JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR VOLUME 6, NUMBER 1 JANUARY, 1963

THE EFFECTS OF UNAVOIDABLE SHOCKS ON A MULTIPLE SCHEDULE HAVING AN AVOIDANCE COMPONENT[1]

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Two dogs were maintained on a multiple schedule having both a food reinforced and an avoidance component (Mult VI 1′ S^{Δ} $Avoid_{SS20\ RS20}$ S^{Δ}). The effects of superimposing an Estes-Skinner procedure for delivering unavoidable shocks on all components of the multiple schedule were observed. The buzzer-shock pairing of the Estes-Skinner procedure produced an increased rate of responding on the avoidance component of the schedule and also on the S^{Δ} components. No persistent change in rate was observed on the food component during the pre-shock stimulus. Control performances on all components could be regained by either extinguishing or eliminating the buzzer-shock pairing. Extinction of the avoidance responding had little effect on the increased rates of responding produced by the Estes-Skinner procedure on the S^{Δ} and avoidance extinction components and did not lead to a conditioned suppression of the food reinforced responding. Rate of responding during the pre-shock stimulus was observed to be relatively independent of changes in the maintaining schedules. Responding during the pre-shock stimulus could be conditioned and maintained after an extensive history of avoidance extinction.

Several recent experiments have shown that the Estes and Skinner (1941) procedure of superimposing a stimulus-shock pairing on a maintained operant behavior does not always decrease rate of responding (Stein, Sidman, and Brady, 1958). In fact the presentation of unavoidable shocks which are preceded by a discriminable stimulus may yield an increase in response output under a variety of conditions.

Sidman, Herrnstein, and Conrad (1957) have shown that monkeys increase their overall rate of avoidance responding when they receive periodic unavoidable shocks. This study also showed that, when the unavoidable shocks were preceded by a distinctive stimulus (Estes-Skinner procedure), the increase in rate came to occur primarily during the pre-shock stimulus. This increase in rate during the pre-shock stimulus persisted even though the animal's avoidance responding was extinguished. Following extinction of the avoidance response the pre-shock stimulus maintained a typical response pattern: an initial low rate that gradually increased until the pre-shock stimulus was terminated with the shock. The monkeys eventually stopped responding during the pre-shock stimulus when they were maintained on the avoidance extinction schedule for an extended period.

It is not essential that the subject's behavior be maintained on an avoidance schedule in order to obtain an increase in rate of responding during the pre-shock stimulus. Herrnstein and Sidman (1958) have shown that, even though the subject was being maintained on a food reinforcement schedule, an increase in rate during the pre-shock stimulus was obtained if the subject had an unextinguished history of avoidance conditioning. Explicit extinction of the avoidance responding prior to conditioning the food reinforced responding tended to reverse the effect of the Estes-Skinner procedure and led to the characteristic conditioned suppression of the food reinforced behavior.

Sidman (1958) conditioned monkeys to make one response on a schedule of food reinforcement and, concurrently, to make another response to avoid electric shock. When the food reinforced responding was maintained by a variable interval schedule of food reinforcement there was considerable induction between the components of the concurrent variable interval-avoidance schedule. Further-

[1]This work was supported by Grant MY 1775 from the National Institute of Mental Health and was completed while the second author was a U.S.P.H. Postdoctoral Fellow, MF 9372.

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more, when an Estes-Skinner procedure was imposed on the concurrent schedule, an increase in rate of responding during the pre-shock stimulus was observed for both the food reinforced responding and the avoidance responding. When the food reinforcement schedule was changed from VI 4′ to a fixed ratio schedule the effect of the pre-shock stimulus on the food reinforced responding was reversed; *i.e.*, a decrease in food responding was observed. Thus, it was possible to manipulate the effect of the Estes-Skinner procedure on the food reinforced responding by changing the schedule of food reinforcement.

The present experiments resulted from an attempt to replicate both the increase in rate of responding on an avoidance schedule and the decrease in rate of responding on a food schedule in the same subjects. A multiple schedule, which brought both the avoidance responding and the food responding under the control of external stimuli and temporally separated these two components with periods of no responding (S^{Δ}), was employed. The failure to obtain the expected results led to a series of experiments which extend the properties of the Estes-Skinner procedure.

METHOD

Subjects

Two male beagle dogs, approximately 2 yr old at the start of the experiment, were maintained at approximately 80% of their free-feeding weights throughout the experiment.

Apparatus

A box-type enclosure with a grid floor, a nose manipulandum (Waller, 1960) mounted on the same wall as a food pan, a stimulus light flush-mounted in the ceiling directly above the nose bar, and a loud buzzer were used. Water was continuously available. In all instances the aversive stimulus was a 2.5 ma. shock of 1 sec duration. (See Waller and Waller (1962) for a more complete description of the apparatus.) All programming was done with a system of electrical switching circuits.

Procedure

Subjects were conditioned to nose the manipulandum by reinforcing each appropriate response with food (CRF). After approximately 100 reinforcements the CRF schedule was changed to a multiple schedule in which S was reinforced for responding on a 1 min variable interval schedule (VI 1′) during the "light on" condition and was on extinction (S^{Δ}) during the "light off" condition (approximately 25 min). When responding had become stable on both the VI and S^{Δ} components, the avoidance component was introduced. The avoidance component was correlated with a flashing light (1 CPS) stimulus. Both subjects were conditioned by the avoidance contingency within the first session (6 hr block on avoidance). An immediate effect of conditioning the avoidance responding was that the subject's responding for food was severely disrupted and considerable responding occurred in the S^{Δ} periods. After approximately 100 hr on the multiple schedule (Mult VI 1′ S^{Δ} $\text{Avoid}_{SS20\ RS20}$ S^{Δ}), performance on all components became relatively stable. This multiple schedule performance was then used to evaluate the effects of chlorpromazine in various doses (Waller and Waller, 1962).

The present experiment began 40 sessions (approximately 4 hr each) after the termination of the drug experiment. Most sessions throughout the experiment were of 4 to 5 hr duration. The Estes-Skinner (1941) procedure used in the present experiment consisted of the presentation of a buzzer for 1 min which was terminated by a 2.5 ma. shock of 1 sec duration. The buzzer-shock pairing was presented on a variable interval schedule where the shortest interval was of 6 min duration. The schedule resulted in approximately seven buzzer-shock pairings being presented each hour. Specific procedures in the present experiment are described at appropriate places in the results.

RESULTS

The results of the various experimental procedures may be seen in the cumulative records shown in Figs. 1A; B, C, and D. In Fig. 1A the record labeled "1" is taken as the first day of the experiment and shows the final performance on Multiple VI 1′ S^{Δ} $\text{Avoid}_{SS20\ RS20}$ S^{Δ} after approximately 600 experimental hours on the schedule. The numbering on all subsequent records indicates experimental sessions after record #1 and shows each change in procedure throughout the ex-

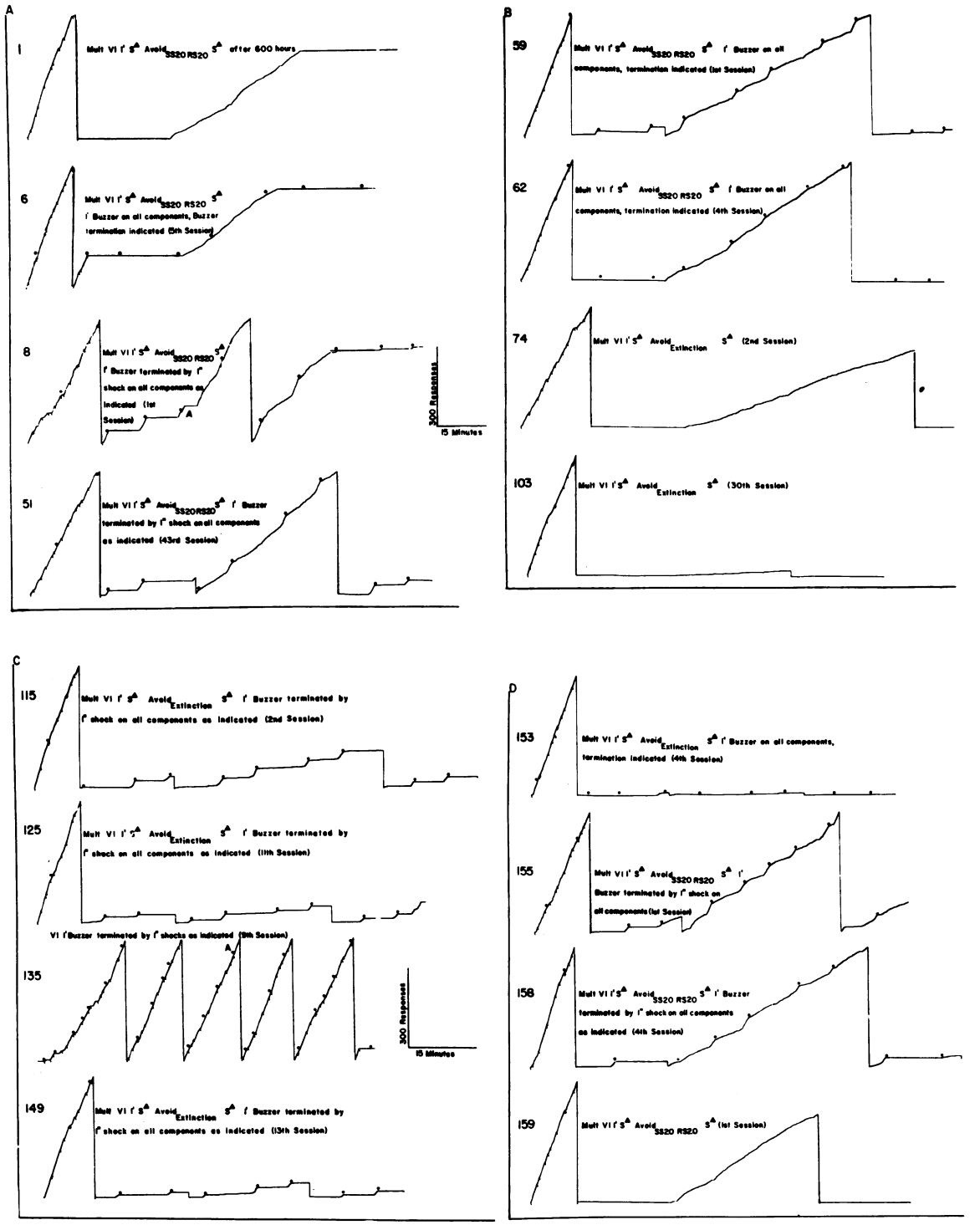

Fig. 1. Sections of the cumulative records for Subject D showing the effects of the various experimental manipulations. The sections of the records show the second occurrence of the VI component and the avoidance component within the session and the third and fourth occurrences of the S^{Δ} component. The order of components in each record shown are (from left to right) VI 1', S^{Δ}, Avoidance, and S^{Δ}.

periment. Unless otherwise indicated the records in Fig. 1 show the second occurrence within the session of each component of the schedule. The order of the components in each record in Fig. 1 (from left to right) is VI 1′, where diagonal marks denote food reinforcement; S^{Δ}; avoidance, where diagonal marks denote shocks; and S^{Δ}. All of the records in Fig. 1 were generated by Subject D. Subject C went through an identical procedure with similar results but was less stable in performance from session to session. Several records from Subject C are used to show the immediate effects of schedule changes and are shown in Fig. 2.

Record #1 of Fig. 1A shows the final performance of Subject D on Mult VI 1′ S^{Δ} $\text{Avoid}_{SS20\ RS20}$ S^{Δ}. The rate of responding on the VI component was approximately one response per second; rate on the S^{Δ} components approached zero; and, rate on the avoidance component was approximately .2 responses per second. Performance on all components was highly stable from session to session. Record #6 Fig. 1A shows the fifth session (sixth session in the experiment) following the institution of a 1 min buzzer on all components of the schedule. The termination of each buzzer presentation is indicated by a closed circle immediately above the record. The buzzer had no persistent effect on performance. The subjects' rates of responding on all components were comparable to those in record #1.

Record #8 Fig. 1A shows the effect of terminating each buzzer presentation with an unavoidable shock. Each unavoidable shock is indicated by a closed circle immediately above the record. It can be seen that the buzzer-shock correlation had an almost immediate effect. The portion of the record shown starts approximately 1 hr after the beginning of the session. There were effects on all components of the schedule. Overall rate on the VI component decreased. The decrease was primarily a result of the increase in grain seen as runs interspersed with pauses. There was no indication of a specific decrease in responding during the buzzer, but there was evidence that pauses tended to follow shocks as well as appearing elsewhere in the run.

The effect of the buzzer-shock procedure on the S^{Δ} performance was dramatic. Within a single session the performance changed from no responding (not shown) during the pre-shock stimulus in S^{Δ} to rapid responding (see figure) during the buzzer. There was also some tendency to respond in S^{Δ} following shock termination (as at "A"). During the portion of the session shown, the extinction contingency in S^{Δ} maintained a near-zero rate except during the pre-shock stimulus. The rate during the pre-shock stimulus was lower than the running rate on the VI component but was approximately the same as the rate during the pre-shock stimulus on the avoidance component.

The immediate effects of the Estes-Skinner procedure on the subject's avoidance responding are shown in record #8 Fig. 1A. Within the first session the effect changed from a general increase in rate of avoidance responding to the effects shown in this record. In the portion shown, there was still an overall increase in rate but the greatest increase was seen to occur during the pre-shock stimulus.

The next record (#51) in Fig. 1A shows the final performance on Mult VI 1′ S^{Δ} $\text{Avoid}_{SS20\ RS20}$ S^{Δ} with the Estes-Skinner procedure programmed on all components. The record was taken from the forty-third session on the procedure. The effects on each component were similar to those seen in record #8 Fig. 1A but more stable. Rate was still down somewhat on the VI component but the record showed less pausing. There was no indication of a decrease in responding during the pre-shock stimulus. Responding during S^{Δ} was almost entirely restricted to the period when the pre-shock stimulus was on. Characteristically, there was a variable delay in responding following the onset of the pre-shock stimulus. This was followed by a rapid rise to the terminal rate of responding, and the termination of responding following the unavoidable shock. Responding during the pre-shock stimulus on the avoidance component was only slightly different from the S^{Δ} responding described above. Subject D tended to respond at the higher rate immediately after the onset of the pre-shock stimulus. There was also some tendency to approach the higher rate gradually (scallop) on the avoidance component. Terminal rates of responding during the pre-shock stimulus for both S^{Δ} and avoidance components were similar, and both were lower than the running rate on the VI component.

Record #59 Fig. 1B shows the immediate effects of deleting the terminal shock from the buzzer-shock pairing. The fourth session on extinction for the Estes-Skinner procedure is seen in record #62 Fig. 1B. A typical extinction function was obtained. This is seen best on the records for the S^{Δ} and avoidance components, since there was little detectable effect of the buzzer-shock pair on the VI component. The S^{Δ} record following the VI component in session #59 shows that the pre-shock stimulus still produced a high rate of responding at that point in extinction. The S^{Δ} record following the avoidance component in record #59 shows a decreased output of responses during the pre-shock stimulus. No evidence of responding during the pre-shock stimulus is seen in the S^{Δ} components in record #62 Fig. 1B.

The effect of the history of unavoidable shocks was observable for a longer time on the avoidance component. In the avoidance component in record #59 Fig. 1B, the buzzer caused an increased rate of responding. Three sessions later (record #62), the pre-shock stimulus still caused a detectable increase in rate on the avoidance component on most occasions. No effect of the previous history of unavoidable shocks was evident on any component after 10 sessions on extinction.

Record #74 Fig. 1B and record #103 Fig. 1B show the extinction of the avoidance component. Record #74 shows all components for the second session on which no shocks were delivered on the avoidance component. The pre-shock stimulus was also discontinued at this time. The effects of the extinction contingency on Subject D's multiple schedule performance were evident within two sessions. Rate of responding on the VI component decreased (this effect was not stable) as did the rate on the avoidance extinction procedure. At this point in extinction, responding on the VI component was at approximately the control rate and very little grain was evident in the records. Rate of responding on the avoidance component was slowly approaching zero. Throughout the extinction of the avoidance component, Subject D almost never responded in S^{Δ}.

Records #115 and #125 Fig. 1C show the effects of reconditioning the Estes-Skinner procedure following extinction of the avoid-

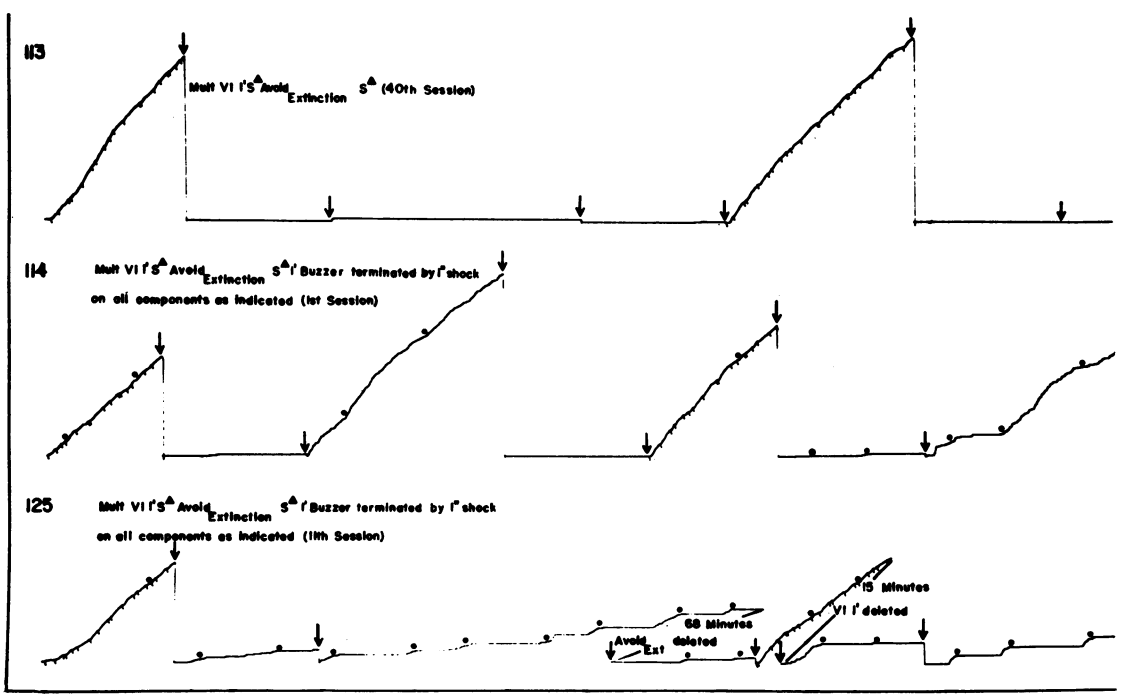

Fig. 2. Sections of the cumulative records for Subject C showing the effects of unavoidable shocks following the extinction of the avoidance component of the multiple schedule. Sessions start at the beginning of each record. Arrows denote changes from component to component.

ance component of the multiple schedule. Record #115 shows the second session with the buzzer-shock superimposed on all components and record #125 shows the eleventh session. The effect of the buzzer-shock was primarily seen on the S^{Δ} and the avoidance extinction components. No observable effect was seen on the VI performance. The effects on the S^{Δ} and avoidance extinction components were similar. In both instances the onset of the pre-shock stimulus led to responding at a fairly high rate until the occurrence of the unavoidable shock. Following shocks there was an abrupt return to near-zero rates of responding.

Figure 2 shows the immediate effects of reintroducing the Estes-Skinner procedure on the second subject (C). Similar effects were observed with Subject D but the results were less dramatic and less prolonged. The first record in Fig. 2 shows the final performance on Mult VI 1′ S^{Δ} $Avoid_{Ext}$ S^{Δ} which was obtained in session #113. The Estes-Skinner procedure was reintroduced at the beginning of session #114, which is shown as the second record in Fig. 2. Only two buzzer-shock pairings were programmed (both during the VI component) prior to the first occurrence of the $Avoid_{Ext}$ component. When the stimulus paired with the avoidance extinction component appeared, Subject C immediately changed from no responding during S^{Δ} to an intermediate rate of responding. The responding began prior to the subject's taking a shock during the $Avoid_{Ext}$ component and continued at a fairly high rate throughout the session, though the rate decreased during the second occurrence of the $Avoid_{Ext}$ component. In this first session of reconditioning of the Estes-Skinner procedure, responding during the pre-shock stimulus on the S^{Δ} component was minimal. The third record shows a portion of session #125. After 11 sessions of reconditioning the Estes-Skinner procedure, responding in both the $Avoid_{Ext}$ component and the S^{Δ} component was restricted primarily to the time the pre-shock stimulus was present. No specific effect was seen on the VI 1′ component.

Several changes in procedure were made prior to the 127th session. The multiple schedule was changed, by dropping the S^{Δ} and avoidance extinction components, to a variable interval of 1 min. The session length was reduced to approximately 1 hr. The Estes-Skinner program was also changed. The density of unavoidable shocks preceded by the buzzer stimulus was increased from approximately 7 per hr to approximately 20 per hr. The effect of these changes in procedure is shown in record #135 Fig. 1C. The record is for the entire ninth session under the new conditions. There is no evidence that the pre-shock stimulus has a particular effect. On several occasions S failed to respond during the pre-shock stimulus but, usually, few rate changes were seen. There was one example of S responding through the magazine cycle (at A). Overall rate of responding on the VI was somewhat lower under these conditions than under the immediately prior multiple schedule conditions.

Record #153 Fig. 1D shows the effect of extinguishing the Estes-Skinner procedure with the avoidance component also extinguished. To assess the effect of having a maintained avoidance component record #153 may be compared with record #62 Fig. 1B. With the avoidance component extinguished the extinction of the pre-shock stimulus proceeded at approximately the same rate on both the S^{Δ} and $Avoid_{Ext}$ components.

Records #155 and #158 Fig. 1D show the results of reconditioning both the avoidance component and the Estes-Skinner procedure simultaneously. Record #155 is from the first session of reconditioning. The reconditioning of both the buzzer-shock and the avoidance component proceeded very rapidly. Although the performance in record #155 was somewhat unstable, the rates of responding in the different components were similar to those in session #51 Fig. 1A. The effect of the buzzer-shock on each component is characteristic. Record #158 shows that the performance became more stable after four sessions but, otherwise, did not change appreciably.

Record #159 Fig. 1D shows the effect of dropping the Estes-Skinner procedure from the schedule. The performance obtained is comparable to the control performance in record #1 Fig. 1A.

DISCUSSION

Many of the effects of the Estes-Skinner procedure observed in these experiments have been previously observed and reported by other experimenters (Sidman *et al.*, 1957). Several effects seen here have not been re-

ported previously, and these shall be discussed in detail.

The most interesting observation in these experiments was that the introduction of the buzzer-shock pair had generalized, nonspecific, effects on the subject's responding. The most explicit example of this nonspecific effect is seen in Fig. 2 for Subject C where the buzzer-shock pair was reintroduced following the extinction of responding in the avoidance component of the schedule. The immediate effect of the reintroduction of the buzzer-shock pair was to reinstate responding in the previously extinguished avoidance component prior to the first occurrence of either the buzzer or the shock on that component. Two buzzer-shock pairs had been presented approximately 40 min before and superimposed on the VI component. This generalized responding on the avoidance extinction component but not on the S^{Δ} component shows the adequacy of the stimulus control for the various components. The lack of differential responding during the pre-shock stimulus during the 114th session, Fig. 2, suggests that responding during the buzzer is a result of repeated presentation of the buzzer-shock pairing. The subsequent sessions (record #125, Fig. 2) revealed that as responding became localized during the pre-shock stimulus the generalized responding seen initially tended to drop out. All responding seen in either the avoidance extinction condition or the S^{Δ} condition tended to occur during the pre-shock stimulus.

It seems unlikely that both the initial effects and the later effects of the buzzer-shock pair in the above instance can be explained by a single process. The two effects have different time courses—*i.e.*, the initial effect is seen prior to the first occurrence of shock on the avoidance extinction component, whereas the later effects become apparent only after repeated presentations of the buzzer-shock pair. The initial and later effects also result in opposite "end" effects, *i.e.*, the generalized effect drops out while the buzzer-correlated increase in responding persists for the duration of the experiment. While the later effect of the buzzer-shock pair may be related to the superstitious conditioning explanation put forward by Sidman *et al.*, (1957), the immediate effect of generalized responding in the avoidance extinction component cannot readily be explained as superstitious conditioning, as the conditions necessary for superstitious conditioning were not present.

Herrnstein and Morse (1957) reported similarly rapid effects of introducing free food on a DRL performance in pigeons. In their situation large increases in responding occurred after as few as two free food presentations, and within the first session all birds showed increases in rates of responding ranging from 3- to 20-fold. With repeated presentation of the stimulus and the free food all birds continued to show an increased rate of responding outside the pre-food stimulus. This was rather surprising as two of the six subjects showed a decreased rate of responding during the pre-food stimulus. Thus, it appeared that the presentation of non-response contingent food had a general, activating effect which tended to increase responding as well as a specific (superstitious conditioning) effect which produced both increases and decreases in responding during the pre-food stimulus. Similar immediate effects of free shock presentation were observed by Sidman *et al.*, (1957) and by Herrnstein and Sidman (1958) under different experimental conditions which were somewhat more explicable in terms of superstitious conditioning.

The original report by Estes and Skinner (1941) showed that a superimposed signal-shock pair on food-maintained responding produced a decrease in rate of responding during the pre-shock stimulus. Later, Herrnstein and Sidman (1958) showed that a monkey with a previous history of conditioned avoidance responding tended to increase his rate of responding during the pre-shock stimulus on a food-reinforced schedule. Neither result was obtained in the present experiments where, throughout all conditions, the buzzer-shock pair had little specific effect on the food-reinforced component. It is unlikely that the lack of an effect on the VI component can be attributed to the properties of the buzzer-shock pair. There is every reason to believe that the buzzer-shock pair used in these experiments was satisfactory to demonstrate the usual effects observed with the Estes-Skinner procedure. The large persistent effects seen on both the avoidance and S^{Δ} components indicate the effectiveness of the procedure. Neither is there reason to believe that the dog is a unique subject. Lindsley and Jetter (1953)

have shown a decrease in rate with dogs using a loud noise instead of shock as the aversive event. More importantly, similar Estes-Skinner procedures have been used successfully with such diverse organisms as rats, cats, pigeons, and monkeys.

It is reasonable to assume that the food-reinforced responding in the present experiments is similar to the food-reinforced responding following avoidance conditioning reported by Herrnstein and Sidman (1958), where an increase in rate of responding during the pre-shock stimulus was obtained. The failure to obtain an increase in rate during the pre-shock stimulus might be accounted for by differences in the rates of responding observed for the different conditions of the experiment. The food-reinforced schedule used in these experiments maintained a fairly high rate of responding compared to the rates maintained by the avoidance schedule. In fact, the rate maintained by the VI component was higher than that generated during the pre-shock stimulus on the avoidance component. If it is assumed that the rate of responding maintained by the pre-shock stimulus takes some value which is determined by the parameters of the Estes-Skinner procedure as well as by the parameters of the avoidance schedule being used, then one would not expect an increase in rate on the VI schedule used in the present experiment. Apparently this assumption has some validity since the rate generated by the pre-shock stimulus on the S^{Δ} component is quite similar to that generated on the avoidance component and, in both instances, was less than the running rate on the VI component.

Sidman *et al.*, (1957) report that the inincreased rate of responding produced by superimposing an Estes-Skinner procedure on avoidance responding was a transitory phenomenon. According to their report, the immediate effect of the stimulus-shock pair was a general increase in avoidance responding. This was followed by a transitory phase during which the rate of responding in the pre-shock stimulus was considerably higher than in the absence of the stimulus. The final phase saw the rate in the stimulus approximate the rate in the absence of the stimulus.

No such clear-cut phases were seen in the present experiments. While there was an immediate, general increase in avoidance responding following the initial presentation of the buzzer-shock pair, the general increase dropped out and the increased rates were seen only during the buzzer presentations. Furthermore, the increase in rate during the pre-shock stimulus persisted throughout these experiments whenever the buzzer was paired with shock. There was some evidence that the rate of responding during the buzzer was decreasing toward the end of the experiments but this seemed to be primarily the result of the fixed interval characteristics of the buzzer-shock pairing. The rate was lower immediately after the onset of the buzzer but increased as time passed, yielding a scallop-like effect, into the terminal shock. The terminal rate of responding in the pre-shock stimulus was remarkably stable. This stability was rather surprising in view of the changes which were made in the avoidance component.

Since the multiple schedule used to maintain the subject's responding in these experiments is probably a crucial determinant of the effects of the Estes-Skinner procedure, the properties of the schedule should be explicated. As shown in record #1 Fig. 1A and record #159 Fig. 1D, the performance of Subject D was highly stable on all components of the schedule throughout the experiment. Subject C was less stable but gave essentially similar results. Furthermore, the performance on the different components was consistently different and appropriate to the component schedule contingencies. There was every indication that each component performance was adequately controlled by the correlated stimulus conditions. The extinction of responding on the avoidance component (record #74 Fig. 1B and record #103 Fig. 1B) had only a very small and temporary effect on responding in the VI 1′ component and had no observable effect on responding in the S^{Δ} components.

The S^{Δ} components of the multiple schedule used in these experiments served several purposes. They provided a demonstration of external stimulus control and also served to separate temporally the VI component from the avoidance component by a period of controlled no-responding. By explicitly recording responding in S^{Δ} and presenting the Estes-Skinner procedure during this component, the effect of the buzzer-shock pairing could be observed under conditions where reinforcement had never occurred.

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Received December 19, 1961