**RESPONDING IN THE CAT MAINTAINED UNDER
RESPONSE-INDEPENDENT ELECTRIC SHOCK
AND RESPONSE-PRODUCED ELECTRIC
SHOCK^{1,2}**

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Key-pressing responses in the cat were maintained under conditions in which brief electric shock was first postponed by responses (avoidance), then periodically presented independently of responses, and finally produced by responses on a fixed-interval schedule of 15 min (FI 15-min). A steady rate of responding occurred under shock avoidance and under response-independent shock; positively accelerated responding was engendered by the FI 15-min schedule. A second experiment studied responding under second-order schedules composed of three FI 5-min components. Responding was suppressed when a stimulus was presented briefly at completion of each FI 5-min component and a shock followed the brief stimulus at completion of the third component. Responding was maintained when each of the first two components was completed either with or without presentation of a brief stimulus and a shock alone was presented at completion of the third FI 5-min component.

The effects of electric shock upon operant responding have traditionally been investigated under conditions in which responding is maintained by terminating or postponing shock (Sidman, 1953), or suppressed by presenting shock (Azrin, 1956). Yet, under certain conditions, electric shock can enhance responding. Sidman, Herrnstein, and Conrad (1957) reported that under a schedule of continuous shock avoidance, rates of responding in the rhesus monkey increased in the presence of a stimulus (pre-shock stimulus) which terminated when a response-independent shock was presented. The enhancing effect was temporary, however; with continued training, higher response rates in the presence of the pre-shock stimulus gradually decreased and approached the rates in the absence of the stimulus. Frequency of responding declined when all shocks, except those delivered when the pre-shock stimulus terminated, were omitted, but the decline was slower in the

presence of the stimulus than in its absence. Later, Herrnstein and Sidman (1958) showed in the rhesus monkey that after training under a schedule of continuous shock avoidance, response rates were higher in the presence of a pre-shock stimulus than in its absence when responding was maintained under a schedule of food presentation.

More-recent investigations have shown that increased rates of responding in the presence of a pre-shock stimulus can persist in other species under different conditions. Waller and Waller (1963), studying responding in the dog under a multiple schedule of food presentation, shock avoidance, and extinction, found that rates of responding in the presence of a pre-shock stimulus consistently increased during the extinction periods and during the avoidance periods. Moderately high response rates in the presence of the pre-shock stimulus persisted even after avoidance responding was extinguished.

In a series of experiments, Kelleher, Riddle, and Cook (1963) found that responding in the squirrel monkey increased in the presence of a pre-shock stimulus presented during the food component of a multiple schedule of food presentation and shock avoidance. Responding during the pre-shock stimulus continued even when the schedules of food presentation and shock avoidance were changed to extinction, but responding ceased when a response-independent shock was not presented at termina-

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tion of the stimulus. Later, responding was maintained when the pre-shock stimulus was continuously present and a response-independent shock was delivered to the subject every 10 min.

Rates of responding in the chimpanzee have also been shown to increase when a pre-shock stimulus was presented during the avoidance component of a complex multiple schedule of shock avoidance and food presentation (Belleville, Rohles, Grunzke, and Clark, 1963). Response rates increased immediately upon presentation of the pre-shock stimulus, and were consistently higher in the presence of the stimulus than in its absence.

Experiments in which response-independent shock was presented without a pre-shock stimulus also indicate that presentation of electric shock can enhance responding. Appel (1960a) reported that after training under a multiple schedule of shock avoidance and extinction, a rat seldom responded during the extinction component. When response-independent shock was presented at regular intervals during the extinction component, however, responding during extinction increased. Appel (1960b), studying responding in the rhesus monkey, reported similar results when response-independent shock was presented at variable times during the extinction component of a multiple schedule of shock avoidance and extinction.

Hearst (1962) trained rhesus monkeys to respond in the presence of a bright light under concurrent schedules of shock avoidance and food presentation, and then tested for generalization at decreased intensities of the light. In the absence of shock delivery and food presentation at the lower intensities, response rates decreased as the intensity of the light decreased. When response-independent shock was delivered at variable times during the lowest light intensity, response rates increased and approached the rates prevailing during the bright light.

All of these experiments studied the effects of presenting response-independent shock, either with or without a pre-shock stimulus, and all showed that response-independent shock can enhance responding in subjects having prior training under continuous shock avoidance. Furthermore, in the one experiment (Kelleher *et al.*, 1963) that studied the effect of response-produced shock, an enhanc-

ing effect was observed in one squirrel monkey during several sessions. That responding under fixed-interval schedules of shock presentation can be maintained in the squirrel monkey without prior training under shock avoidance has been shown by Kelleher and Morse (1968). However, there is no evidence that response-produced shock can maintain responding in subjects having histories of shock avoidance.⁴

The present paper describes two experiments which studied responding in the domestic cat when responses postponed shocks, when shocks were presented independently of responses, and when shocks were response-produced. These experiments demonstrated that responding in cats having prior training under continuous shock avoidance can be maintained when electric shock is response-produced under a 15-min fixed-interval schedule (FI 15-min) and when shock is presented independently of responses. These experiments also demonstrated that responding can be maintained under some second-order schedules of shock presentation, and that subjects' responding can be suppressed when a stimulus which is occasionally paired with shock is presented at completion of each of the components.

EXPERIMENT I: PERFORMANCE UNDER RESPONSE-INDEPENDENT SHOCK AND UNDER AN FI 15-MIN SCHEDULE OF SHOCK PRESENTATION

The first experiment attempted to determine if responding in the cat could be maintained by occasionally presenting a response-independent electric shock after training under a schedule of continuous shock avoidance, and whether responding would persist when shocks were response-produced under a fixed-interval schedule. Performance was studied when responding postponed shock presentation, when shocks were presented at regular intervals independently of responding, and when shock presentation was response-produced (FI).

⁴While the present paper was undergoing editorial review, a study similar to Exp. I appeared (McKearney, 1968) in which responding in squirrel monkeys was maintained under an FI 10-min schedule of shock presentation.

METHOD

Subjects

Two adult cats, *Felis domestica*, one a female (FC-I) and one a male (MC-II), served. FC-I weighed approximately 3.3 kilograms and MC-II weighed approximately 3.9 kilograms. Both had previously responded under a variable-interval schedule of food presentation and under a schedule of continuous shock avoidance. During the present investigation, food and water were continuously available in the home cages.

Apparatus

The experimental chamber was a cubicle measuring approximately 24 in. on each side. The four walls and the ceiling were wood. The floor consisted of 0.25-in. steel bars mounted 0.50 in. apart, center to center, to form a grid through which electric shock could be delivered. The shock source was a generator and scrambler (Grason-Stadler, Model E1064GS) modified to provide a 60 cps alternating current in excess of 4.0 ma. Modification consisted of replacing an 86,000 ohm series resistor with a multiple-position selector switch and appropriate resistors.

A small speaker through which an auditory stimulus could be presented was located at the bottom of one wall of the chamber. Also on this wall were a bar-type lever and a liquid feeder, both disconnected and unrelated to the present study. Mounted on the outer surface of an adjacent wall was a standard pigeon response key (R. Gerbrands Co.) which could be transilluminated by a white or a red 28-v dc lamp (G.E. #1028). Affixed to the surface of the response key was a cylindrical piece of transparent Plexiglas, 0.75 in. in diameter and approximately 0.75 in. in length. The response key was mounted so that the cylindrical Plexiglas extension passed through an opening 2.50 in. in diameter in the wall of the chamber, and the exposed end of the Plexiglas was flush with the inner surface of the wall. A force of at least 20 g operated the response key. Each response produced an audible click of a relay and caused the key to be illuminated with the white lamp for 0.05 sec. In the absence of responses the key was normally illuminated with the red lamp.

A 60-w, 115-v ac lamp mounted behind white, translucent glass in the center of the

ceiling served as a houselight. The light went off and on once per second during each session. Usually there were six sessions per week, each lasting approximately 2 hr. Relay switching circuits and timers arranged the experimental conditions, and data were tabulated on counters and cumulative recorders as described by Ferster and Skinner (1957).

Procedure

Subjects were trained under a schedule of continuous shock avoidance (Sidman, 1953) in which a response postponed the presentation of shock for 60 sec (response-shock interval). If 60 sec elapsed without a response, a shock of 4.0-ma intensity and 0.75-sec duration was presented every 5 sec (shock-shock interval) until a response occurred.

After 15 sessions under continuous avoidance there were two sessions during which the schedule of shock avoidance remained in effect and, in addition, an electric shock was delivered every 15 min independently of shocks presented under the avoidance schedule, and independently of responding. Shocks presented during these two sessions were also 4.0 ma in intensity and 0.75 sec in duration. After these two sessions, the schedule of shock avoidance was omitted; thereafter, only a response-independent electric shock was presented every 15-min. The intensity of the shock was unsystematically varied and was either 4.0, 6.4, or 8.1 ma. Duration of shocks remained at 0.75 sec.

After 33 sessions under response-independent shock, the schedule was changed to a 15-min fixed-interval schedule of shock presentation (FI 15-min), *i.e.*, a shock was produced by the first response occurring after 15 min had elapsed since the previous shock. During 50 sessions under FI 15-min, shock intensity was, at various times, either 5.4, 6.4, or 8.1 ma for FC-I, and 4.0, 5.4, 6.4, or 8.1 ma for MC-II. Shock duration was 0.75 sec during the first 31 sessions, and 0.50 sec during the remaining 19 sessions.

Shock intensity was increased from 4.0 to 8.1 ma and shock duration was decreased from 0.75 to 0.50 sec to determine if a change in performance would accompany changes in these parameters, and to determine shock intensities appropriate to maintaining patterns of responding characteristic of the schedules studied.

RESULTS

Under the avoidance schedule, both subjects responded steadily and shocks occurred infrequently (Fig. 1 and 2). For each subject the mean number of shocks per session was approximately one; seldom did as many as three shocks occur during an individual session and occasionally none occurred. Mean rates of responding during the last three sessions were approximately 0.18 responses per second for FC-I and 0.11 responses per second for MC-II (Fig. 3).

When a response-independent shock was delivered every 15 min, rate of responding by FC-I was higher than under the avoidance schedule, but responding by MC-II was only slightly enhanced. Response rates during the last three sessions had increased to approximately 0.26 responses per second for FC-I and approximately 0.11 responses per second for MC-II (Fig. 3). Although a shock was pre-

sented at regular intervals there was only minimal evidence of a periodic change in response rate. For FC-I, and to a lesser extent for MC-II, the most noticeable change was an occasional slight decrease in response rate for a brief period immediately after a shock. Otherwise, the patterns of responding under response-independent shock, like those under continuous avoidance, showed relatively steady responding (Fig. 1 and 2).

The rates and patterns of responding changed after the FI 15-min schedule of shock presentation was introduced. FC-I developed a pattern of responding similar to the pattern typically engendered by an FI schedule of food presentation. Responses were infrequent during the initial part of the interval, and occurred with increasing frequency toward the end of the 15-min period (Fig. 1). MC-II showed less-marked contrast between responding during the initial and final segments of the interval; except for a brief pause after

Fig. 1. Performance of FC-I under: (Avoid) continuous shock avoidance; (Response-Independent) presentation of a response-independent shock every 15 min; presentation of a response-produced shock every 15 min. A short diagonal mark of the response pen indicates presentation of a shock; the event pen marks successive 15-min periods. The response pen reset upon cumulation of 550 responses, or upon presentation of a shock.

Fig. 2. Performance of MC-II under: (Avoid) continuous shock avoidance; (Response-Independent) presentation of a response-independent shock every 15 min; presentation of a response-produced shock every 15 min. A short diagonal mark of the response pen indicates presentation of a shock; the event pen marks successive 15-min periods. The response pen reset upon cumulation of 550 responses, or upon presentation of a shock.

shock presentation, responding tended to occur at a steadier rate (Fig. 2). After 50 sessions under FI 15-min, the mean response rates were 0.11 responses per sec for FC-I and 0.18 responses per sec for MC-II (Fig. 3).

Responding in both cats was relatively insensitive to changes in shock parameters under response-independent shock and under response-produced shock. Over the range studied, both cats responded at relatively steady rates under shock avoidance and under response-independent shock, and for FC-I, to a greater extent than for MC-II, responding was positively accelerated under FI 15-min.

EXPERIMENT II: PERFORMANCE UNDER SECOND-ORDER SCHEDULES OF SHOCK PRESENTATION

Experiment I demonstrated that in cats having histories of shock avoidance, responding can be maintained under an FI 15-min sched-

ule of shock presentation and under response-independent shock. After the determination that response-produced shock can maintain responding in cats, a second experiment was conducted to determine if responding would persist when shock was presented under second-order schedules (Kelleher, 1966a) and to examine the effect of presenting, at completion of individual components, a brief stimulus occasionally paired with shock. To the extent that the FI 15-min schedule of shock presentation engendered response patterns typical of an FI schedule of food presentation, it was of interest to determine whether a stimulus paired with shock, like a stimulus paired with food, would enhance responding. Kelleher (1966b) and others have shown second-order schedules to be especially sensitive procedures for assessing the effects of stimuli which are presented briefly during responding that is maintained under food presentation.

Fig. 3. Mean rates of responding during successive daily sessions under: (Avoid) continuous shock avoidance; (CO) continuous shock avoidance concurrent with presentation of a response-independent shock every 15 min; (Response-Independent) presentation of a response-independent shock every 15 min; presentation of a response-produced shock every 15 min. Changes in shock intensity (ma) are indicated below each abscissa. MC-II made no responses and produced no shocks during the twenty-eighth, forty-first, and forty-third sessions under FI 15-min, but immediately responded at beginning of the twenty-ninth, forty-second, and forty-fourth sessions.

METHOD

Subjects and Apparatus

The subjects and apparatus were the same as in Exp. I.

Procedure

The FI 15-min schedule studied in Exp. I was changed to a second-order schedule in which each fixed-interval component was completed by the first response occurring after 5 min (FI 5-min), and a 0.5-sec shock was presented upon completion of three FI 5-min components. Under the schedule studied first (Noise-Shock: Not Paired), a response-produced white noise of 0.75-sec duration was presented at completion of the first and second FI 5-min components, and a shock was produced by the response that completed the third component. A white noise was not presented at completion of the third FI 5-min component. Shock intensities for FC-I were 4.0 and 6.4 ma; for MC-II they were 1.3, 2.0, and 4.0 ma. Shock intensity was varied between 1.3 and 6.4 ma to determine if particular intensities in this range would further enhance positively accelerated responding, especially in MC-II.

After 38 sessions, the schedule was changed so that a response-produced white noise was presented when each of the three components

was completed; when the third component was completed, the white noise was immediately followed by shock (Noise-Shock: Paired). Intensity of the shock was 4.0 ma for FC-I and 1.3 ma for MC-II.

At the end of eight sessions, the schedule was changed so that responses at completion of the first and second FI 5-min components produced no stimulus change, and a response at completion of the third FI 5-min component produced a shock (Shock Only). A white noise was never presented during the 11 sessions under this procedure. Shock intensity remained at 4.0 ma for FC-I, and was either 1.3 or 2.0 for MC-II.

During the final phase of Exp. II, a white noise was presented at completion of each of the three FI 5-min components, and a shock immediately followed every third presentation of the white noise (Noise-Shock: Paired). Shock intensity was 4.0 ma for FC-I and 2.0 ma for MC-II. The experiment was terminated after two sessions under this schedule.

RESULTS

Responding by each subject was maintained at a mean rate of approximately 0.09 responses per second when a white noise was presented at completion of the first and second components only (Noise-Shock: Not Paired) (Fig. 4). FC-I showed a pronounced increase in the frequency of responding during each successive component of the three-component schedule. Rate of responding was lowest during the first or initial component and highest during the third or terminal component. (Fig. 5 and 7). MC-II did not show a uniform increase in frequency of responding during each successive component, but tended to respond at a relatively steady rate during each of the components (Fig. 6 and 7).

When a white noise was presented at completion of the terminal component, as well as at completion of the first and second components (Noise-Shock: Paired), responding decreased significantly (Fig. 4). FC-I responded at decreased rates during the first five sessions under this schedule, but made no responses during the sixth and subsequent sessions. Cumulative records of the performance of FC-I during the fifth session are shown in the second frame of Fig. 5. Responding by MC-II decreased to 0.05 responses per second, but did not cease during eight sessions under this

Fig. 4. Mean rates of responding during successive daily sessions under: (Noise-Shock: Not Paired) a white noise was presented at completion of the first and second FI 5-min components and a shock alone was presented at completion of every third component; (Noise-Shock: Paired) a white noise was presented at completion of each component and a shock immediately followed every third presentation of the white noise; (Shock Only) no stimulus change occurred at completion of the first and second components and a shock alone was presented at completion of every third component. Changes in shock intensity (ma) are indicated below each abscissa.

schedule. Records of the performance of MC-II during the seventh session are shown in the second frame of Fig. 6.

Omitting the white noise (Shock Only) did not immediately result in the recovery of responding by FC-I. During each of the first four sessions under this procedure, FC-I did not respond until a single 0.5-sec shock of 15.9 ma had been delivered; but once a response-independent shock had been presented, FC-I responded for the remainder of the session. During the third session, a shock was not delivered and FC-I made no responses. After a delay of approximately 6 min at the beginning of the fifth session, responding began without the presentation of a 15.9-ma shock, and responding persisted during the fifth and subsequent sessions. Responding was maintained at mean rates of 0.09 responses per second by FC-I and 0.06 responses per second by MC-II during the last three sessions under the Shock-Only procedure (Fig. 4). Although the trend was much more pronounced in FC-I, both subjects tended to increase the frequency of responding during successive components (Fig. 7). Cumulative records of terminal performances are presented in Fig. 5 and 6 for FC-I and MC-II respectively.

Fig. 5. Performance of FC-I under three second-order schedules of shock presentation (Noise-Shock: Not Paired). A white noise was presented at completion of the first and second FI 5-min components and a shock alone was presented at completion of every third component: (Noise-Shock: Paired). A white noise was presented at completion of each component and a shock immediately followed every third presentation of the white noise. The second frame shows performance during the fifth session when the procedure was studied the first time. The bottom frame shows performance during the second session when the procedure was studied a second time (Shock Only). No stimulus change occurred at completion of the first and second components and a shock alone was presented at completion of every third component. A short diagonal mark of the response pen indicates completion of an FI 5-min component. A mark of the event pen and resetting of the response pen indicate presentation of a shock.

Fig. 6. Performance of MC-II under three second-order schedules of shock presentation: (Noise-Shock: Not Paired). A white noise was presented at completion of the first and second FI 5-min components and a shock alone was presented at completion of every third component (Noise-Shock: Paired). A white noise was presented at completion of each component and a shock immediately followed every third presentation of the white noise. The second frame shows performance during the seventh session when the procedure was studied the first time. The bottom frame shows performance during the first session when the procedure was studied a second time (Shock Only). No stimulus change occurred at completion of the first and second components and a shock alone was presented at completion of every third component. A short diagonal mark of the response pen indicates completion of an FI 5-min component. A mark of the event pen and resetting of the response pen indicate presentation of a shock.

The effect of changing to presentation of a white noise at completion of each component (Noise-Shock: Paired) was, as before, suppression of responding. Within two sessions the mean rate of responding had decreased to 0.02 responses per second for FC-I and to 0.004 responses per second for MC-II (Fig. 4). The effect upon responding can be seen in the records of MC-II during the first session after the change to this procedure (bottom frame of Fig. 6), and in the records of FC-I during the second session (bottom frame of Fig. 5). Both subjects showed a pronounced decrease in frequency of responding and a change in the pattern of responding.

Changes in shock intensity did not produce changes in patterns of responding under the present procedures, but the slightly decreased response rates for MC-II at 2.0 and 1.3 ma suggested that these intensities may be approaching the minimum necessary to maintain responding.

DISCUSSION

The present investigation demonstrated that responding in cats having prior training under shock avoidance can be maintained by

response-produced electric shock. Responding in both subjects persisted under an FI 15-min schedule of shock presentation and under two second-order schedules of shock presentation. That response-produced shock could temporarily enhance responding in subjects with histories of shock avoidance was shown previously by Kelleher *et al.* (1963). One of three squirrel monkeys had positively accelerated responding during four sessions under an FI 2-min schedule of shock presentation.

The present investigation also demonstrated that responding in cats with histories of shock avoidance can be maintained under response-independent electric shock. These data are consistent with earlier experiments (Kelleher *et al.*, 1963; Waller and Waller, 1963) which showed that after training under shock avoidance, responding was maintained in the presence of a stimulus terminating with a response-independent electric shock. These data are also consistent with previous experiments (Appel, 1960a, 1960b; Hearst, 1962) which showed that in subjects with histories of avoidance, response-independent shock engendered increased rates of responding during the extinction components of multiple schedules.

Fig. 7. Mean rates of responding during each of three components under: (Noise-Shock: Not Paired) a white noise was presented at completion of the first and second FI 5-min components and a shock alone was presented at completion of every third component; (Noise-Shock: Paired) a white noise was presented at completion of each component and a shock immediately followed every third presentation of the white noise; (Shock Only) no stimulus change occurred at completion of the first and second components and a shock alone was presented at completion of every third component. Mean response rates during the last session only are shown for the Noise-Shock: Paired procedure. Mean response rates during the last three sessions are shown for the Noise-Shock: Not Paired and for the Shock Only procedures.

Some earlier studies of electric shock reported that positively accelerated responding frequently developed in the presence of a stimulus which terminated with a response-independent shock (Sidman *et al.*, 1957; Herrnstein and Sidman, 1958; Kelleher *et al.*, 1963; Waller and Waller, 1963). In the present study, delivering a response-independent shock every 15 min engendered rather steady rates of responding similar to performance under continuous shock avoidance. Although response rate occasionally decreased immediately after a response-independent shock, positively accelerated responding did not develop in either cat until shocks were response-produced. Under the FI 15-min schedule and under two of the second-order schedules, responding by FC-I, and to a lesser extent by MC-II, was positively accelerated.

In Exp. II, responding was not maintained

under a three-component second-order schedule when a white noise was presented at completion of each component and the white noise was paired with shock at completion of the third component (Noise-Shock: Paired), but responding was maintained when the white noise was not paired with shock (Noise-Shock: Not Paired) and when the white noise was omitted (Shock Only). While this experiment may not offer an exhaustive analysis of the effects of pairing a stimulus with shock presented under second-order schedules, it does show clearly that responding can be maintained when shock is response-produced under a second-order schedule, and that responding can be suppressed when a stimulus paired with shock is presented at completion of each component. Before a reasonably complete explanation of these effects can be proposed, it must be determined whether the effect of shock and the effect of a stimulus paired with shock are alike or different. If the effects are similar, suppression of responding may be due to increasing shock frequency, in this case, three-fold. If the effects are dissimilar, the white noise paired with shock may suppress responding even though shock presentation enhances responding.

The similarity or dissimilarity of the effects of white noise and shock cannot be determined from the present study. However, because a stimulus paired with food presentation has been shown by Findley (1962), Kelleher (1966a, 1966b) and others to enhance responding, a stimulus paired with shock presentation might have been expected to enhance responding. Suppression of responding when white noise was paired with shock is not consistent with the enhancing effects of a stimulus paired with food presentation, and may suggest differences between response-produced food and response-produced shock in maintaining responding.

Perhaps the most sensitive indicator of the effectiveness of an event in modifying behavior is the pattern of responding engendered by the occurrence of that event. The present investigation showed that patterns of responding characteristic of fixed-interval schedules and of two second-order schedules can be maintained under response-produced electric shock. When shock was scheduled as the terminal stimulus-event, responding by FC-I was positively accelerated under an FI 15-min

schedule and under two second-order schedules comprising three components. MC-II displayed less sensitivity than FC-I to the schedules under which shock was presented, and tended to show less uniform changes in response rate. In terms of the stability of responding and the patterns of responding, response-produced shock maintained behavior in both cats.

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