew, Ahlskog, and Kramer (1969), by Terrace (1971), and by Seraganian in a preliminary experiment reported by Honig *et al.* (1972). In all of these studies, only one pigeon, our number 77, stopped responding to obtain TO.

There is some question in any case whether termination of S— in TO was maintained by the negative reinforcement of “escape” from S—. In a recent analysis of the maintenance of such behavior, von Sturmer, Beale, and Davison (1975) found that when pigeons had been trained to terminate S— by pecking a control key, the response was maintained at an appreciable level even when S— was not presented during the extinction period. The only consequence of a peck on the control key in that condition was termination of the stimulus on it. When even this consequence was removed, responding to the control key stopped. One

possible conclusion from that study is that termination of S— is supported not by “escape”, but by stimulus change—either the darkening of the control key, or of the food key, or both. In our work, termination of S— and of the control-key stimulus were confounded, so that the separate effects of these changes could not be evaluated. In any case, the asymptotic level of performance supported by termination of S— (and of the control-key stimulus) was low. It seems unlikely that these consequences, be they interpreted as escape from S— or as stimulus change, played an important part in the maintenance of control-key responding in the FCP.

The SC condition produced much higher levels of control-key behavior than did TO, and the production of S+ may therefore be considered of paramount importance in maintaining advance response. However, initiation of the reinforcement schedule after a control-key response in the FCP also plays some part, since the asymptotic values are all higher from the FCP than from SC. Three factors related to initiation of the reinforcement schedule could be responsible for this difference: (1) The onset of the reinforcement schedule follows a control-key response immediately in the FCP, but it is delayed in the SC condition until the end of the scheduled negative period. The average time to the first reinforcement after the onset of S+ will thus be longer in SC, and this difference is directly related to the efficiency of responding to the control key in that condition. (2) Control-key responses in SC decrease the reinforcement density in S+ because the reinforcement schedule is not initiated immediately. The effective schedule will lie between VI 1-min if there are no responses to the control key, and VI 2-min with maximally efficient responding. This may make S+ less reinforcing in the SC condition than in the FCP, where S+ is invariably correlated with a VI 1-min schedule. (3) Control-key responses in SC do not affect overall reinforcement density, which remains constant throughout the session. However, in the FCP, efficient use of the control key will increase the sessional reinforcement density.

It is difficult to sort out these three possibilities conclusively; in particular, it is not clear how one could equate sessional reinforcement densities between these two procedures without destroying the difference of interest be-

tween them. One could, however, arrive at some conclusion regarding the first and second alternatives by a procedure in which a control-key response in S- initiates the reinforcement schedule immediately, as in the FCP, but only for 1 min. No reinforcement would be available for a span of time equal to the balance of the trial in which the control-key response is made, but this span would be located at the end of the next "regular" positive period. If delaying initiation of the reinforcement schedule is critical in producing the difference under discussion, then this proposed procedure should maintain control-key responding better than does SC, even though such a superior performance will actually result in a lower density of reinforcement in S+. On the other hand, if the latter factor is critical, the proposed procedure should lead to control-key responding at the same level as that obtained with SC.

At the outset, we suggested that a response controlling a stimulus situation that in turn determines the emission of other instrumental behavior—in our case the food response—is governed by the general principles of instrumental learning. The present results certainly support such a view. Such behavior comes readily under stimulus control, and it is very sensitive to its consequences. The production of S+ appears to be a relatively powerful positive reinforcer. The termination of S- is a weak reinforcer, whether it is interpreted as "escape" from an aversive condition or as stimulus change. The improvement of the reinforcement schedule probably plays some part in maintaining control-key behavior, but it is of course impossible to determine whether this should be interpreted as negative reinforcement,

due to termination of the poorer schedule, or as positive reinforcement, inherent in the onset of the better schedule. Such consequences are hopelessly confounded, and there would seem to be no way to separate them.

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