A RESPONSE-SPACING EFFECT: AN ABSENCE OF RESPONDING DURING RESPONSE-FEEDBACK STIMULI¹

D. F. HAKE AND N. H. AZRIN

ANNA STATE HOSPITAL

In most studies of operant reinforcement a response-feedback stimulus is used which is so brief that the nature of the responding during it is virtually undetectable. The present study investigated the nature of this responding by lengthening an initially brief feedback stimulus. The key-pecking responses of pigeons were maintained by a variable-interval schedule of food reinforcement. Each response produced a brief stimulus light in addition to the usual auditory response feedback. When the duration of the feedback stimulus light was gradually increased, it was found to control a nearly zero rate of responding. The result was a paced, metronomic-like performance in which the pigeon made a single response, paused until the stimulus terminated, and then responded again. As a result, the overall response rate was greatly reduced; the mean interresponse time approximated the stimulus duration. A plausible interpretation is that brief feedback stimuli acquire control over responding because they coincide with few responses and few reinforcers. These findings show that in addition to their known functions as conditioned-reinforcing stimuli and discriminative stimuli, response-feedback stimuli also exert direct stimulus control: responding is reduced during the feedback stimulus itself.

Virtually all operant conditioning procedures arrange a brief stimulus to follow immediately after each response. This response feedback is intended to function as an immediate conditioned-reinforcing stimulus and as a discriminative stimulus. The reinforcing function of feedback stimuli has been discussed by Skinner (1951) and has been demonstrated by several experiments in which the feedback had always been paired with the unconditioned reinforcer, *e.g.* Bugelski (1938) and Skinner (1938). Feedback stimuli are presumed to acquire a conditioned-reinforcing function and to provide immediate reinforcement of all responses even during an intermittent schedule of reinforcement, since the feedback stimuli are sometimes paired with the unconditioned reinforcer. The discriminative-stimulus function of response-feedback stimuli has been demonstrated by Ayllon and Azrin (1967). Using an alternative response procedure, they found that when a response-produced noise was selectively paired with reinforcement, the subjects

responded on the operandum with that stimulus. When responses on that operandum were no longer followed by the stimulus, the subjects switched to the operandum that did have the stimulus, indicating that the stimulus had acquired control over responding. The discriminative-stimulus function of a response-produced light or electric shock that has been selectively paired with either the presence or absence of reinforcement has also been demonstrated in a single-response situation (Holz and Azrin, 1961; Holz and Azrin, 1962; McMillan and Morse, 1967). Bolles and Popp (1964) showed that feedback stimuli can also improve performance during shock avoidance.

Most studies of operant reinforcement use a response-feedback stimulus which is so brief that the nature of the responding during it is virtually undetectable. Consequently, little is known about responding during feedback stimuli. The present study investigated the extent of this responding by extending the duration of an initially brief feedback stimulus. There is reason to suspect that response-feedback stimuli control a reduced rate of responding. Although reinforcement is usually possible during a feedback stimulus, the stimulus is usually so brief that few responses can occur during it and, as a result, responses will be reinforced only very infrequently, if at all,

¹This research was supported by grants from the Mental Health Fund of the Illinois Department of Mental Health. The advice and assistance of Miss Rebecca Oxford, Mr. Dan Dinsmoor, and Dr. Harris Rubin are gratefully acknowledged. Reprints may be obtained from either author, Behavior Research Laboratory, Anna State Hospital, Anna, Illinois 62906.

during it. For example, one experiment found that few responses during variable-interval reinforcement had interresponse times less than 100 msec (Blough, 1963). The prediction follows that stimulus control will be acquired by a brief response-feedback stimulus that coincides with few responses and few or no reinforcers.

METHOD

Subjects and Apparatus

Ten experimentally naive, male White Carneaux pigeons were maintained at about 80% of free-feeding body weight.

The experimental space, measuring 35- by 35- by 40-cm high, was inside a sound-attenuating and light-proof box. A 1.9-cm diameter Gerbrands pigeon key was centered on the front wall 23 cm up from the floor and was transilluminated by a green or a white light. There were two types of response feedback: (1) the usual auditory feedback consisting of the "click" from the operation of a heavy duty relay and (2) a change in the color of the response key. The force required to operate the normally-closed key was determined by the amount of resistance in series with an electro-magnet that held the key in the normally closed position. The key did not move or operate until the specified minimum force requirement was met. The force requirement was specified in terms of grams of force required at the center of the key. The series resistance, and hence the force requirement, could be varied without interrupting the experiment. Reinforcement consisted of a 2-sec presentation of a grain mixture which could be reached when the bird put its head into a wall aperture located below the response key. During reinforcement the aperture was illuminated; the key lights and houselights remained illuminated.

Procedure

The feedback stimulus that was to be extended consisted of a change in the color of the response key and initially had a duration of 200 msec; this is longer than the relay click usually employed. Both the longer duration and the change in the color of the response key were used to enhance the perceptibility of the feedback stimulus. With the use of this longer duration feedback stimulus it

seemed desirable to prevent the development of high response rates in order to follow the usual practice of having the feedback stimulus terminate before the next response and thereby follow each response. For this reason, the first six subjects were tested with a high force requirement on the response key and all 10 subjects were tested soon after the key-pecking response was conditioned. As an additional precaution against the development of high response rates, care was taken to shape a discrete pecking response that involved the downward movement of the head toward the response key. With the first six subjects (P-1 to P-6), pecks with a force of 10 g were initially conditioned. For these subjects, each response was immediately followed by the relay-click feedback, the 200-msec change in the color of the response key, and food reinforcement. The key color changed from white to green for four of the subjects (P-2, P-3, P-5, and P-6) and from green to white for the remaining two (P-1 and P-4). Responses during the stimulus did not extend it. After 100 reinforcements, the force requirement was increased by 10-g steps to 100 g. A given force was in effect until visual observation revealed that nearly every pecking response activated the response key. A minimum of 30 reinforcements was provided at each force except 100 g, where a minimum of 150 was provided. The 100-g requirement was reached in four sessions, each containing 150 reinforcements, beyond the shaping session. Then, the schedule of reinforcement was changed to a 1-min variable-interval (VI 1-min) schedule with a distribution of reinforcement intervals determined by the formula of Fleshler and Hoffman (1962). Each session lasted 150 min. One VI session during which responses produced the 200-msec stimulus was given to help ensure a fairly constant VI response rate before increasing the duration of the feedback stimulus. Then, in a single 150-min session, the duration of the stimulus was gradually increased from 0.0 to 8.0 sec and then gradually decreased back to 0.0 sec. The session was divided into fifteen 10-min periods with stimulus durations of 0.0, 0.0, 0.2, 0.6, 1.0, 1.6, 2.0, 3.0, 4.0, 6.0, 8.0, 3.0, 0.2, 0.0, 0.0 sec respectively. The same sequence was used again following a 150-min control session during which responses did not change the color of the response key. One of the subjects (P-5)

responded at a very low rate and was retested at longer stimulus durations. The stimulus durations for the 10-min periods were 0, 0, 8, 16, 24, 32, 64, 64, 32, 8, 0, 0 sec respectively.

For the last four subjects (P-7, P-8, P-9, P-10) the force requirement was lower and responses were not followed by the change in key color during FR 1 training. Pecks with a force of 10 g were conditioned. The 10-g force remained in effect throughout the experiment. Each response was followed by the auditory feedback and food reinforcement, but the color of the response key did not change. This FR 1 training lasted from one to three sessions of 75 reinforcements. Then the schedule of reinforcement was changed to VI 1-min with each response producing a 200-msec change in the color of the response key. For three subjects (P-7, P-8, P-10) responses changed the key color from white to green; for the other subject (P-9) the change was from green to white. Responses during the stimulus did not extend it. Each subject was given either two to three 30-min sessions or one to three 2-hr sessions to allow the VI response

rate to become fairly constant within sessions. Then, in a single session the duration of the feedback stimulus was gradually increased from 0.0 to 5.0 (P-7, P-8, P-10) or 9.5 (P-9) sec and then decreased back to 0.0. The durations for P-7, P-8, and P-10 were 0.0, 0.2, 0.4, 0.6, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 0.2, 0.0 respectively. The durations for P-9 were 0.0, 0.2, 0.4, 0.6, 1.0, 2.0, 3.0, 4.0, 5.0, 8.0, 9.5, 0.2, 0.0 respectively. Each duration lasted for 10 min except 0.4, 0.6, and 2.5 sec, which lasted only 5 min.

RESULTS

Figure 1 shows the extent of responding during and immediately following the stimulus for the six subjects tested with the 100-g force requirement. Responses are distributed as a function of time since the start of the stimulus; responses in the absence of the stimulus produced the stimulus and restarted the distribution timer, which continued until the stimulus terminated and another response in the absence of the stimulus produced it. First,

Fig. 1. Responding distributed as a function of time since the start of the feedback stimulus for the six subjects tested with a 100-g force requirement. The arrows indicate the duration of the stimulus "S" and the shaded areas indicate responding during the stimulus. The stimulus durations shown for P-1, P-2, P-3, P-4, and P-6 were 0, 4, and 8 sec respectively. The longer stimulus durations shown for P-5 were 0, 32, and 64 sec respectively. The data for each duration are the mean of the two sessions in which the feedback stimulus was gradually increased.

consider Subjects 1 through 4. The graphs in the top row were obtained with no stimulus (0-sec stimulus) and are interresponse time distributions; the majority of interresponse times was between 0 and 4 sec. However, in the second row of graphs obtained with a 4-sec stimulus, few responses occurred during the 4-sec stimulus period and the majority of responses occurred soon after the stimulus terminated. There were also few responses during the 8-sec stimulus (third row) with the majority of the responses occurring within 4 sec after the stimulus terminated. It can be seen that few responses were emitted during the longer stimulus durations (up to 64 sec) used with P-5 and that responding occurred soon after the stimulus terminated. The results of these five subjects may be contrasted with those of P-6, the only subject for which the feedback stimulus had no effect. Well over 50% of this subject's responses occurred during the stimulus at both the 4-sec and 8-sec durations.

Figure 2 shows the responding during and following the stimulus for the other four subjects tested with the 10-g force requirement. Response distributions are shown for 0-, 3-, and 5-sec stimulus durations. The top row of graphs shows that before the stimulus (0 sec), over half of the responding occurred within 1 or 2 sec of a previous response for subjects P-7, P-9, and P-10. The interresponse times of P-8 were somewhat longer. When the stimulus was increased to 3 sec (second row) few responses were emitted during the period of the stimulus and over half of the responses were emitted 1 to 2 sec after the stimulus ended. With the exception of P-10, responding was also reduced during the stimulus at the 5-sec stimulus duration.

The relationship between stimulus duration and mean interresponse time is shown in Fig. 3 for the six subjects tested with the 100-g force requirement. Theoretically perfect stimulus pacing is indicated by the solid diagonal line which can be seen to increase as a linear function of the stimulus duration. Interresponse times above this line are longer than the stimulus while interresponse times below this line are shorter and necessarily indicate some responding during the stimulus. For all but P-6, the mean interresponse time increased as a direct function of the stimulus duration. With the exception of P-4, the mean

interresponse time curve was above and roughly parallel to the theoretical function, suggesting that the latency from the end of the stimulus to the next response was the major deviation from theoretically perfect stimulus pacing. For all subjects except P-6, the longest stimulus duration resulted in mean interresponse times of two to five times as long as those obtained without the stimulus.

This increase in interresponse time as a function of stimulus duration cannot be attributed to progressive satiation, since the re-determinations (solid points) were comparable to the initial determinations. Similarly, the mean interresponse time for the entire control session with the stimulus absent (dashed line) was very close to the mean interresponse time obtained with the stimulus absent at the start of the experimental sessions.

Figure 4 shows a similar relationship between interresponse time and stimulus duration for the four subjects tested with the 10-g force requirement. Interresponse time increased as a function of stimulus duration for three of the four subjects. For the fourth subject (P-10) the mean interresponse time increased from the 0-sec duration to the 3-sec duration but at the 5-sec duration, the mean interresponse time was again about the same as it had been without the stimulus.

Table 1 shows the extent to which the 200-msec feedback stimulus coincided with the absence of responding before it was extended. The number of responses during, and in the absence of, the 200-msec stimulus is given for the first VI stabilization session and for the 10-min period immediately before the stimulus was extended in the first experimental session. First, consider all the subjects except P-6, the subject that did not come under control of the stimulus. During the VI stabilization session few responses were emitted during the stimulus; two subjects made no responses during the stimulus. For the 10-min period immediately preceding the increases in stimulus duration, seven subjects made no responses during the 200-msec stimulus; the other two emitted only three responses during the stimulus. The last column of Table 1 shows that the pecks of these nine subjects were never reinforced during the 200-msec stimulus. Now consider P-6, the subject that did not come under the control of the feedback stimulus. The pecks of this subject, un-

Fig. 2. Responding distributed as a function of time since the start of the feedback stimulus for the four subjects tested with the 10-g force requirement. The arrows indicate the duration of the stimulus "S" and the shaded areas indicate responding during the stimulus. The stimulus durations for the three rows of graphs were 0, 3, and 5 sec respectively.

like the others, were reinforced during the 200-msec stimulus in the first VI stabilization session. Also, P-6 emitted about 9% of its responses during the brief stimulus.

Visual observation of the subjects revealed that they did not stand quietly in front of the response key and wait for the feedback stimulus to end. Rather, most of the subjects developed consistent behavior patterns during

the extended feedback stimulus. After emitting a key-pecking response, the subjects usually turned away from the response key and started moving around the chamber in a circular pattern. The extent to which the circular pattern was completed depended upon the duration of the feedback stimulus. As soon as the feedback stimulus terminated, the subjects approached the response key either by

Fig. 3. Interresponse time as a function of stimulus duration for the six subjects tested with the 100-g force requirement. The open, connected circles are for the ascending series and the solid, unconnected circles for the descending series. The connected point at 0 sec is for the 10-min period immediately before the stimulus was introduced and the unconnected point at 0 sec is for the first 10-min period after the stimulus was disconnected. Each point is the mean of the two experimental sessions. The dashed line shows the mean interresponse time for the control session when the stimulus was absent.

retracing their path or by completing the circle. At the longest stimulus durations, the subjects frequently completed the circle before the stimulus terminated. In these instances,

the subjects started another circle instead of pecking the response key. This circling was not evident when the feedback stimulus was reduced to brief durations or eliminated. The

Table 1

Responses during and in the absence of the 200-msec feedback stimulus before it was extended.

(1) Subjects	(2) VI Stabilization Session		(3) 10-Min Period of First Experimental Session with 200-msec Stimulus		(4) Reinforcement during 200-msec Stimulus
	During	Absence	During	Absence	
P-1	7	1766	0	83	0
P-2	25	2933	0	282	0
P-3	49	2327	3	178	0
P-4	0	1913	0	251	0
P-5	0	1288	0	79	0
P-6	188	2224	17	182	1
P-7	4	666	0	145	0
P-8	2	308	0	145	0
P-9	9	888	3	100	0
P-10	13	437	0	174	0

NOTE: Column 2 shows the first VI stabilization session for those subjects that had more than one stabilization session.

Fig. 4. Interresponse time as a function of stimulus duration for the four subjects tested with the 10-g force requirement. The open, connected circles are for the ascending series and the solid, unconnected circles for the descending series.

significance of this circling behavior has not been ascertained but is noted here because of its consistency.

DISCUSSION

The present results show that a brief response-feedback stimulus controlled a near-zero rate of responding during it. In most previous studies, feedback stimuli have been so brief that the control over responding during the stimuli, and the effect of this control

upon the overall response rate, have been virtually undetectable. These effects were made observable in the present study by extending an initially brief response-feedback stimulus to encompass normal periods of responding. The result was a paced, metronomic-like performance during which the subject made a single response, paused until the stimulus terminated, and then responded again. As a result, the mean interresponse time increased over that observed without the stimulus and approximated the stimulus duration. These

findings show that in addition to their known functions as conditioned-reinforcing stimuli and discriminative stimuli, response-feedback stimuli can also control the temporal spacing of responding. This response-spacing can produce a reduction in the overall response rate without requiring a change in the reinforcement schedule or the introduction of aversive stimuli.

There are several ways in which the feedback stimulus could have come to control a near-zero rate of responding. For example, the absence of responding during a stimulus can result from the physical properties of that stimulus. It is doubtful that this was a factor in the present experiment, since some of the subjects responded during the white stimulus and did not respond during the green stimulus while others responded during the green stimulus and not during the white stimulus. It might also be that key pecking decreased during the feedback stimulus because the feedback stimulus was serving as a discriminative stimulus for the incompatible response of approaching the food magazine. For example, for the first six subjects, the feedback stimulus was present during FR-1 training; approaching the food magazine could have been reinforced during each occurrence of the feedback stimulus. This was not a critical factor, however, since the feedback stimulus was absent during magazine training for all subjects and was also absent during FR 1 training for the last four subjects. Nor can the absence of responding during the feedback stimulus be attributed to the absence of the usual reinforcing and discriminative stimulus functions of feedback stimuli because a second feedback stimulus that was not extended always followed responses. It appears that the factors mentioned above cannot explain why the feedback stimulus controlled a near-zero level of responding.

There are two other more plausible reasons why the feedback stimulus controlled a near-zero level of responding. The first is that the initial 200-msec feedback stimulus simply coincided with periods of non-responding. The explanation of the stimulus control exerted at the extended stimulus durations would be that offered by Terrace (1963) to account for errorless discrimination learning. That is, a brief stimulus which initially coincides with periods of non-responding will continue to

control a near-zero level of responding when gradually extended to encompass normal periods of responding. The 200-msec feedback stimulus was brief relative to the mean inter-response time and, therefore, usually terminated before the next response. Indeed, for two subjects the 200-msec stimulus always coincided with periods of non-responding. However, this explanation does not appear as plausible for the other seven subjects that emitted responses during the 200-msec stimulus and still showed at least some stimulus control when the stimulus was extended. Two of these subjects made 25 or more responses during the 200-msec stimulus in the VI stabilization session. A second and more probable reason why the brief feedback stimulus controlled a near-zero level of responding was that the frequency of reinforcement was lower during the stimulus. In fact, only P-6, the subject that did not come under control of the feedback stimulus, obtained a reinforcer during the 200-msec feedback stimulus. Under any interval schedule of reinforcement, such as the VI schedule used here, the probability of reinforcement must increase as a function of increasing interresponse times (Anger, 1956). A response during a 200-msec response-feedback stimulus necessarily has a very short interresponse time and a very low associated probability of reinforcement. It is also likely that the few reinforcers that did become available during the 200-msec feedback stimulus were not obtained during the stimulus, since only a small percentage of the presentations of the 200-msec stimulus contained any responses (Table 1). Since the few responses that did occur during the 200-msec stimulus were not reinforced, responding during the stimulus would be expected to decrease further. Table 1 showed that five of the seven subjects that emitted unreinforced responses during the 200-msec stimulus in the VI stabilization session were not responding at all during the 200-msec stimulus by the time it was to be extended.

The Morse and Skinner (1957) experiment on superstitious stimulus control is the best known example of stimulus control resulting from unequal densities of reinforcement when reinforcement had been scheduled to be equally available at all times. In that experiment, a stimulus accidentally coincided with either a higher or lower than average rate of

reinforcement. In the present experiment, unequal frequencies of reinforcement also resulted, even though reinforcement was scheduled to be equally available at all times. However, in the present experiment this was not due to chance. As noted above, the unequal frequencies of reinforcement resulted because the 200-msec feedback stimulus was brief relative to the average interresponse time and was response contingent. This reasoning suggests that the response spacing effect will occur during interval schedules of reinforcement whenever responses produce a feedback stimulus that is short relative to the average interresponse time.

REFERENCES

- Anger, D. The dependence of interresponse times upon the relative reinforcement of different interresponse times. *Journal of Experimental Psychology*, 1956, **52**, 145-161.
- Ayllon, T. and Azrin, N. H. Punishment as a discriminative stimulus and conditioned reinforcer with humans. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 411-419.
- Blough, D. S. Interresponse time as a function of continuous variables: a new method and some data. *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 237-246.
- Bolles, R. C. and Popp, R. J. Parameters affecting the acquisition of Sidman avoidance. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 315-321.
- Bugelski, R. Extinction with and without sub-goal reinforcement. *Journal of Comparative and Physiological Psychology*, 1938, **26**, 121-134.
- Fleshler, M. and Hoffman, H. S. A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 529-530.
- Holz, W. C. and Azrin, N. H. Discriminative properties of punishment. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 225-232.
- Holz, W. C. and Azrin, N. H. Interactions between the discriminative and aversive properties of punishment. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 229-234.
- McMillan, D. E. and Morse, W. H. Schedules using noxious stimuli II: low-intensity electric shock as a discriminative stimulus. *Journal of the Experimental Analysis of Behavior*, 1967, **10**, 109-118.
- Morse, W. H. and Skinner, B. F. A second type of superstition in the pigeon. *American Journal of Psychology*, 1957, **70**, 308-311.
- Skinner, B. F. *The behavior of organisms*. New York: Appleton-Century-Crofts, 1938.
- Skinner, B. F. How to teach animals. *Scientific American*, 1951, **185**, 26-29.
- Terrace, H. S. Discrimination learning with and without "errors". *Journal of the Experimental Analysis of Behavior*, 1963, **6**, 1-27.

Received 5 July 1968.